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Frontiers in Artificial Intelligence and Applications

DIGITALIZATION AND MANAGEMENT INNOVATION III

Proceedings of DMI 2024, Beijing, China, 25-27 October 2024

Edited by
Antonio J. Tallón-Ballesteros

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Preface

DMI2024 was the third edition in the conference series Digitalization and Management Innovation (DMI), held annually.

DMI2024 was held as a hybrid event from 25 to 27 October, onsite in Beijing, China and online. The conference achieved a high attendance rate of more than 100 participants from more than ten countries.

This book is divided into four parts: Part 1: Digitalization and Business Model, Organizational Behaviour in Digital Transformation; Part 2: Management Innovation and Innovation Management; Part 3: Special Session on "Lifelong Education"; Part 4: Interdisciplinary Applications of Digitalization and Management Innovation. The most popular topics in this book concern management and digital aspects such as transformation, bus iness and different kinds of chain.

A total of 293 submissions were received for the conference. These were meticulously reviewed by programme committee members, who carefully considered the breadth and depth of the research topics falling within the scope of DMI. Following the review, 88 of the most promising and FAIA mainstream-relevant contributions were selected for inclusion in this book, resulting in an acceptance rate of 30.03%. These selected papers present original ideas or results of significant importance, underpinned by rigorous methodologies, clear reasoning, and compelling evidence.

We would like to extend our sincere gratitude to all the keynote and invited speakers, authors, and anonymous reviewers for their invaluable contributions, which were instrumental in fostering the success of DMI2024. Additionally, we are profoundly grateful to all those who dedicated their time and expertise to evaluating the submissions, particularly the members of the programme committee and our diligent reviewers. Their efforts have been crucial in ensuring the quality and success of this conference. It is an honour to have started from the beginning with the publication of these proceedings in the prestigious series Frontiers in Artificial Intelligence and Applications (FAIA) from IOS Press. Our particular thanks also go to the FAIA series editors, for supporting this conference.

December 2024

Antonio J. Tallón-Ballesteros
University of Huelva (Spain)

About the Conference

The 3rd International Conference on Digitalization and Management Innovation (DMI2024) was successfully conducted from 25 to 27 October 2024. This event took place both online and onsite at the campus of Beijing Wuzi University in Beijing, China, and featured a distinguished line-up of six keynote speakers from around the globe: Professors Felix Arndt and Jing Chen from Canada; Karen Hopkins from the United States; Gilles Lambert from France; Elzbieta Pustulka from Switzerland; and Md. Mamun Habib from Bangladesh.

The overarching themes of the conference were categorized into three primary streams: Innovation and Business Models, Algorithms for Management Research and Applications, and Digital Technology. Beyond these core areas, DMI2024 also delved into pertinent contemporary topics such as leadership, the circular economy, green computing, human resource management, and online education management.

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Research on the Policy Model for the Sustainable Development of China's Digital Industry – A Rooted Analysis Based on Policy Texts

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Abstract. The digital economy is the key force driving the sustainable development of the digital industry, and the development and growth of the digital industry cannot be separated from the policy support and innovation drive, and only through the establishment of a scientific and reasonable policy system, can we better utilize the important role of the digital industry. Based on 54 policy documents issued by national and local governments about the sustainable development of China's digital industry from 2017 to 2023, this paper adopts the policy informatics theory, content analysis method, rooted theory, and NVivo 12.0 software to analyze and quantify the content of the policy texts related to the digital industry. The study found that the text of the digital industry policy continues the internal logic of "goal - foundation - drive - means - guarantee". The results show that the sustainable development of China's digital industry should be based on digital infrastructure, the accumulation of data elements as the driving force, the development of digital industrialization, the digital transformation of industries, the digitization of public services, and the international cooperation of the digital economy, and through the digital economy governance system and security system as the guarantee of the sustainable development of the digital industry.

Keywords. Digital industry, rooted theory, policy modeling, content analysis approach

1. Introduction

The digital economy represents the prominent trend in the contemporary global economy and serves as a new driving force for economic growth. In line with national objectives, the 14th Five-Year Plan for the Development of the Digital Economy, formulated by the State Council, emphasizes the imperative to enhance digital infrastructure, strengthen governance systems for the digital economy, and facilitate the synergistic advancement of both digital industrialization and industrial digitization. These efforts aim to provide robust support for the establishment of a digitalized China. Furthermore, the twentieth report sets forth a clear vision for digital industry development, namely, to foster

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profound integration between the digital economy and the real economy and to construct internationally competitive digital industry clusters.

The digital economy encompasses a diverse array of economic activities that utilize digitized knowledge and information as critical inputs for production. It relies upon modern information networks as pivotal conduits, while the proficient harnessing of information and communications technology assumes a paramount role in advancing efficiency and optimizing the overall economic structure [1]. The core of the development of the digital economy is "digital industrialization" and "industrial digitization", which emphasizes the role of data and information and digital technology as a penetrator in the traditional economy [2]. Digital industry refers to the industrial field based on digital technology, covering information technology, communication technology, Internet technology and so on. With the rapid development and application of information technology, the digital industry has gained widespread attention and importance globally [3]. Digital economy is the key force driving the sustainable development of digital industry, and the sustainable development of digital industry is the important support for the development of digital economy. The development and growth of the digital industry cannot be separated from policy support and innovation drive, and only through the establishment of a scientific and reasonable policy system can the important role of the digital industry be better utilized.

Policy analysis is an effective tool for sorting out and dissecting public policy. Analyzing the policy text to reveal the evolution law and value turn of the basic public policy is the action guide to promote the sustainable development of China's digital industry. In recent years, the Central Committee of the Communist Party of China , the State Council, major ministries and commissions and local governments have issued a series of relevant policy documents, which have played a huge role in promoting industrial digitization and intelligence, expanding the scale of the digital economy, improving the scale efficiency of the industry, stimulating the demand for enterprises and innovation, and enhancing the competitiveness of industries and enterprises. This paper tries to construct a policy analysis framework for the sustainable development of digital industry, taking the above policy texts as the research object, and using Nvivo 12.0 software to conduct content analysis and quantitative research on the policy texts related to China's digital industry. By rooting the theoretical research method, we will clarify the policy logic and usage preference for the sustainable development of China's digital industry and promote the sustainable development of China's digital industry.

2. Literature Review

Many experts and scholars have offered their insights into the study of China's digital industry. Gong Weibin (2021) puts forward the basic principles of the construction of digital China and the direction and path of the development of China's digital industry [4]. Shu Zhan and Wang Caini (2023) focus on the three major changes in high-quality economic development, and argue that the digital economy is an important strategic choice for promoting China's economic transformation, industrial upgrading, and realizing high-quality economic development [5]. Ren Baoping and He Haifeng (2023) proposed to strengthen the investment in digital economy, especially focusing on the development of digital industry and the promotion of key technological innovations in digital economy [6]. Meng Yanju, Chen Sinanian and Chen Lei (2023) studied the effect of digital industry on economic growth by using industrial input-output tables. Through econometric modeling and empirical analysis, they derived the positive impact of digital industry on economic growth [7]. Ai Yang, Song Pei and Li Lin (2023) studied the effect of digital industrialization on economic structural transformation. They constructed a theoretical model and verified the positive impact of digital industrialization on economic structural transformation through empirical tests [8]. Zhang Keyu, Wu Xiaoting and He Zilong (2023) analyzed the macroeconomic effects of China's digital industry from the perspective of input-output. They revealed the macroeconomic effects of digital industries by constructing models and analyzing data [9]. Li Liangliang (2024) studied the development level, spatio-temporal characteristics and regional differences of digital industries in China. By analyzing the relevant data, it was concluded that there are differences in the development level of digital industry in different regions, and some improvement measures were proposed [10].

These literatures have studied the development level, spatial and temporal characteristics, regional differences, economic growth effects, structural transformation effects, and macroeconomic effects of China's digital industry from different perspectives and methods. These studies are of great significance in gaining a deeper understanding of the development trend of digital industries, optimizing industrial layout and promoting economic growth. However, the existing research is less from the policy level on the sustainable development of digital industry, only from the literature analysis and other traditional methods, the content analysis of China's digital industry policy and quantitative research is still relatively rare. This paper opens up new research ideas and perspectives, through the use of rooted theory methods, research and analysis of the policy of sustainable development of the digital industry and expects to obtain the relevant policy characteristics to promote the sustainable development of China's digital industry.

3. Research Methods and Data Collection

3.1. Rooted Theory

Rooted theory is a bottom-up qualitative research methodology that was proposed by American sociologists Glaser and Strauss (1967). The method requires the researcher to make no theoretical assumptions before the start of the study, and to generalize the experience directly through actual observation, and to rise to a theory with universal applicability in the process of collecting and analyzing the data. Through the collection of a large amount of empirical data and through the three coding processes of open coding, spindle coding and selective coding of the data. Conceptualization, categorization and theoretical abstraction from raw data, continuous comparison, induction and revision between data and information, theory and theory, and continuous incorporation of new categories into the theory, until no new theoretical categories or classes appear, and eventually reach theoretical saturation, forming a theory that can reflect the essence and significance of the phenomenon [11].

3.2. Data Sources and Collection

The purpose of this study is to sort out and analyze the relevant policy models for promoting the sustainable development of China's digital industry from publicly available policy documents. In 2017, "digital economy" appeared for the first time in the current government work report, and the core of the data economy is the digital industry. So, after thinking and analyzing about the feasibility of the study, the time frame of this study was determined to be from 2017 to 2023. After summarizing and analyzing the relevant research results in the previous period, we selected the official websites of the CPC Central Committee, the State Council, the people's governments at all levels, the portals of various ministries and commissions, as well as the "BeiDaFaBao" and the China Economy Information Network (a special section for Digital China) as the sources of data collection, and collected a total of 67 policy documents related to the digital industry and the digital economy. Through manual identification and screening, some of the policies and policy documents such as replies and approvals with excessive duplication, too short content or those that have lapsed were eliminated, and 13 of them were screened out, resulting in a final selection of 54 policy documents. Of these, 8 are national policy plans, 13 are local normative documents, and 33 are local working papers, given numbers 1-54, as shown in Table 1.

Table 1. Policy documents related to China's digital industry, 2017-2023 (part)

Type of Policy	Policy Title	Source	Particular Year
Srategic planning	"The 14th Five-Year Plan for the Development of the Digital Economy	State Council	2022
	Overall Layout of Digital China Construction	State Council	2023
	Report of the State Council on the Development of the Digital Economy	State Council	2022
Local normative documents	Chongqing Digital Industry Development "14th Five-Year Plan" (2021-2025)	Chongqing Municipal Government	2021
	Henan Province to speed up the creation of digitalization demonstration aggregation area implementation opinion notice	Henan Provincial Government	2019
	Several Opinions on Promoting the High-Quality Development of the Internet Industry and Enlarging and Strengthening the Digital Industry	Hunan Provincial Government	2020
Local working papers	Implementation Plan for the Reform of Market-based Allocation of Data Elements in Guizhou Province	Guizhou Provincial Party Committee and Provincial Government	2023
	Shanxi Provincial Digital Industry Cultivation and Strengthening Action Plan 2023	Shanxi Province Department of Industry and Information Technology	2023
	Hubei Province Digital Economy Promotion Measures	Hubei Provincial Government	2023

4. Data Encoding

4.1. Open Coding

Open coding is the initial stage of organizing and analyzing the information collected. Thematic coding, extraction of concepts, naming and categorization are continuously performed by analyzing primary sources. In this study, procedural rooted theory was selected for coding, and the labeling, conceptualization, and categorization procedures were strictly followed to import 54 policy documents into the Nvivo 12.0 software. And the initial concepts formed by the automatic coding function were used as a reference, then all the policy texts were read and analyzed one by one and coded, and a total of 296 initial concepts were obtained. Subsequently, 296 concepts were clustered and analyzed for conceptual categorization, resulting in a total of 163 open categories. Due to space limitations, only some of the open coding processes are listed here (see Table 2).

Table 2. Excerpts from open codes

Serial Number	Content of selected policy texts (source material)	Initial Concepts	Openness Scope
1-1	Promote the transformation of digital technology achievements, take the integration and application of digital technology with various fields as the guide, optimize the mechanism of rapid transformation of innovative achievements, and create a safe, reliable and systematic industrial development ecology.	Achievement transformation, transformation mechanism, industry development ecology	Innovation Ecosystem
2-1	Further strengthen the protection of personal information, standardize the collection, transmission and use of identity information, privacy information and biometric information, and enhance the ability to safely monitor the collection and use of personal information.	Collection and Protection of Personal Information	Regulation of personal information security
3-1	To establish a sound national public data resource system, coordinate the development and utilization of public data resources, and promote the safe and orderly opening of basic public data.	Data resource development and openness	Data resource system
4-1	Establish a digital transformation service ecosystem driven by both market-based services and public services and supported by multiple elements such as technology, capital, talent and data.	Market-based versus public services	Service Platform
5-1	Aiming at strategic forward-looking fields such as sensors, quantum information, network communications, integrated circuits, key software, big data, artificial intelligence, blockchain, new materials, etc., to improve the basic R&D capability of digital technology.	Digital technology-based R&D capabilities	Technological innovation capacity

4.2. Spindle Coding

Through open coding, we have conceptualized and categorized the primary source statements, but the category meanings and relationships are still vague, and the interconnections are not very clear. While the main task of open coding in the first phase was to uncover categories, spindle coding in the second phase focused on linking separate categories. Discovering and establishing potential logical connections between categories, merging and reorganizing conceptual categories based on interconnections and logic, and reassigning new categories. The cluster analysis function of Nvivo 12.0 software was used to categorize them and give them new concepts, resulting in 27 independent categories, and the meanings represented by each main category and their corresponding open coded categories are shown in Table 3.

Table 3. Main categories of spindle code formation

Main Category	Subcategory	Open Category
Digital infrastructure	Information network infrastructure	digital information infrastructure, IoT accessibility, network technology reserves, spatial information infrastructure, 6G network construction
	Infrastructure intelligence upgrading	life services convergence facilities, convergence infrastructure, artificial intelligence infrastructure, digital transformation of infrastructure, industrial internet infrastructure
	Cloud-network synergy and computer-network fusion	integrated arithmetic network, integrated big data center, intelligent infrastructure, integrated arithmetic scheduling, data center energy utilization, data center clustering
Data Elements Accumulation	Data element supply	government data sharing, data resource processing, data resource standards, data management level, data classification and grading, data security risk assessment, monitoring, early warning and emergency response, public data resource system, public data resource development and utilization, public data security and openness
	Data element development	data operation and development level, data development and utilization mechanism, data technology scenarios, value-added development, business data value, data development models
	Data elements marketed circulation	data factor circulation standards, data factor market rules, data market operation system, data pricing system
Digital industrialization	Key technologies innovative capacity	innovation main body construction, digital technology basic R&D capability, innovation resources sharing and common construction, innovation ecosystem, innovation results transformation mechanism
	Core industries competitiveness	key industrial supply chain system, basic integrated innovation fusion, key technology innovation and supply capacity, key product supply capacity, service model innovation, competitiveness of key links in the industry chain
	Entrepreneurship and innovation ecology	resource sharing, data openness, collaboration platform, digital industry innovation ecology, entrepreneurship and innovation service platform, industry innovation service platform
	New business model	intelligent product service, employment and entrepreneurship platform, platform resource sharing, platform economic development
Industrial digitization	Enterprise digital transformation	focus on business digital transformation, integrated digital platforms, information system integration, intelligent decision-making capabilities, digital skills and data management capabilities, upstream and downstream collaboration efficiency, "Cloud and Digital Empowerment" service
	Key industries digital transformation	smart manufacturing standard system, smart energy, total factor productivity, territorial spatial basic information platform, industrial digitization, smart agriculture
	Parks and clusters digital transformation of parks and clusters	park digital infrastructure, digital industrial ecology, joint operation of platform enterprises and parks, industrial virtual resources, industry chain supply chain supporting capacity, industry cluster collaborative innovation
	Support services ecosystem	market-based service platforms, public service platforms, digital transformation promotion centers, third-party

		professional service organizations, industry common solutions
Digitization of public services	Internet+Government	government data sharing and coordination mechanism, integrated government service platform, online and offline linkage, integration of data with business and services, rapid response and joint disposal of public affairs
	Smart social services	intelligent photovoltaic network, information accessibility construction, integration of social services and digital platforms, supply matching in the field of people's livelihood, digital supply of public services, equalization of public services
	Smart digital life	smart community, smart home, smart service lifestyle circle, cloud life, digital consumption habits, digital consumption scenarios
	Digital urban-rural integration	synergizing urban and rural public services, digital urban-rural integration and development, digital twin cities, urban-rural public services
International cooperation on the digital economy	International cooperation environment	intermediaries, public service platforms, cyberspace community of destiny, digital economy standards, governance rules
	Digitization of trade development	institutional provision and legal safeguards, access to digital economy business, digital environment for trade, international digital information channels, introduction of international innovation resources
	Digital Silk Road	digital economy partners, offshore digital infrastructure cooperation, cooperation models, service networks, application support platforms, multilateral trade cooperation
Digital economy governance system	Digitization of government governance	critical issues research, risk early warning, statistical monitoring and decision analysis, regulatory mechanism, risk emergency response, risk prevention
	Multi-body cooperative governance	synergistic deployment and division of labor, industry service standards, market access mechanism, main body responsibilities and obligations, fair competition review system, fair competition regulatory system
	Regulatory mechanism	credit service, credit service supply, credit governance and sharing, tax supervision and tax inspection, cross-sectoral joint supervision, supervision system
Digital economy security system	Data risk	business risk, self-regulatory mechanism, digital financial innovation, digital technology application risk, labor protection credit evaluation, diversified supply of key products, comprehensive risk research and evaluation, dynamic monitoring, insurance system and rights protection system
	Data security protection	early warning mechanism for cybersecurity emergencies, cybersecurity emergency response capacity, cybersecurity information-sharing and work coordination mechanism, cybersecurity technologies and products, cybersecurity infrastructure, socialized cybersecurity services, security risk assessment
	Data security assurance	industry data security management policy, network security review, data cross-border flow security management system, data classification and hierarchical protection system, data security governance system, data security standards, data security protection responsibility, personal information security regulation, service security assessment

4.3. Selective Coding and Modeling

Selective coding is the third stage of procedural rooted coding, where the main purpose is to mine the core categories from the main categories. Primary sources, concepts, categories and inter-category relations are then used to outline the story line and establish the link between the core category and other categories before it. Finally, the theoretical model is refined [12]. This paper mainly explores the policies related to the sustainable development of China's digital industry. A "story line" for the sustainable development of China's digital industry has been formed through the coding of "digital infrastructure as the foundation, data element accumulation as the driving force, promotion of digital industrialization, digital transformation of industries, digitalization of public services, international cooperation in the digital economy as the means, and digital economy governance system and security system as the guarantee". The policy evolution of the digital industry is described, and a core category, the Digital Industry Sustainability Policy Model (DISPM), is finally unearthed.

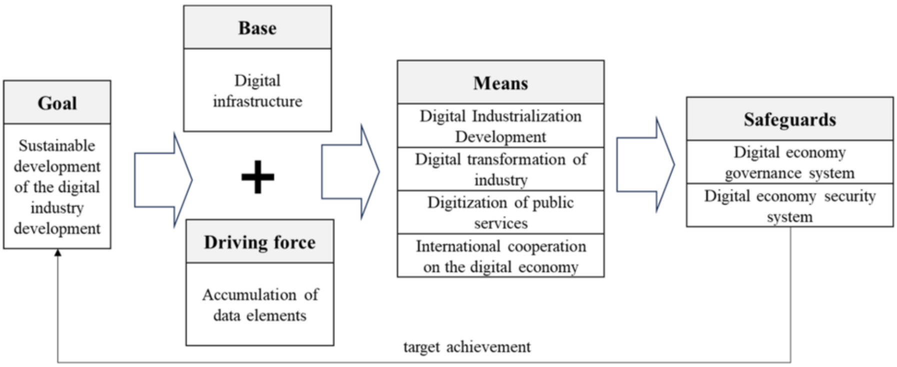

Figure 1. Policy model for sustainable development of the digital industry

4.4. Theoretical Saturation Validation

In order to comply with the theoretical saturation principle of rootedness theory, three policy documents were used in this study for the saturation test. To guarantee scientific validity, one strategic plan, one local normative document, and one local working document were selected for coding and conceptualization. The results showed that no new concepts or categories were found to be generated and the theoretical saturation test for coding analysis was passed.

5. Model Interpretation

5.1. Digital infrastructure development is the foundation for the sustainable development of China's digital industry

At present, a new round of scientific and technological revolution and industrial change accelerates the evolution of digital technology to profoundly change production and life. The areas of computing represented by artificial intelligence and cloud computing, and connectivity represented by 5G are the focus of digital infrastructure construction, constantly activating new applications, expanding new businesses and creating new models. China is actively investing in the development of digital infrastructure and accelerating the construction of an intelligent and comprehensive digital framework. This infrastructure is characterized by high-speed connectivity, integration of cloud and network technologies, intelligent agility, environmental sustainability, and security and controllability [13]. Only by improving digital infrastructure can we provide a good environment for realizing technological innovation, mechanism innovation and model innovation.

5.2. Data elements are the driving force behind the sustainable development of our digital industry

Data is a key factor of production that intertwines with various stages including production, distribution, circulation, consumption, and social service management. With the accelerating pace of digital technology innovation and iteration, data has become a crucial force driving the sustainable development of the digital industry. To give full play to the advantages of data resources and tap the potential of data value, it is necessary to continuously improve the system and mechanism related to the cultivation and development of data elements, accelerate the construction of the data base system, so that the data elements can better empower innovation, and inject a strong kinetic energy for promoting the high-quality development of digital industry.

5.3. Digital industrialization and industrial digitization are important means for the sustainable development of China's digital industry

Digital industrialization refers to the application of digital technology in traditional industries to achieve digital transformation and upgrading of industries. Industrial digitization, on the other hand, focuses more on the digital development of a specific industry and is the digitization of all or part of an industry's business processes, data and information to improve the efficiency and quality of business operations. Digital industrialization and industrial digitization are means to promote the sustainable development of the digital industry. It not only enhances the competitiveness of enterprises and the ability to innovate key technologies, but also helps to cultivate new business models and create a new ecosystem for innovation and entrepreneurship.

5.4. The digital economy governance system and security system are the guarantee for the sustainable development of China's digital industry

Accelerating the improvement of the legal and regulatory system, strengthening the network security mechanism, perfecting the governance system of the digital economy, and enhancing the ability to prevent network risks are important guarantees for the sustainable development of the digital industry. First, the legal and policy system has been gradually improved, and the "four pillars and eight pillars" of the database system have been initially constructed. Second, the network security protection capability has been continuously enhanced. A working mechanism for network security monitoring and early warning and information notification has been established, and network security situational awareness, monitoring and early warning, and emergency response capabilities have been continuously strengthened. Third, the governance capacity of the digital economy has been continuously enhanced. A cross-sectoral coordination mechanism such as the Inter-Ministerial Joint Conference on the Digital Economy has been established to strengthen inter-departmental coordination and supervision.

6. Conclusions

Policy is an industry in the development process, the need for the government to use the hands of the public resources as well as policy tools to give support, in the development of China's digital economy has played a positive role. Industrial policy is not only a specific policy formulated by the government to help the development of a particular industry, but also includes the policy direction needed to establish the elements of economic development. This paper analyzes 54 policy texts related to digital industry through Nvivo 12.0 software and constructs a policy model for the sustainable development of China's digital industry. It is found that the digital industry policy text continues the internal logic of "goal-foundation-driver-means-guarantee", which can better control the direction of industrial policy and avoid a series of information asymmetry and rent-seeking problems in the process of policy implementation. The results show that the sustainable development of China's digital industry should be based on digital infrastructure, data elements as the driving force, digital industrialization development, digital transformation of industries, digitalization of public services, and international cooperation in the digital economy as the means, and the digital economy governance system and security system as the guarantee for the sustainable development of the digital industry. This paper explores the picture of digital industry policy research in China, which is conducive to deepening the understanding of policy behavior, and at the same time provides a theoretical perspective on the logic of practice for the sustainable development of the digital industry.

Acknowledgments

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Digitalization and Management Innovation III
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Investigating Challenges and Implementing Strategies for Digital Transformation in the Field of Circulation Enterprises

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Abstract. With the profound development of the global economy and the continuous innovation of information technology, circulation enterprises are encountering unprecedented challenges and opportunities for digital transformation. As one of the world's largest consumer markets, China's circulation enterprises' process and outcomes of digital transformation will exert a significant impact on the global business ecosystem. Revised sentence: "This paper conducts a comprehensive analysis of the questionnaires collected from 356 circulation enterprises in the wholesale, retail, and logistics industries through literature review and questionnaire survey. It deeply examines the challenges faced by Chinese circulation enterprises in their digital transformation process and proposes corresponding countermeasures to provide valuable insights for the sustainable development of these enterprises. The challenges encountered in the digital transformation of circulation enterprises include low security performance, inadequate talent reserve, limited government funds, and legal support.

Keywords. Digital transformation, circulation enterprise, operational efficiency.

1.Introduction

In the digital economy era, as a crucial link between production and consumption, the digital transformation of distribution enterprises has become pivotal in enhancing competitiveness. With the continuous advancement of cloud computing, big data, Internet of Things, and other technologies, distribution enterprises have gradually transitioned from traditional business models to digital and intelligent ones[1]. Digital transformation not only enhances operational efficiency but also provides consumers with more convenient and personalized services. During this process, Chinese distribution enterprises face internal challenges such as technological innovation, talent shortage, and information security while also encountering external pressures like intensified market competition and diversified consumer demand. In recent years, the application of digital technology has presented new opportunities for the development of distribution enterprises but has also brought forth new challenges. Effectively utilizing digital technology to improve operational efficiency and accelerate enterprise digitization has become an urgent issue for distribution enterprises. Therefore, studying the impact of digital transformation on distribution enterprises holds great theoretical and practical significance.

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2. Research methods and innovations

2.1. Research methods

2.1.1 Literature research method

This paper conducted a comprehensive review of academic journals and doctoral papers related to keywords such as "digital transformation of circulation enterprises" through authoritative platforms such as CNKI and Wanfang, using the collected data as the theoretical foundation for the research. Through in-depth study and analysis, relevant literature on digital transformation of circulation enterprises at home and abroad was organized and summarized to understand key concepts and clarify the theoretical framework for problem analysis.

2.1.2 Questionnaire survey method

Relevant data was collected for research purposes through a questionnaire survey.

2.2. Innovation

2.2.1 Technological application innovation

In the process of digital transformation, circulation enterprises should actively adopt advanced technical means such as big data, artificial intelligence, Internet of Things, etc., to enhance operational efficiency and service quality.

2.2.2 Business model innovation

Digital transformation presents opportunities for business model innovation in circulation enterprises. Enterprises can explore new retail models integrating online and offline channels to expand sales channels beyond traditional restrictions; simultaneously, by developing their own e-commerce platform or collaborating with others, they can achieve seamless integration between online and offline operations to improve customer experience.

2.2.3 Organizational management innovation

Digital transformation necessitates internal organizational management changes and innovations. Enterprises should establish flat and flexible organizational structures adaptable to rapidly changing market environments; concurrently strengthen internal communication and collaboration across departments and levels to foster cross-functional teamwork capabilities that facilitate smooth implementation of digital transformation.

3. Literature review

The issues of industrial digitalization and digital industrialization have garnered widespread attention and thorough examination by experts and scholars. This study primarily focuses on the challenges present in the digital transformation of the circulation industry. Regarding the main issues in the digitization of the circulation industry, Wang Yuxiang and Xu Hongbo (2021) [2] conducted an empirical analysis on the impact of digital transformation on residents' consumption upgrading, highlighting that improving circulation efficiency has a greater effect on expanding township residents' consumption than urban residents, but has a greater impact on enhancing urban residents' consumption quality than township residents. Yang Haichao (2022) [3] emphasized that constructing new infrastructure is a crucial approach to accelerate China's circulation industry's digital transformation and facilitate domestic circulation. Tang Renwu and Zhang Jingsen (2022) [4] stressed that digital technology enhances modern circulation systems, transforming it into a system interconnected by various modes, organizations, carriers, and technologies to promote common prosperity realization. Lin Gang and Fan Canghai (2022) [5] argued that online retail has reshaped supply-demand structure and mode of circulation while accelerating value chain upgrade within supply chains. Chen Zekai and Guo Wenxing (2022) [6] through empirical analysis, demonstrated how higher levels of digital economy development can drive high-quality development within the circulation industry. Zhou Lin and Wang Xiaoyi(2022)[7] discussed obstacles to digital transformation at three levels: macro-economic environment, middle-market operation mechanism, micro-enterprise operation mode; they proposed corresponding suggestions from policy, technology, and industry perspectives respectively. Wu Hailan & Liu Yuqiang (2023) [8] suggested commercial enterprises should further research consumer shopping habits & increase R&D for new logistics technologies to achieve internal & external innovation.

(Autio et al 2018; Li 2020)[9][10] noted existing research mainly focuses on business models organizational structures & innovation performance; big data application changes enterprise cost mechanisms & value exchange reducing intermediary power in value chains innovating business models; Chen Yuchan(2023)[11]suggested strengthening goods quality control developing promotion plans according to goods particularities improving brand values promoting enterprise development. Zhou Ruohan(2022)[12]argued modern circulations reflect integrated logistics-business flow developments where business flow drives logistics feedbacks develop business flows conducive domestic economic cycles.

The above literature indicates increasing global scholarly attention towards understanding impacts of digital transformations. The focus lies mainly upon resident impacts & circulation modes[13]. Although studies exist regarding computer, internet, intelligence, digital transformations effects upon circulations, &demonstrated importance in reducing transaction costs & accelerating goods/services circulations[14][15], no definitive conclusions reached, few studies address challenges posed by such transformations. Based holistic thinking, this paper analyzes advantages, challenges, &countermeasures related to digitizing the circulating industries.

4. Questionnaire design and investigation

4.1 Questionnaire design

Circulation enterprises encompass a wide range of industries, including commerce, trade, logistics, retail, wholesale, and transportation[16][17]. This study focused on conducting a questionnaire survey within the representative supply chain of retail, logistics, and wholesale sectors to ensure the effectiveness and relevance of the questionnaire. The designed questionnaire specifically targets the application of digital transformation in circulation enterprises and its influencing factors. It covers various aspects such as advantages, existing problems, effects, and aims to comprehensively reflect the impact of digital transformation on circulation.

4.2 Survey

Between December 2023 and February 2024, a total of 356 enterprise questionnaires were obtained through face-to-face interviews with individuals from the retail industry, wholesale industry, logistics industry as well as online questionnaires. The effective rate of the questionnaire was 100%. The statistical information regarding the questionnaire is as follows:

Table 1. presents the basic information of the survey objects

		Wholesale industry		**Retail industry**		**Logistics**	
Categories	Options	Number of people	Percentage %	Number of people	Percentage %	Number of people	Percentage %
1. Gender	male	49	48.04%	64	43.24%	60	56.6%
	female	53	51.96%	84	56.76%	46	43.4%
2. Age	18 to 25	15	14.71%	14	9.46%	12	11.32%
	25 to 35	36	35.29%	55	37.16%	31	29.25%
	35 to 45	34	33.33%	56	37.84%	38	35.85%
	45 to 55	4	3.92%	15	10.14%	15	14.15%
	55 to 60	13	12.75%	8	5.41%	10	9.43%
4. Practice Time	Within three months	10	9.8%	8	5.41%	9	8.49%
	3-12 months	27	26.47%	54	36.49%	31	29.25%
	1-3 years	28	27.45%	42	28, 38%	29	27.36%
	More than three years	38	36.27%	44	29.73%	37	34.91%
Total		102	100%	148	100%	106	100%

5. Analysis and Interpretation of Survey Findings

Table 2. presents the survey findings regarding the benefits of digital transformation in circulation enterprises

Questions	**Options**	**Wholesale industry**	**Retail industry**	**Logistics**	**Survey statistics**
1. Is your organization undergoing digital transformation?	yes	81.37%	73.65%	84.91%	79.1%
	no	18.63%	23.65%	15.09%	20.79%
2. Has digital transformation improved your	Significantly improved	28.43%	22.97%	34.91%	28.09%
	Some improvement	45.1%	47.3%	36.79%	43.54%

business's ability to innovate?	No noticeable effect	14.71%	17.57%	11.32%	14.89%
	Somewhat reduced	11.76%	12.16%	16.98%	13.48%
3. Has digital transformation made your business more productive?	Significantly improved	42.16%	28.38%	32.08%	33.43%
	Some improvement	39.22%	45.95%	42.45%	42.98%
	No noticeable effect	10.78%	13.51%	14.15%	12.92%
	Somewhat reduced	7.84%	12.16%	11.32%	10.67%
4. Has digital transformation improved the operational efficiency of your business?	Significantly improved	40.2%	29.05%	34.91%	33.99%
	There is some improvement	35.29%	36.49%	37.74%	36.52%
	No noticeable effect	11.76%	20.95%	12.26%	15.73%
	Somewhat reduced	12.75%	13.51%	15.09%	13.76%
5. Whether digital transformation has improved the quality of customer service at your business	Significantly improved	39.22%	29.73%	33.96%	33.71%
	Some improvement	32.35%	45.27%	37.74%	39.33%
	No obvious effect	14.71%	1.54%	18.87%	16.29%
	Somewhat reduced	13.73%	9.46%	9.43%	10.67%
6. How does the business process cycle change after digital transformation?	Greatly shortened	31.37%	25%	32.08%	28.93%
	Somewhat shortened	41.18%	43.92%	38.68%	41.57%
	No significant change	13.73%	18.92%	7.55%	14.04%
	Some growth	10.78%	8.78%	18.87%	12.36%
	Substantial increase	2.94%	3.38%	2.83%	3.09%

5.1 Advantages of digital transformation in the distribution sector

Based on survey data, digital transformation has become a widespread trend, with 79% of enterprises in the three industries surveyed having undergone digital transformation, while only about 20% have not. The majority of those that have not are concentrated in the retail industry. Digitalization within the distribution industry involves the application of technologies such as big data, Internet, cloud computing and blockchain to enhance market efficiency. The development of digital technologies has led to optimized business processes, improved customer service quality and time savings within the distribution industry.

5.1.1 Optimize business processes and innovate business models

According to our survey data, among enterprises that have undergone digital transformation, 28.93% have significantly improved their business processes and 41.57% have shortened their business process cycle to some extent. Information technology enables automation and digitization of business processes leading to enhanced efficiency and reduced cycle times for businesses. For logistics enterprises, real-time monitoring and data analysis through IoT and cloud computing has resulted in shorter cycles, reduced costs and increased efficiency; however, the most significant change is seen in innovative business models facilitated by digital technology applications which provide greater flexibility for creating new models tailored to different user needs. For retail enterprises' employees who rely heavily on e-commerce sales driven by digital technology during this internet era - providing consumers with more convenient personalized shopping experiences - it also brings additional market share opportunities for these companies.

5.1.2 Enhance operational efficiency and save working time

By leveraging digital technology, distribution enterprises can achieve real-time tracking and management of the supply chain, optimize inventory and logistics management, enhance the speed of goods flow, and mitigate inventory costs and unsalable risks. Research indicates that approximately 80% of enterprises have experienced improved operational efficiency post digital transformation. This is attributed to the substantial data support provided by digital transformation, enabling distribution enterprises to conduct data analysis, identify potential market opportunities and areas for improvement, as well as establish a scientific foundation for decision-making. The advancement of digital technology has bolstered the volume, immediacy, and effectiveness of data information, ensuring efficient transmission with integrity and accuracy across industries. Data production factors serve as crucial groundwork for enterprise production and operation decisions.

5.1.3 Enhance the quality of customer service and reduce operational costs

Based on survey data, digital transformation has the potential to significantly elevate enterprise service standards.70%-80% of employees believe that through digital technology, enterprises can promptly gather customer feedback, data, and other information for analysis and insight mining, leading to continuous product and service optimization and enhanced customer satisfaction. For instance, in the retail industry, digital technology enables improvements in service levels and cost reduction through online ordering, intelligent queuing systems, and smart vending machines. The application of digital technology also elevates customer experience and service models while bolstering customer satisfaction and loyalty. Interviews with delivery personnel reveal that intelligent customer service systems can enhance the quality of customer support; big data analysis facilitates personalized services; mobile apps offer a convenient shopping experience—all contributing to improved customer satisfaction and loyalty which ultimately enhances enterprise competitiveness.

5.2 Circulation enterprises face challenges in their digital transformation

Table 3. Results of the survey on challenges in digital transformation are presented

Problems	**Options**	**Wholesale industry**	**Retail industry**	**Logistics**	
1. What challenges do you face in digital transformation? (multiple choices)	Technology implementation is difficult	37.25%	37.16%	36.79%	37.08%
	Under-skilled staff	68.63%	70.95%	66.04%	68.82%
	Data security concerns	66.67%	70.27%	72.64%	69.94%
	Low level of government support	48.04%	42.57%	59.43%	49.16%
2. What kind of support has your company received? (Multiple choices)	Policy support	36.27%	34.46%	30.19%	33.71%
	Legal support	18.63%	41.89%	25.47%	30.34%
	Financial support	38.24%	31.76%	22.64%	30.90%
	Basically none	28.43%	28.38%	38.68%	31.46%
3. Have you received any training in digital transformation?	yes	40.2%	43.92%	34.91%	40.17%
	no	59.8%	56.08%	65.09%	59.83%

4. Has digital transformation improved data security in your business?	Significantly improved	26.47%	14.19%	16.98%	18.54%
	Slightly up	24.51%	35.14%	27.36%	29.78%
	No change	24.51%	27.7%	29.25%	27.25%
	Somewhat reduced	24.51%	22.97%	26.42%	24, 44%

According to our survey, while the majority of respondents are optimistic about digital transformation, some have identified challenges in the process, such as rapid technological advancements, low security performance, a shortage of skilled professionals, and inadequate government funding and legal support.

5.2.1 From the perspective of enterprise investment, businesses are under immense pressure to keep up with rapid technological advancements, which often surpass their expectations and capabilities

With the continuous evolution of cloud computing, big data, artificial intelligence, and other technologies, circulation enterprises are confronted with the challenge of swift technological updates. According to survey results, 37.08% of enterprises encounter technical difficulties. Businesses must stay abreast of new technologies in order to ensure seamless operations. However, the pace of technological obsolescence frequently exceeds enterprises' expectations and capacities, resulting in significant pressure on them. Rapid technological changes can also disrupt strategic planning and decision-making processes. Companies need to continuously adjust their strategic direction and business models to adapt to technological shifts; however, such frequent adjustments may lead to strategic instability and impact long-term enterprise development.

5.2.2 From the perspective of the social environment, the insufficient legal and financial support from the government for circulation enterprises has significantly hindered their digital transformation

According to survey results, inadequate financial and legal support from the government may result in circulation enterprises not receiving sufficient policy incentives and legal protection during their digital transformation process. 30% of enterprises indicated a lack of preferential tax policies and financial support for digital technologies during their transformation. Additionally, over 30% of employees believe that there is a lack of legal protection in digital transformation, leading to reluctance among circulation enterprises to pursue digital transformation due to fear of risks and losses. The substantial investment required for digital equipment as part of long-term income generation becomes a deterrent if government funding is lacking along with legal protection.

5.2.3 From a security performance perspective, the digital transformation of circulation enterprises poses security risks that impact the enterprise's ability to guarantee security

Digital transformation simplifies data, facilitating collection and analysis for circulation enterprises handling large amounts of customer and business data. However, over 50% of individuals still perceive digitization as potentially causing security issues. Without proper security measures in place, this could result in data breaches exposing personal or sensitive corporate information, leading to financial and reputational damage. As online business grows, circulation companies' network infrastructure faces increased security pressure from cyberattacks, virus transmission, and malware which can disrupt normal operations. Physical logistics also require attention to physical security such as storage facility management and goods safety during transit due to inadequate security measures.

5.2.4 From a staffing perspective, circulation enterprises lack sufficient technical personnel and provide inadequate technical training for existing staff, which hinders the digitalization progress of these enterprises

The survey revealed that 69% of employees in circulation enterprises feel that there is a shortage of technical personnel, leading to challenges in implementing or updating technologies. This can result in project delays or even impact the successful implementation of projects. With only 40% of current employees receiving technical training, companies are not investing enough in enhancing their technical capabilities to keep up with technological advancements. This may put them at a disadvantage compared to their competitors. Insufficient staffing and low levels of technical training may impede a company's ability to innovate. Neglecting the staffing and technical training of technicians can also affect employee morale and work enthusiasm, potentially leading to decreased work efficiency and overall operational impacts on the enterprise. In some cases, insufficient technology may pose security risks.

6. Improved Measures and Recommendations for Advancing the Digital Transformation of Distribution Enterprises

6.1 Increase investment in technology research and development

Establish a dedicated research and development department or team to focus on the advancement and application of novel technologies. These teams should consist of professionals with relevant technical and industry expertise to ensure the professionalism and effectiveness of R&D activities. We will augment our investment in technology research and development, elevating the proportion of R&D funds in total enterprise expenditures. This will ensure that companies have ample capital to support technology research and development activities, driving the translation and application of innovative results. Strengthen collaboration with external partners such as universities and scientific research institutions to jointly undertake technology research and development projects. Through industry-university-research cooperation, enterprises can access more innovative resources and technical support, accelerating the process of technology research and development. Formulate a digital transformation strategy and plan. Enterprises should delineate clear goals for digital transformation, formulate specific implementation plans with timelines, ensuring orderly progress in digital transformation initiatives. Leverage advanced technologies like big data analytics and artificial intelligence to optimize business processes, enhancing operational efficiency.

6.2 The government should enhance financial support for the digital transformation of circulation enterprises

Governmental financial aid can alleviate the financial burden on enterprises and expedite their digital transformation process. In the era of digital economy development, many circulation enterprises are eager to undergo digital transformation; however, breaking away from traditional modes may lead to bankruptcy due to disrupted capital chains. Throughout the process of digital transformation, circulation enterprises often require loans and financing from banks and other financial institutions. Due to their limited scale or insufficient collateral, these enterprises may encounter difficulties in obtaining costly financing. Governmental financial support can serve as a guarantee or interest reduction for these enterprises, thereby lowering their financing costs and facilitating smoother completion of their digital transformation efforts. Digital transformation demands significant investments in technology, equipment, talent acquisition, among other aspects—a considerable expense for numerous circulation enterprises. Governmental financial assistance can help address this issue by providing necessary support for these investments.

6.3 The government should enhance legal assistance to facilitate the digital transformation of distribution enterprises

In the current digital era, the digital transformation of distribution enterprises has become an inevitable trend. This transformation not only enhances operational efficiency and reduces costs but also better aligns with consumer needs and improves market competitiveness. However, enterprises often encounter various legal risks and challenges during this process. Therefore, it is essential for the government to enhance legal support for the digital transformation of distribution enterprises and provide improved legal protection and guidance. Throughout the digital transformation process, enterprises will face a range of legal issues including data protection, privacy, intellectual property rights, etc. By formulating relevant laws and regulations, the government can offer legal protection for distribution enterprise's digital transformation efforts while reducing associated risks and improving success rates. The government should also refine laws related to data protection, privacy, and intellectual property rights in order to clarify rights and obligations during digital transformations while safeguarding legitimate interests of enterprises. Strengthened supervision over these transformations is necessary to ensure compliance with relevant laws as well as providing legal advisory services to help resolve any encountered issues.

6.4 Enhance staff training and foster team cohesion

In the process of digital transformation, distribution enterprises must enhance the training of relevant talents. On one hand, enterprises should focus on talent acquisition and development. To support digital transformation, companies need to recruit and nurture professionals with expertise in digital technology or upgrade the skills of current employees through training and refresher courses. In order to advance digital transformation more effectively, distribution enterprises need to intensify employee training by developing personalized training plans tailored to different positions and business needs in order to enhance their digital skills. Additionally, companies can establish an internal training system and regularly organize internal training activities to share experiences and results related to digital transformation. Furthermore, businesses can also bolster their intellectual support for digital transformation by recruiting exceptional external talents.

6.5 Enhancing security protocols

As the volume of enterprise data grows and digitalization deepens, cybersecurity risks, data protection, and business continuity will also increase. Strengthening security mechanisms is crucial for circulation enterprises during the digital transformation process due to its impact on various aspects such as data processing, business operations, and customer information. Security issues can lead to significant economic losses and damage the reputation of the enterprise and customer trust. Establishing a robust data security management system including data classification, encryption processing, permission control, backup and recovery is essential to ensure data integrity, confidentiality, and availability. Additionally, enhancing employee training to raise awareness of data security is necessary in order to prevent operational errors or malicious behaviors leading to data leakage or damage. The emergency response mechanism should encompass emergency planning, dedicated response teams, allocation of emergency resources, among other components. Furthermore, regular security audits and risk assessments are essential for identifying potential security vulnerabilities and points of risk in a timely manner; corresponding measures can then be implemented for improvement purposes to ensure the efficacy of the security assurance mechanism during digital transformation.

7. Conclusion

The digital transformation of distribution enterprises is a multifaceted and challenging endeavor, necessitating collaborative efforts from businesses, government, and society. Only through sustained innovation and proactive adaptation to challenges can the circulation industry achieve digital transformation and high-quality development. We anticipate that in future developments, the digital transformation of distribution enterprises will yield even more remarkable outcomes and contribute significantly to societal prosperity and advancement.

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ML-Based AI Conceptual Framework for Assessing SMEs Digitalization Through the Lens of Sentiment Analysis

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Abstract. Tools from the machine learning and data mining domain become even more popular in the fields of economics, entrepreneurship, and policy-making. At the same time, the research on small and medium-sized enterprises (SMEs) is getting amplifying importance for governments and policy-makers especially when it comes to support of SME's digitalization. A good understanding of the current level of digitalization of SMEs by industries is a prerequisite for design and integration of effective national policies. The goal of this paper is to design the architecture of an ML-based AI conceptual framework for assessing SMEs digitalization. We do this from the perspective of customers assuming that their preferences are absorbed in the publicly available (online) data that they generate in social media and community forums. This approach forms a significant contribution of this paper. Furthermore, we define an algorithm for data preparation, and we develop an algorithm based on sentiment analysis, which generates a set of industry-specific digitalization indices, which is another important contribution of this paper.

Keywords. Digitalization, small and medium-sized enterprises (SMEs), machine learning, natural language processing, artificial intelligence, sentiment analysis.

1. Introduction

Small and medium enterprises (SMEs) are nowadays an important driving force towards economic development, particularly in developing and emerging economies (see for example [1] and [2] as well as the references therein). The latest figures as published in [3] emphasizing SMEs importance for the EU economy are as follows. They constitute 99.8% of the number of enterprises in the EU indicating a growth of 2.7% for the period 2021-2022; the share of employed by SMEs is 64.4% with SMEs value added share amounting to 51.8%. Furthermore, [2] highlights the crucial role of SMEs for poverty alleviation and sustainable economic growth.

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This motivates the increased research interest in the determinants behind success and survival of SMEs [4]. As outlined in [2] information communication technology and changes of consumer preferences are among the major challenges within the context of economic globalization. In particular, the rapid development of information communication technology speeds up globalization and market liberalization, which amplifies the importance for SMEs to integrate technological innovations in the business.

However, while technological innovation fosters the growth of firms operating in high-tech resource rich environments of growing demand, it might be an additional challenge to small firms' survival in a disrupted declining industry [5]. Combined with fast changing customer preferences shaping an increasing demand for high-quality, diverse goods and services, the pressure towards digitalization of SMEs is determined mainly by the necessity to stay competitive at the globalized markets even for firms operating at the local market only.

Therefore, well-designed government policies in support of SMEs digitalization are imperative in order to mitigate this pressure and the starting point for such policies is the good understanding of the current level of digitalization of SMEs. This task requires sound assessment tools. Our paper contributes to this problem through embracing the power of data analytics. Application of tools from the machine learning and data mining domain has already proven their ability to provide new specific knowledge that might complement and support the intuition behind design and implementation of policies. Examples such as the SHARE project evidence this.

Taking into account the importance of SMEs and their survival for national economies, the goal of this paper is to design the architecture of an ML-based AI conceptual framework for assessing SMEs digitalization. We do this from the perspective of customers assuming that their preferences are absorbed in the publicly available (online) data that they generate in social media and community forums. This approach forms a significant contribution of this paper. Furthermore, we define an algorithm for data preparation, and we develop an algorithm based on sentiment analysis, which generates a set of industry-specific digitalization indices, which is another important contribution of this paper.

The rest of the paper is organized as follows. In Section 2 is provided a review of related studies. In Section 3 is introduced a case study that illustrates distinctly the research gap and the necessity to develop the proposed conceptual framework. Section 4 introduces the developed integrated framework for data engineering, knowledge extraction, and analytics of SME's data, followed by a discussion in Section 5.

2. Literature Review

The current study explores the possibilities of assessing SMEs digitalization level by employing a data-driven approach relying on the application of AI techniques. Since the beginning of the XXIst century, sentiment analysis represents a very active research area that integrates various natural language processing and mathematical approaches to understand and interpret the sentiment or subjective information expressed in a piece of text [6].

Sentiment analysis is an AI approach that has numerous applications in studies devoted to understanding public opinion and might be considered as an important complementary tool in large-scale surveys utilized in the social and management science [7]. When it comes to the assessment of digitalization level of a service/company/industry, sentiment analysis might be helpful in at least several directions. First, it might be effectively used to provide insights into how the digitalization efforts are being perceived by the customer or general public. Second, it might be used in establishing benchmarks and key performance indicators (KPIs) for digitalization initiatives based on public sentiments. Furthermore, the analysis of internal communication can provide insights into the effectiveness of company's digital tools and processes as perceived by employees (internal subjective perspective). Following is a brief literature review of recent studies focused on digitalization assessment through the application of sentiment analysis and other NLP techniques.

Several up-to-date research papers examine the potential of AI, and natural language processing in particular, in the assessment of digitalization efforts in the government domain. In [8] is proposed an architecture of an ML system for mining public opinion on e-government services. The system combines topic modeling, sentiment analysis and visualization techniques applied on news and citizens' discussions in forums in an attempt to capture the progress in e-government development and the expressed opinions towards public e-services in Bulgaria. The main objective in [9] is to leverage state-of-the-art natural language processing technologies, particularly transformer-based language models, for public opinion analysis. The study focuses on the analysis of citizens' sentiments and emotions regarding the digitalization of services in the educational, administration, and health public sectors. Main source of data are discussions in community forums. The published results reveal interesting insights into public sentiments and emotions towards learning in an electronic environment, usage of electronic signature, e-voting, e-health systems etc.

In [10] sentiment analysis is applied on the aspect level in order to extract explicit aspects related to government software applications. The proposed approach captures reactions and emotions to e-government services development with the help of deep learning methods applied on citizen reviews. Muliawaty et al. [11] focus on the potential of big data and sentiment analysis technologies for enhancing bureaucratic public services and adoption of digital technologies. The authors propose a design of a sentiment analysis application that utilizes Twitter posts to understand public opinion on existing bureaucracy services. Yue et al. [12] present an insightful study on public perceptions towards smart city construction in China. Similar to the approach adopted in related studies, the authors apply a combination of sentiment analysis and topic modeling techniques on social media public comments. The utilization of the established topic modeling algorithm Latent Dirichlet Allocation (LDA) leads to the extraction of various topics related to smart cities among which are captured public concerns about technology applications, digital transformation of enterprises and digital industry economy. After topic extraction, sentiments in each topic are detected through deep learning techniques in order to gain deeper insights into public opinion.

Another study utilizing sentiment analysis to capture citizen opinion on government digitalization efforts is proposed in [13]. The authors develop an e-government gamification model aimed at motivating citizens to actively use digital public services for paying bills, renewing licenses etc. In [14] is presented novel research on the identification of emerging technologies in public services delivery with the aim of guiding policymakers in their implementation. The authors apply natural language processing techniques on a large database of academic papers focused on the topics of digital governance and digital democracy. Cluster analysis and network visualization techniques are applied in order to develop a better understanding of the role of emerging technologies in e-government and current trends in the field. Other studies aimed at assessing digitalization efforts in the government domain through the application of AI techniques can be found in [15, 16, 17, 18].

Our review of related work reveals that in the last two years there has been an increasing volume of studies focused on the application of modern AI technologies in attempt to evaluate e-government development and various digitalization efforts in the public sector. We would adapt the recent developments from this domain to the domain of SMEs digitalization for the following reasons. AI provides extremely powerful tools that have the ability to reveal insights that could not be captured otherwise. Sentiment analysis and topic modeling are among the most frequently applied natural language processing techniques used in discovering public opinion towards digitalization initiatives and measures. The results from the reviewed studies have important implications for policy-makers and experts engaged in the development and implementation of policies related to digitalization within the government domain.

Our literature review reveals the almost complete lack of studies focused on the potential of AI applications in support of SMEs digitalization efforts. To the best of the authors' knowledge currently there are no research papers exploring the possible uses of natural language processing in the analysis of public opinion on SMEs current digitalization level and efforts. We bridge this gap in the literature by proposing a conceptual framework for assessing SMEs digitalization based on machine learning and natural language processing techniques.

3. Fostering Understanding of SMEs Effective Digitalization: A Case Study from Bulgaria

To illustrate how the proposed conceptual framework contributes to existing approaches for digitalization assessment, we provide as a context a case study based on survey data analysis. We should note that this survey is conducted under the same research project as the current paper. Details are provided in the first footnote of this text. Data for this study was collected through a national representative sociological survey among 1000 SMEs for the country of Bulgaria. The survey used a quota sampling technique based on type of SMEs (50% microenterprises and 50% small and medium-sized enterprises), Nomenclature of Territorial Units for Statistics NUTS 2 developed by the EU, and economic sector based on NACE Rev. 2 (Section A - Agriculture, Forestry and Fishing; high-technology and medium-high technology; medium-low technology and low technology; knowledge-intensive services; less knowledge-intensive services).

As explained in the introduction section, the rapid development of information communication technology speeds up globalization and market liberalization, which amplifies the importance for SMEs to integrate effectively technological innovations in the business. However, while technological innovation is known to foster the growth of high-tech firms, it might be an additional challenge to low-tech firms. Therefore, in this example we focus our attention on a subsample of firms that operate in the high-technology and medium-high technology sector, and in the medium-low technology and low technology sector. For simplicity of notation, we refer to the former as high-tech sector and to the latter as low-tech sector. Out of 1000 firms constituting our sample, 104 are classified as high-tech firms, and 127 firms are classified as low-tech firms. We consider the answers provided in a conducted survey on the self-assessed degree of digitalization and the integration of digital technologies in their businesses.

Figure 1 represents visually the self-assessed degree of digitalization at Likert scale ranging from 1 to 5, where 1 indicates that the firm considers itself as not digitalized at all and 5 stands for fully digitalized firm self-assessment. The share of companies at each level of digitalization for the high-tech and low-tech sector is represented as a percentage of all the SMEs in the respective sector. We could easily see that the highest saturation of companies is at levels 3 and 4. Even though high-tech firms are more digitalized as compared to low-tech SMEs, the differences are not as severe as we could intuitively assume.

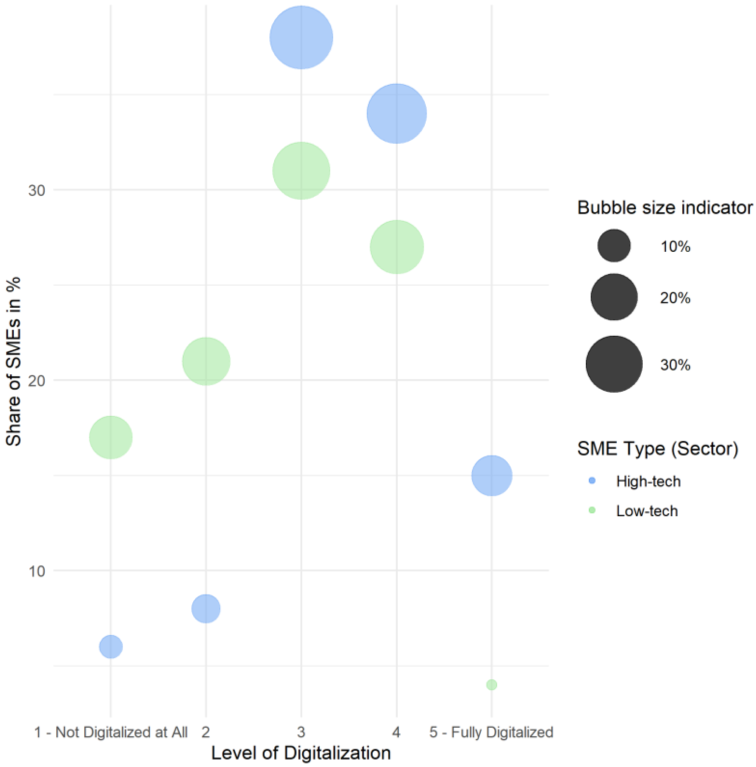

Figure 1. Self-assessed level of digitalization for high-tech and low-tech Bulgarian SMEs

Consequently, we look closely at the integration of two particular technologies that are intimately related to economic globalization. These are e-commerce, which includes online sales via website, as well as social media. Results are summarized in Figure 2. We observe that the share of SMEs integrating e-commerce in their business is approximately the same for high-tech and low-tech firms and even though the percentage of high-tech companies integrating social media is greater than that for low-tech companies, the latter show catch-up numbers. However, these numbers are not indicative on plausible differences in the effectiveness of integration of digital technologies between high-tech and low-tech companies. Customer opinion might provide valuable insights fostering comprehensive understanding of such kind of differences.

Therefore, we propose a conceptual framework embracing the power of publicly available text data that aims to complement the understanding of SMEs digitalization traditionally assessed through survey data analysis. Customer opinion that might be found in community forums, social media platforms etc. contains important information on the degree of effective adoption of some common digital technologies by SMEs such as usage of e-trade instruments and social media presence. In order to illustrate this concept, we provide an example based on simulated data depicted at Figure 3.

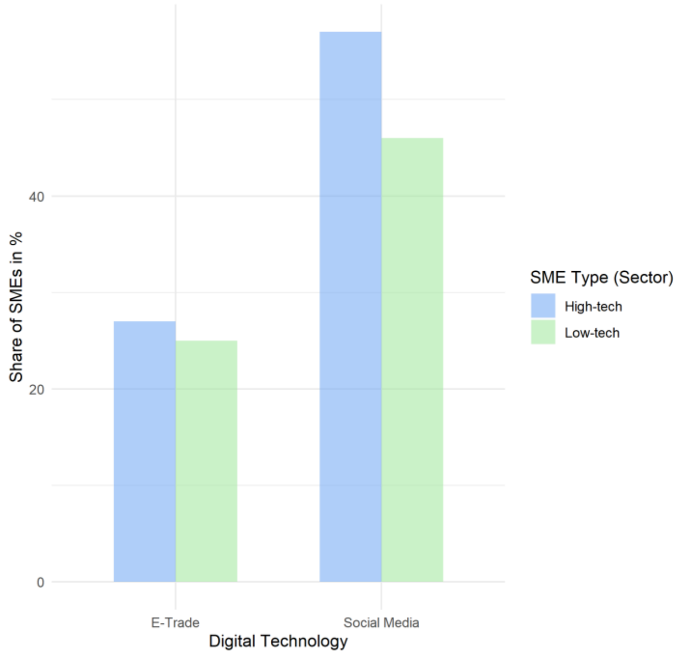

Figure 2. Digital technology adoption in high-tech and low-tech Bulgarian SMEs

We have generated three examples of customer feedback for a company that has a website for online sales and uses social media. While we observe integration of these technologies in its business, the client sentiment might be viewed as an additional source of information that could foster understanding on how effectively they actually work. In the next section we describe the proposed conceptual framework based on machine learning and natural language processing techniques that enable understanding SMEs digitalization from the client's perspective.

Customer feedback 1 (Text 1): *"Wow, their **website** is incredibly disorganized! It's frustrating trying to find the information I need. Plus, with the frequent occurrence of recent data breaches, I'm really worried about the **security** of my personal information when using this **website**."*

Customer feedback 2 (Text 2): *"I really like their digital **delivery** management process. It is really convenient to track your order and know when to expect it!"*

Customer feedback 3 (Text 3): *"OMG! Love their **Instagram** page! The visuals are great, and I like it that there is information about prices."*

Figure 3. Simulated customer feedback data

4. ML-based AI Conceptual Framework for Assessing Digitalization in SMEs

The main objective of the current paper is to develop a conceptual framework for assessing SMEs digitalization at industry level via application of ML and AI methods on SME's data. Figure 4 illustrates the main stages and key elements in the proposed framework.

In a nutshell, the framework relies on publicly available online data on SMEs operating in different industries. We motivate our choice of data as follows. We assume that opinions expressed in social media and community forums absorb customer preferences. This would allow us to assess SMEs digitalization through the lens of customers, which is a novel way to approach the issue.

Data is then processed via NLP and ML techniques so as to extract synthetic features subject to further analysis. These features are integrated to create an empirical study database that will be later used to derive insights on SMEs digitalization at industry level. Nevertheless, it is important to note that the proposed conceptual framework could be applied to evaluate the digitalization initiatives of SMEs not just at the industry level but also at the level of individual companies.

An important result, coming as an output of the conceptual framework for data analytics of SME's data, is the delivery of an empirical database providing insights into public opinion on SMEs digitalization efforts on industry level. The database encompasses insights from external sources, providing a comprehensive collection of objective digitalization measures for SMEs. Thus, such a database might be considered as an important complement to surveys focused on measuring digitalization development and efforts based on the internal "subjective" perspective of company's management board and staff.

Five important stages could be outlined in the proposed conceptual framework for assessing SMEs digitalization. The next subsections will describe in detail each of the main analytical stages of the framework displayed in Figure 4.

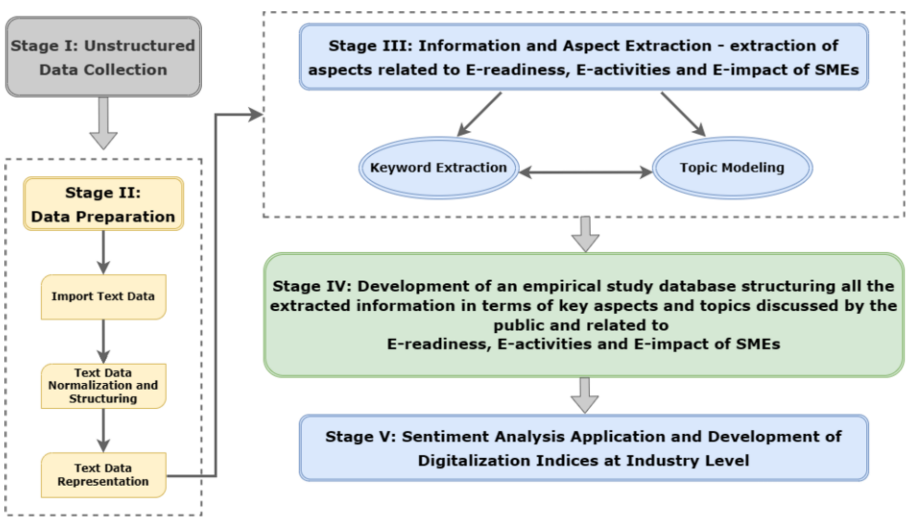

Figure 4. Analytical process behind the proposed conceptual framework for assessing digitalization in SMEs

4.1. Stage I – Unstructured Data Collection

The framework suggests that unstructured publicly available (online) data discussing small and medium sized enterprises is collected through web scraping. Such data could provide information on digitalization KPIs from an independent observer's perspective. Instead of scraping text data based on general keywords like "small and medium-sized enterprises" or abbreviations of this term, we broaden the scope of our search by extracting public comments for particular SMEs. To accomplish this, we first develop a sample of selected SMEs operating in different industries. This sample is derived with the help of official lists of SMEs names provided by government services. Then, using this information, text data is collected using carefully selected key words (for example, names of the companies, abbreviations of the names etc.). Thus, we are able to capture a wider spectrum of public opinion on SMEs performance and digitalization efforts. In addition, such data collection strategy enables empirical analysis not only at the "industry level", but also at "individual company" level (provided that sufficient amount of data is found for a specific company).

In the proposed conceptual framework, we put the most emphasis on the extraction and utilization of related to the selected SMEs online interactions in the form of reviews or public comments in social media and community forums. Similar to what have been already accomplished in the e-government domain [9], the application of sentiment analysis techniques on such data will enable the identification of public opinions regarding digital initiatives, processes and services and provide valuable insights into public perceptions of digital experiences with a given company. Such insights could highlight areas where improvements are required in the digitalization endeavors or where there might be deficiencies in digitalization development among SMEs in a particular industry. By applying different NLP tools on the publicly available online data, we are also able to extract key aspects related to SMEs digitalization on industry level. The aggregation of the results from information extraction and sentiment analysis, enables us to assess the digitalization efforts in each of these aspects from the customer (public) viewpoint.

4.2. Stage II – Data Preparation

This subsection describes the methodology for text data preparation (Stage II). The first step consists of the application of several important analytical techniques for text data normalization. After ensuring that text data crawled from the Internet are imported and read correctly in the software used for data analysis, we apply necessary NLP techniques for text data processing. The final aim is to derive text data fit for further analysis. Textual data collected from social networks and discussion forums exist in different formats and often include a significant amount of irrelevant or noisy content. Due to this reason, within Stage II, we implement essential procedures for data cleaning and employ necessary techniques to structure the data.

Let D denote the corpus of publicly available text data in the form of online reviews and public comments related to SMEs operating in a pre-defined set of K industries. Thus, each document d_i $(i = 1...N)$ is associated to a particular industry I_u, where $u = 1...K$. Given D consists of N text documents, then each document d_i will undergo the following text normalization techniques in the specified order:

1. Removal of HTML tags or analogous fragments presented in text data as a result of the data crawling process.

2. URL removal – URLs part of text data are considered irrelevant for subsequent analyses and therefore are removed.
3. Text data translation – this step might be skipped depending on the exact use case and choice of a particular country which SMEs will be under analysis. If the native language spoken in that particular country is considered a "low-resource" language (meaning that few language resources are available for processing and analysis of text data in this language), then text data translation might be applied. For example, performing sentiment analysis in unsupervised settings would require the availability of appropriate tools for carrying out the task on text data in the respective language. However, there might be the case that few such language resources exist for the particular language, while those that are available might not be appropriate for the domain of text data under analysis. In such scenario, data will be translated to English since there is an abundance of linguistic resources for this language.
4. Case normalization and digits/special characters removal.
5. Stop words removal – removal of the most frequently appearing words (stop words refer to the frequently used words in a particular language that contribute minimal information in data analysis). It is important to note that depending on the choice of text data representation technique this step might be skipped.

After the application of key text normalization methods, data will be put into more "structured" format through text tokenization applied on word level. Each document d_i consisting of z_i number of words ($z_i = \{1,2,...\}$) will be split to word tokens. At this point, it is important to mention that based on the specific characteristics of the text data sample at hand, z_i might be set to values larger than a given threshold value (and documents filtered out based on this criteria) since extremely low values of z_i for some text documents might imply lack of enough context and inability to extract useful insights in further stages of the analysis.

The final step in Stage II is text representation i.e., turning textual data into numerical format. The choice of an appropriate text representation technique hugely depends on the choice of machine learning algorithms that will be applied in subsequent data analysis. For example, traditional topic modeling algorithms like LDA [19] would require representing data using the vector space model which applies the bag-of-words assumption. However, more recent approaches like BERTopic [20] utilize document embeddings. The latter can effectively capture complex relationships within textual data, including semantic meanings. Both classical and novel approaches for text representation have their pros and cons [21]. However, an extensive discussion on this topic is outside the scope of the current study.

For the sake of maintaining simplicity within the context of the proposed framework, we briefly describe the text representation process when applying the classical vector space model. Utilizing the latter means that each document d_i will be represented as a fixed-length vector v_i ($v_i \in \mathbb{V}^S$) of word weights in the vector-space $\mathbb{V}^S$. Each vector v_i contains S elements (where S denotes the total number of unique words/tokens in corpus D) of which exactly y_i are non-zero (equals the number of unique words/tokens in d_i and $y_i \leq z_i$). Some established approaches for turning tokenized textual data to numerical format [22] that might be applied include integer vectorization and term frequency-inverse document frequency (TF-IDF). The latter is preferred in the application of classical topic models like LDA. Furthermore, TF-IDF is also employed in most recent approaches like BERTopic where class-based TF-IDF weights are utilized in the development of more efficient topic representations.

The final output from Stage II is a document-term matrix $F_{(N \times S)}$ which contains the numerical representation of all text data related to SMEs.

4.3. Stage III – Information and Aspect Extraction

This subsection describes the methodology for application of NLP techniques for information extraction on publicly available (online) data related to SMEs. Stage III is crucial since we aim at the extraction of key factors/aspects/concepts related to SMEs digitalization and presented in text data. For the sake of illustration, we define three such aspects - E-Readiness, E-Activities and E-Impact of SMEs operating in a given industry I_u $(u = 1 \ldots K)$. It is important to note, that these aspects might be subject to change during empirical analyses.

First, we employ a simple keywords extraction technique. A list of carefully selected keywords/phrases associated to each component of SMEs digitalization (E-Readiness, E-Activities and E-Impact) is developed based on domain knowledge. Each keyword/phrase is denoted by p_j, where $j = 1 \ldots P$. Information about the presence of p_j in document d_i is stored in the form of a dummy variable, where the value of 0 indicates the absence of p_j, while the value of 1 indicates its presence in a given document. This idea is illustrated in Figure 5 - see Keyword 1, Keyword 2 etc. at each section related to E-readiness, E-activities and E-impact. As might be seen, each dummy variable associated to a particular keyword is a column in the dataframe, developed to structure all the extracted knowledge from text data.

			E-Readiness						E-Activities						E-Impact					
Industry	**Company**	**Text**	**Keyword 1**	**Keyword 2**	**…**	**Topic 1**	**Topic 2**	**…**	**Keyword 1**	**Keyword 2**	**…**	**Topic 1**	**Topic 2**	**…**	**Keyword 1**	**Keyword 2**	**…**	**Topic 1**	**Topic 2**	**…**
Industry I_1	Company 1	…	1	0	…	1	0	…	0	1	…	0	0	…	1	0	…	0	0	…
Industry I_1	Company 1	…	0	0	…	0	1	…	1	1	…	0	1	…	1	0	…	0	1	…
Industry I_1	Company 2	…	0	1	…	0	1	…	1	1	…	0	1	…	0	0	…	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Industry I_K	Company C	…	1	1	…	1	0	…	0	0	…	1	0	…	1	0	…	1	0	…
Industry I_K	Company C	…	1	0	…	0	0	…	1	0	…	0	0	…	1	1	…	1	0	…

Figure 5. Output from Stage IV – an empirical study database, that structures all the extracted information from the publicly available text data (for all SMEs part of the sample). For the sake of illustration, keywords and topics are related to three main aspects of SMEs digitalization level - E-Readiness, E-Activities and E-Impact.

The second technique for information extraction applied in an attempt to extract more aspects related to SMEs digitalization is topic modeling. This is a statistical technique used to discover latent topics or themes presented in a collection of text documents [23]. As mentioned earlier, classical topic modeling approaches like LDA or Non-negative Matrix Factorization (NMF) would require a text representation based on the vector space model. Such algorithms can be directly applied on the document-term matrix $F_{(N \times S)}$ to extract T main topics of interest discussed in reviews and comments related to SMEs. Each discovered topic t $(t \in \{1, \ldots, T\})$ is represented by a set of keywords considered as being most important in providing its general context.

After manual review of the extracted topics by domain experts, each of them is being assigned to one of the three main components of SMEs digitalization - E-Readiness, E-Activities and E-Impact. Since main focus is put on these three aspects of digitalization, topics that cannot be related to any of these aspects are disregarded. Finally, the presence of a particular topic in a given text document is encoded using dummy variables (Figure 5 - see Topic 1, Topic 2 etc. at each section related to E-readiness, E-activities and E-impact), where the value of 0 indicates the absence of the topic, while the value of 1 indicates its presence in a given document (similar to the logic applied during keywords extraction). It is important to note that the topic assignment process hugely depends on the specifics of the finally chosen topic modeling algorithm and details could be provided in future research. As noted earlier, recent approaches for topic modeling as BERTopic would require a text representation based on the development of document embeddings rather than document-term matrices. Nevertheless, rest of the general logic behind the described analytical process for information extraction remains the same.

			E-Readiness						E-Activities						E-Impact					
Industry	**Company**	**Text**	**"website"**	**"security"**	**...**	**Topic 1**	**Topic 2**	**...**	**"chatbot"**	**"delivery"**	**...**	**Topic 1**	**Topic 2**	**...**	**"ads"**	**"instagram"**	**...**	**Topic 1**	**Topic 2**	**...**
Low-tech (I_1)	Company 1	Text 1	1	1	...	1	1	...	0	0	...	0	0	...	0	0	...	1	0	...
Low-tech (I_1)	Company 1	Text 2	0	0	...	0	0	...	0	1	...	0	1	...	0	0	...	0	0	...
Low-tech (I_1)	Company 1	Text 3	0	0	...	0	1	...	0	0	...	0	0	...	0	1	...	1	0	...

Figure 6. Example of the empirical study database (output from Stage IV) for "Company 1"

Coming back from our example set of customer feedback in Figure 3, we illustrate with Figure 6 how the first three rows of the empirical study database would look like. As might be seen from Figure 6, we have assumed that the company's name is "Company 1" and that it operates in the low-tech sector (denoted by I_1). Furthermore, in the first customer feedback the most predominantly discussed aspect of digitalization is E-readiness of "Company 1". We sum the dummy variables for each aspect in order to find out which aspect is most dominant. Sentiment is negative. In the second customer feedback, the most predominantly discussed aspect is E-activities of "Company 1". Sentiment is positive. In the third customer feedback, the most predominantly discussed aspect is E-impact of "Company 1". Sentiment is positive.

Topic	Keywords
Topic 1 (E-readiness)	GDPR, security, breach, confidence, privacy
Topic 2 (E- readiness)	easy, information, contact, fast, navigate
...	...
Topic 1 (E-activities)	assistant, digital, prompt, question, information
Topic 2 (E-activities)	digital, delivery, fast, track, information
...	...
Topic 1 (E-impact)	social, instagram, facebook, message, media
Topic 2 (E- impact)	ads, google, media, month, new
...	...

Figure 7. Illustrative example of topics

Figure 7 illustrates further the concept of topics and how they will be formed after the topic analysis is performed over the full sample of customer feedback for all companies. Each topic is represented by a set of keywords considered as being most important in providing its general context.

4.4. Stage IV – E-Readiness, E-Activities and E-Impact of SMEs at Industry Level

Stage IV is crucial for any subsequent analysis since it aims at developing an empirical study database containing in structured format all the extracted information related to each of the three components of SMEs digitalization. This idea is illustrated in Figure 5.

We develop the matrix $M_{(N\times(P+T))}$ structuring the extracted information about all aspects of the three main components of SMEs digitalization (E-Readiness, E-Activities and E-Impact) that are presented in the text documents in corpus D. As depicted on Figure 5, each row in the dataframe corresponds to a particular review/comment about a given SME, while each column is a dummy variable indicating the presence of a particular aspect of digitalization discussed in the given review/comment. Since each SME in the sample operates in a particular industry I_u ($u = 1 \ldots K$), the empirical study database allows to draw important insights on digitalization efforts at both company and industry level.

4.5. Stage V – Sentiment Analysis

In Stage V of the proposed conceptual framework are applied sentiment analysis techniques aimed at understanding the sentiments expressed by the public towards the three main components of SMEs digitalization efforts - E-Readiness, E-Activities and E-Impact. The output from this stage are three main digitalization indices - $SI_{\text{E-Readiness}}$, $SI_{\text{E-Activities}}$ and $SI_{\text{E-Impact}}$ calculated at industry level. Each of these indices measures the overall public sentiment expressed towards the digitalization efforts of SMEs operating in a particular industry. This idea is illustrated in Figure 8.

Industry	E_1 **(E-Readiness)**	E_2 **(E-Activities)**	E_3 **(E-Impact)**
I_1	SI_{11}	SI_{12}	SI_{13}
I_2	SI_{21}	SI_{22}	SI_{23}
I_3	SI_{31}	SI_{32}	SI_{33}
…	…	…	…
I_K	SI_{K1}	SI_{K2}	SI_{K3}

Figure 8. Output from Stage V – a matrix of (digitalization) indices measuring the overall public sentiment expressed towards the digitalization efforts of SMEs operating in a particular industry. Each index SI_{ug} provides information on the overall public sentiment about SMEs digitalization efforts towards E_g ($g = \{1,2,3\}$) in industry I_u.

To derive the digitalization indices depicted in Figure 8, we employ the following methodology. First, we apply a suitable sentiment analysis model on each document d_i ($d_i \in D$) in which one (or more) of the three main components of SME digitalization is predominantly discussed (component dominance is calculated using the dummy variables in the matrix $M_{(N\times(P+T))}$ – see Figure 5). In case more than one component is equally represented in a given document d_i, sentiment analysis will be applied on aspect level [24], rather than document level, in order to capture the sentiments towards each of these main components of digitalization.

Sentiment analysis will enable us to evaluate the opinions expressed by the author of the text towards one (or more) of the main components of SMEs digitalization.

Sentiments are broadly defined in two categories - “positive” and “negative”. For example, in the following public comment “I really like their digital delivery management process”, the mainly discussed component of digitalization is “E-Activities” and the expressed sentiment is positive. Sentiment analysis is applied in an unsupervised manner by utilizing the pre-trained language model SiEBERT [25]. The latter is a sentiment analysis model designed for general-purpose application, trained on an extensive corpus of text data spanning diverse domains, including tweets, social media posts, and reviews of products and services. Its robustness and suitability for our use case stem from the extensive fine-tuning on a large volume of texts from various domains. It is important to note that natively SiEBERT operates on document level and additional fine-tuning might be performed in order to apply the model on the aspect level when necessary.

As explained earlier, our methodology for collecting text data results in the creation of a sample that permits empirical analysis on both “individual company” and “industry” level. Nevertheless, we are mostly interested at capturing insights on SMEs digitalization efforts at the industry level. For that reason, the final step in Stage V is to aggregate the extracted information about expressed opinions at company level and derive digitalization indices that measure the overall public sentiments expressed towards E-Readiness, E-Activities and E-Impact of SMEs operating in a particular industry.

For clarity, we denote each of the three main components of SMEs digitalization efforts (E-Readiness, E-Activities and E-Impact) with E_g, where $g = \{1,2,3\}$. Let SI_{ug} denote the overall public sentiment regarding E_g expressed towards companies operating in a particular industry I_u $(u = 1...K)$. SI_{ug} is an aggregated measure calculated by applying the following formula:

$$SI_{ug} = \frac{Po_{ug} - Ne_{ug}}{A_{ug}} \tag{1}$$

Eq. (1) calculates the overall public sentiment towards SMEs digitalization efforts E_g in industry I_u, where:

Po_{ug} - total number of positive sentiments expressed towards digitalization efforts E_g of companies operating in industry I_u. For example, Po_{11} is the total number of positive sentiments towards E-Readiness of SMEs operating in industry I_1.

Ne_{ug} - total number of negative sentiments expressed towards digitalization efforts E_g of companies operating in industry I_u. For example, Ne_{11} is the total number of negative sentiments towards E-Readiness of SMEs operating in industry I_1.

A_{ug} – total number of sentiments expressed towards digitalization efforts E_g of SMEs operating in industry I_u.

$SI_{ug} \in [-1,1]$, where the value of (-1) indicates strong negative public sentiments, while the value of 1 indicates strong positive public sentiments towards SMEs digitalization efforts E_g in industry I_u. Applying Eq. (1) leads to the development of the matrix $H_{(K \times G)}$ illustrated in Figure 8.

The constructed indices SI_{ug} serve as objective (“through the lens of the customer”) measures of SMEs digitalization efforts at industry level. In addition, these indices combined with other available information about digitalization level and efforts in a particular industry might be used to reveal many new insights on the processes, degree, effects, and problems of SMEs digitalization as well as on the scope of digital entrepreneurship in a particular country.

5. Discussion and Conclusions

In this paper we proposed an ML-based AI conceptual framework for assessing digitization of SME's data. We combine ML and NLP techniques in an attempt to create a robust methodology that could be used to assess SMEs digitalization level and efforts through the lens of customer preferences. One of the major contributions of our study is the development of a framework that integrates the analysis of unstructured data related to SMEs digitalization initiatives. Our literature review reveals the almost complete lack of studies in this research direction. Another important contribution of the paper is that our methodology relies on sentiment analysis thus capturing tendencies in customer preferences.

Such a framework has the potential to allow the extraction of valuable insights that are unobservable when conventional methodologies are being applied. Our approach for SMEs digitalization assessment in a given country is applicable not only at industry level, but also at "individual company" level (provided that sufficient amount of data is available for a given SME). We believe that the suggested framework might prove particularly valuable not only in assessing the digitalization level, but also in facilitating the development of measures aimed at supporting the digitalization of SMEs.

One of the major difficulties in the development of the framework stems from the noisy nature of unstructured textual data in the form of public comments freely expressed in social media. Acquirement, processing, and extraction of structured knowledge from such data pose considerable challenges because of the lack of standardized formats, diversity of platforms and the usage of informal language, abbreviations, slang, and misspellings.

One future refinement of the proposed framework includes the application of topic modeling analysis separately for each industry under analysis. Another direction for future research is studying the possibilities for improving and automating some of the manual tasks in the process of digitalization aspects extraction from text data. We believe that the current study will be valuable for researchers, policy-makers and other authorities involved in the development of digitalization policies and methodologies for assessment of the adaption of digital technologies in the business.

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Empowering IT-Supported Research Management: Leveraging Data Science Methods for Informed Decisions

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Abstract. In today's landscape of research management, the integration of Information Technology (IT) methods and data science has emerged as a powerful paradigm for enhancing decision-making processes. This paper examines the central role of IT-supported research management, such as Research Information Systems (RIS), in leveraging data science methods for informed decision-making. It addresses the importance of integrating IT infrastructure with advanced analytical techniques to enable data-driven insights and optimize research management strategies. Through a comprehensive review of relevant literature and case studies, this paper elucidates how RIS enables organizations to harness the full potential of data science methods for improved decision support across various facets of research activities. Additionally, it discusses the challenges and opportunities associated with this integration and provides insights into future directions for advancing IT-supported research management practices.

Keywords. IT-supported research management, research information systems (RIS), data science, decision-making processes, research management, research infrastructure, research outcomes, data-driven insights.

1. Introduction

In the current era of digital transformation, data plays an indispensable role across various domains, notably in research [1]. Research management, which involves organizing, planning, executing, and evaluating research endeavors, confronts the daunting task of efficiently handling the exponentially expanding reservoir of research data. Within this framework, data science methods are becoming increasingly vital as they aid research institutions in extracting valuable insights and executing informed decisions amidst this inundation of data [2].

Research management entails a multitude of tasks, including identifying research goals and priorities, allocating resources, planning research projects, fostering collaboration among researchers, and evaluating research outcomes [3]. Effectively managing these processes requires not only careful planning and organization but also

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the application of advanced analytical methods to optimize performance and achieve research objectives [4].

A central component of IT-supported research management is the Research Information System (RIS), serving as a database to store, organize, and manage research data [5]. These databases comprise a wealth of information, including publications, research projects, researchers, funding sources, and more [6]. The potential of data science methods in these databases lies in analyzing and interpreting this vast amount of data to gain valuable insights and make informed decisions [7].

Data science methods, as depicted in Figure 1, can contribute to enhancing the efficiency and effectiveness of RIS by, for example:

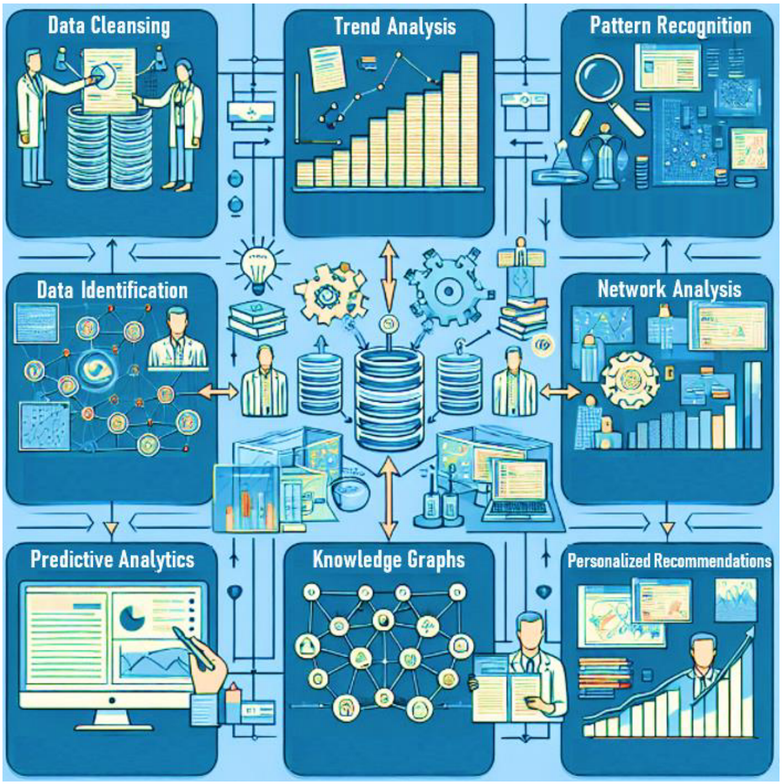

Figure 1. Effective Applications of Data Science Methods.

- Enabling data cleansing and integration to improve the quality of information stored in the database.
- Conducting pattern recognition and trend analysis to identify significant developments in specific research areas.
- Performing network analysis to visualize and understand collaboration among researchers and institutions.
- Applying predictive analytics to forecast future research trends and allocate resources accordingly.
- Utilizing knowledge graphs to model complex relationships between research entities and facilitate semantic search for research content.

- Providing user-centric recommendations to assist researchers in identifying relevant publications, projects, or collaboration opportunities.

The deployment of data science methods in research management and information systems holds immense potential for significantly enhancing the efficiency and effectiveness of research endeavors. By analyzing large volumes of data, research institutions can discern patterns, identify trends, and make predictions for future developments [8]. Consequently, they can better plan research activities, allocate resources more efficiently, and develop innovative solutions for complex scientific inquiries.

While there is already a considerable amount of literature on data science and research management, the specific consideration of the integration of IT and data science methods in this context is relatively novel [9, 10]. Some authors who have explored similar topics include Foster Provost and Tom Fawcett in their book "Data Science for Business" [11], which addresses the application of data science in various business domains. However, there are still few studies specifically focusing on the integration of data science into research management, underscoring the relevance and significance of this topic for the research community.

The objective of this paper is to examine the importance of integrating information technology (IT) and data science methods in research management and emphasize how this integration can support informed decision-making processes. We aim to elucidate the various ways in which data science can enhance research management, ranging from efficient data collection to analysis, visualization, interpretation, and decision-making.

The relevance of this topic to the user lies in the opportunity to improve the performance of RIS and advance research activities overall. By integrating data science methods into research management and information systems, research institutions can develop a data-driven approach to decision-making, thereby enhancing their competitiveness and positively impacting the scientific community.

This paper is divided into eight sections. The (1) section provides an introduction to the paper's topic. The (2) section defines the term "Research Information Systems" (RIS) and elucidates the functions and purposes of these systems in research. Furthermore, it provides a clear definition of research pursuits and their primary categories. The (3) section discusses the significance of data science for research activity management. The (4) section delves into how data science methods can be specifically employed to support decision-making processes in IT-supported research management. It includes detailed examples of how data science can improve activities such as resource allocation, project selection, and strategic planning. The (5) section explores how a holistic approach to integrating data science into all aspects of IT-supported research management can be implemented. The (6) section discusses the obstacles and opportunities associated with integrating data science into IT-supported research management. The (7) section sheds light on potential developments and trends in IT-supported research management. Finally, the (8) section summarizes the key findings of the paper and underscores the importance of data science for IT-supported research management.

2. Understanding IT-Supported Research Information Systems

RIS serve as comprehensive platforms designed to facilitate and streamline various stages of the research lifecycle within the context of research management [12]. These systems encompass a broad spectrum of tools and technologies tailored to support the diverse needs of researchers, academic institutions, funding agencies, and other stakeholders involved in the research process [13, 14]. A deeper comprehension of RIS is essential for appreciating their role in modern research endeavors.

At its core, a RIS serves as a centralized repository for storing, managing, and disseminating research-related data and information [15]. This includes but is not limited to publications, datasets, project descriptions, funding information, patents, and collaborations. By consolidating these diverse resources into a unified platform, RIS facilitate easy access to critical information, thereby enhancing collaboration, transparency, and knowledge sharing among researchers and institutions [16].

One of the primary functions of RIS is to support data collection and management throughout the research lifecycle. This involves capturing and organizing various types of research data, ranging from experimental results and survey responses to literature citations and research outputs. By providing structured data management tools, RIS enable researchers to maintain data integrity, track changes, and ensure compliance with data governance standards and regulatory requirements [17].

Moreover, RIS play a pivotal role in facilitating data analysis and visualization. These systems often integrate analytics platforms and tools that enable researchers to explore, analyze, and interpret research data effectively. By leveraging advanced analytical techniques, researchers can uncover patterns, trends, and insights hidden within large and complex datasets, thereby informing decision-making processes and driving scientific discovery [18].

In addition to data analysis, RIS support the publication and dissemination of research findings. These systems provide functionalities for manuscript submission, peer review management, and publication tracking, streamlining the scholarly publishing process. Furthermore, RIS offer mechanisms for disseminating research outputs, such as institutional repositories, preprint servers, and open-access platforms, thereby enhancing the visibility and impact of research within the academic community and beyond [5].

Collaboration is another critical aspect supported by RIS. These platforms facilitate collaboration among researchers, enabling them to share resources, coordinate activities, and work together on interdisciplinary projects [19]. By providing features such as project management tools, discussion forums, and collaborative workspaces, RIS promote teamwork and knowledge exchange, fostering innovation and accelerating research progress [20].

2.1 Defining Research Pursuits and Activities

To fully understand the role of RIS in research management, it is crucial to define what constitutes research pursuits and the specific activities involved. Research pursuits encompass a broad range of activities essential for the successful execution and management of research projects. These activities can be categorized into the following key areas:

- Setting Research Goals: Identifying and prioritizing research questions and objectives.
- Planning Projects: Designing research methodologies, timelines, and resource requirements.
- Allocating Resources: Distributing financial, human, and material resources to various research tasks.

- Fostering Collaboration: Encouraging interdisciplinary and inter-institutional partnerships and teamwork.
- Evaluating Outcomes: Assessing research results, impact, and overall success of research initiatives.

It is important to note that these activities can vary across different research domains. For instance, scientific research may place a heavier emphasis on experimental data and lab resources, whereas social science research might prioritize survey data and fieldwork collaboration. Figure 2 provides a visual representation of these core research activities and their interconnections, illustrating the typical workflow within a research lifecycle.

Figure 2. Core Research Activities and Their Interconnections.

In summary, RIS encompass a diverse array of tools and technologies aimed at supporting various facets of the research lifecycle. By facilitating data collection, analysis, publication, and collaboration, these systems enhance the efficiency, effectiveness, and impact of research activities, ultimately advancing scientific knowledge and innovation.

3. The Role of Data Science in IT-Supported Research Management

Data science has emerged as a transformative force in research management, offering sophisticated techniques to analyze and interpret vast amounts of data generated throughout the research lifecycle (see Figure 3). The integration of data science methods within IT-supported research management systems has revolutionized the way researchers extract insights and make informed decisions, thereby enhancing the efficiency and effectiveness of research management processes.

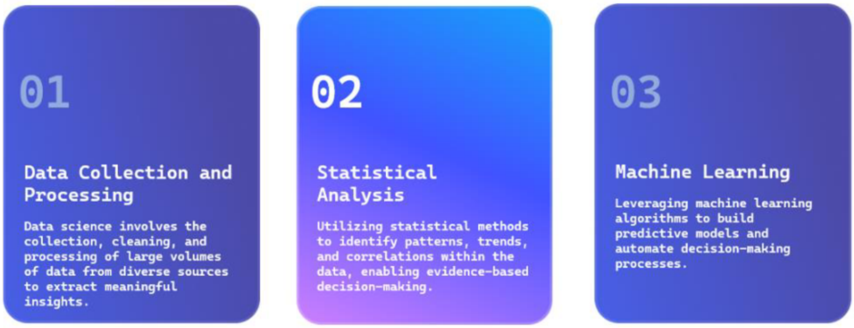

Figure 3. Foundations of Data Science.

One of the primary contributions of data science to IT-supported research management is its capability to uncover hidden patterns, trends, and correlations within large and complex datasets. Traditional analysis methods often struggle to unveil insights buried within extensive datasets due to their sheer volume and complexity [21]. Data science techniques, such as machine learning (ML) algorithms, enable researchers to sift through massive datasets and identify meaningful relationships and patterns that may not be apparent through manual examination. By leveraging these insights, research managers can gain a deeper understanding of research trends, emerging topics, and interdisciplinary connections, empowering them to make informed decisions about resource allocation and strategic planning [22].

Furthermore, data science optimizes resource allocation within research institutions [23]. By analyzing data on funding allocation, research output, and impact metrics, predictive models can forecast the potential impact of research investments and allocate resources accordingly. This ensures that funds are directed towards projects with the greatest likelihood of success [24]. Data-driven approaches also help identify inefficiencies in resource allocation processes, enabling research managers to reallocate resources more effectively and maximize research productivity [25].

Additionally, data science aids in identifying research priorities and strategic focus areas based on data-driven insights. By examining research outputs, citation patterns, and collaboration networks, data science methods can pinpoint emerging research trends and areas for interdisciplinary collaboration. This information informs strategic decision-making, guiding institutions in prioritizing funding, establishing research agendas, and fostering collaborations that drive innovation and address complex societal challenges.

Beyond resource allocation and priority setting, data science facilitates the assessment of research impact and effectiveness. By leveraging data analytics and visualization techniques, research managers can track and evaluate the impact of initiatives, publications, and collaborations. Metrics such as citation impact, social media mentions, and other indicators of research influence help assess the reach and significance of research outputs. Furthermore, data science methods can identify emerging trends and collaboration opportunities, enabling research managers to adapt strategies and initiatives to maximize impact and relevance.

4. Leveraging Data Science for Decision Support

Decision support is a critical facet of research management, involving the utilization of data-driven insights and predictive analytics to make informed decisions [26]. Data science assumes a central role in decision support by empowering research institutions to scrutinize research data, discern patterns, and forecast future trends, thereby guiding strategic decision-making processes concerning funding allocation, project selection, and overarching research strategy.

4.1 Enhancing Resource Allocation with Data Science

Predictive analytics, a fundamental element of data science [27], equips research managers with the capability to prognosticate the potential impact of research investments and pinpoint areas of research offering the highest return on investment. Through the analysis of research data pertaining to funding allocation, research outputs, and impact metrics, predictive models can anticipate future trends and outcomes, thereby enabling research institutions to allocate resources judiciously and optimize the impact of their research investments.

Example: A research institution can use predictive analytics to analyze historical funding data and research outputs. By identifying patterns in successful projects, the institution can forecast which new proposals are likely to yield high-impact results. This ensures that funds are directed towards the most promising areas of research, maximizing the return on investment. For instance, predictive analytics can aid in identifying burgeoning research domains with considerable growth prospects or areas necessitating additional investment to address pressing societal challenges.

4.2 Improving Project Selection through Data Science

Moreover, data science methodologies can aid research managers in project selection by evaluating the prospective success and impact of proposed research endeavors. By scrutinizing research data concerning project outcomes, funding success rates, and collaboration networks, data science models can discern promising research proposals and evaluate their likelihood of success. This empowers research institutions to prioritize funding for projects exhibiting the greatest potential for scientific breakthroughs or societal impact, ensuring that resources are allocated efficiently to advance research objectives.

Example: A university can employ ML algorithms to analyze past research project data, including success rates, funding amounts, and collaboration networks. By applying these models, the university can predict which new projects are likely to succeed based on similar characteristics. This data-driven approach helps in selecting projects with the highest potential, thereby optimizing the use of available funds and resources.

4.3 Strategic Planning with Data Science

Strategic planning represents another domain where data science can furnish valuable decision support to research institutions. By analyzing research data pertaining to research trends, collaboration networks, and emergent technologies, data science models can identify strategic priorities and avenues for innovation. This encompasses the identification of research domains aligning with institutional strengths and capabilities, alongside the projection of future trends and challenges impacting research agendas. Armed with this intelligence, research managers can formulate strategic plans congruent with organizational goals and priorities, thereby ensuring that research endeavors are concentrated on areas boasting the greatest potential for impact and relevance.

Example: By analyzing collaboration networks and citation patterns, a research institution can identify key areas for potential growth and interdisciplinary collaboration. Data science models can forecast emerging research trends and highlight strategic opportunities for investment, helping institutions align their research agendas with long-term goals and societal needs.

Overall, harnessing data science for decision support empowers research institutions to make evidence-based decisions propelling scientific innovation and discovery. By scrutinizing research data, forecasting future trends, and identifying strategic priorities, data science enables research managers to allocate resources effectively, select promising research projects, and devise strategic plans fostering research goals and tackling societal challenges. This ultimately amplifies the efficiency and efficacy of research management processes, propelling scientific advancement and societal impact.

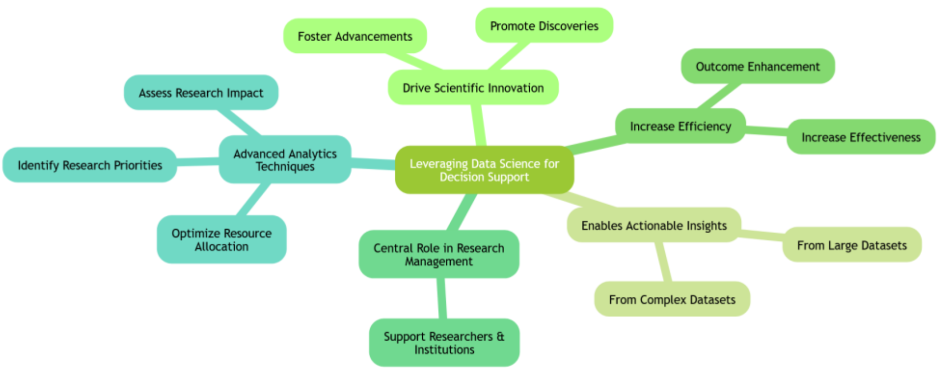

Figure 4. Leveraging Data Science for Decision Support.

Figure 4 illustrates the process of leveraging data science for decision support in research management. It delineates the various stages involved, encompassing data collection, analysis, modeling, and decision-making. At each juncture, data science techniques such as predictive analytics, ML, and data visualization are employed to distill insights and guide strategic decisions pertaining to funding allocation, project selection, and strategic planning [28]. Through this iterative progression, research institutions can refine their research management practices and propel scientific innovation and discovery.

5. Implementing a Holistic Approach to IT-Supported Research Management

In the realm of contemporary research management, the integration of data science methods throughout the entirety of the research lifecycle has garnered significant importance. This holistic approach encompasses a series of interconnected phases, commencing with data collection and preprocessing, progressing through analysis and visualization, and culminating in interpretation and decision-making. By adopting a comprehensive strategy encompassing the following steps (1-5), research institutions can effectively harness the potential of data-driven insights to inform and optimize decision-making processes at each juncture of the research endeavor.

1. Data Collection: The initial step in implementing a holistic approach to research management entails the collection of pertinent data from diverse sources. This may encompass experimental data, survey responses, literature reviews, and external datasets. Leveraging data science techniques such as web scraping, data mining, and sensor data acquisition empowers research institutions to efficiently and comprehensively amass diverse datasets. Furthermore, ensuring data quality and integrity through robust data governance practices is imperative for the success of this stage.

2. Preprocessing: Following data collection, the gathered data undergoes preprocessing to clean, transform, and prepare it for analysis. Data preprocessing encompasses tasks such as handling missing values, removing outliers, standardizing formats, and integrating disparate datasets. Data science methods, including data cleaning algorithms, feature engineering techniques, and dimensionality reduction approaches, assume a pivotal role in this stage. By preprocessing data effectively, research institutions can augment the quality and usability of their datasets, establishing a robust foundation for subsequent analysis.

3. Analysis: Data analysis constitutes a fundamental component of research management, involving the exploration and interpretation of data to extract meaningful insights and patterns. Data science methods such as statistical analysis, ML algorithms, and data visualization techniques empower researchers to unveil hidden relationships, identify trends, and formulate hypotheses. Through exploratory data analysis (EDA) and hypothesis testing, researchers can attain a deeper understanding of their data and draw evidence-based conclusions to guide further research directions.

4. Visualization: Data visualization assumes a critical role in effectively communicating research findings and insights. By leveraging data science methods to generate visual representations of data, such as charts, graphs, and interactive dashboards, researchers can elucidate complex information in a clear and intuitive manner. Visualization techniques facilitate the identification of trends, patterns, and outliers visually, thereby facilitating data-driven decision-making and enhancing the accessibility and impact of research outcomes.

5. Interpretation: The final stage of the research lifecycle entails interpreting the results of data analysis and visualization to derive actionable insights and conclusions. Data science methods support this process by furnishing tools for statistical inference, hypothesis testing, and predictive modeling. Through meticulous interpretation of research findings, researchers can formulate meaningful conclusions, validate hypotheses, and make informed decisions to advance scientific knowledge and address research questions effectively.

Utilizing the mind map presented in Figure 5 below, these five steps are succinctly encapsulated. Employing this holistic approach to research management, bolstered by data science methods, within a RIS like Elsevier's (https://www.elsevier.com/products/pure), empowers research organizations to efficiently collect, preprocess, analyze, visualize, and interpret research data. Through the integration of these methodologies, institutions can streamline decision-making processes, enhance research outcomes, and propel scientific innovation forward.

Figure 5. Research Management with Data Science Integration.

6. Challenges and Opportunities in Research Management

The integration of data science into research management, particularly in RIS, undoubtedly offers numerous opportunities to optimize decision-making processes and enhance the efficiency of scientific activities. However, it also presents challenges that need to be addressed. One of the key challenges is ensuring data quality. Since research data often originates from various sources and may exist in different formats, it is crucial to ensure that the data is consistent, complete, and of high quality [29]. Data errors or deficiencies can distort analysis results and lead to erroneous decisions [30].

Another central concern is the protection of privacy and security of research data [31]. Given the sensitivity of many research datasets, especially in areas such as medical research or social sciences, it is essential to implement adequate security measures to safeguard the confidentiality and integrity of the data [32]. This may involve implementing secure data access controls, anonymizing sensitive information, and adhering to applicable privacy regulations.

Another issue that is often overlooked is the interpretability of data science models and results. Complex algorithms such as neural networks or deep learning models can lead to "black-box" problems, where decision-making becomes opaque and difficult to understand [33]. This complicates the acceptance and application of results in research practice and requires the use of methods for model interpretation and explainability.

In addition to these technical challenges, cultural barriers within research institutions can hinder the adoption of data-driven decision-making processes. This may include resistance to change, lack of trust in new technologies, or insufficient training and resources. To overcome these obstacles, it is important to raise awareness of the benefits of data science, provide training, and foster an organizational culture of innovation and collaboration.

Despite these challenges, numerous opportunities exist for research institutions looking to integrate data science into their management practices. By leveraging advanced analytical techniques, researchers can gain new insights, identify connections, and make informed decisions. Furthermore, automating routine tasks can increase productivity and free up researchers' time for creative activities and innovation. With the right strategy and investment, research institutions can fully harness the potential of data science and further enhance their contributions to scientific knowledge and innovation.

7. Future Directions and Emerging Trends

The future trajectory and evolution of research management point towards further transformations as new technologies and methods continue to emerge. Some of the key trends to monitor include the integration of artificial intelligence (AI) and ML into RIS, the proliferation of Open Science practices, and the increasing emphasis on interdisciplinary collaboration. By proactively engaging with these developments, research institutions can position themselves for success in an increasingly data-driven world.

The integration of AI and ML into RIS holds promise for a variety of applications and benefits. Through the deployment of AI algorithms, RIS can develop automated decision support systems, aiding researchers in identifying relevant literature, predicting research trends, and generating tailored recommendations. Furthermore, advanced ML models enable more precise data analysis and prediction, leading to more informed research decisions.

The growing adoption of Open Science practices has the potential to fundamentally alter the research landscape [34]. Open Science initiatives aim to promote free access to scientific results, data, and methods to enhance the transparency, reproducibility, and reusability of research findings [35]. By opening up research data and results, research institutions can facilitate collaboration, accelerate knowledge transfer, and increase the rate of innovation.

Another important trend is the increased emphasis on interdisciplinary collaboration in research. Given the complex societal challenges, more researchers recognize the necessity of collaborating across disciplines to develop holistic solutions. Research institutions should thus promote the creation of frameworks and incentives that facilitate and support interdisciplinary collaboration.

By actively pursuing and preparing for these future trends, research institutions can strengthen their competitiveness and solidify their position as leading players in the research landscape. Through the integration of AI, the promotion of Open Science practices, and the fostering of interdisciplinary collaboration, research institutions can develop innovative solutions to drive scientific progress and address societal challenges.

8. Conclusion

In summary, data science methods offer tremendous potential for enhancing research management and decision support within RIS. By adopting a holistic approach to data-driven decision-making, research institutions can optimize their workflows, improve the efficiency of their research projects, and ultimately accelerate the pace of scientific discoveries.

The deployment of data science methods enables research institutions to gain valuable insights from a wealth of research data and make informed decisions. From identifying research goals to resource allocation and forecasting research trends, data analytics and models can help enhance research efficiency and optimize strategic alignment.

A holistic approach to data analysis and interpretation ensures that research institutions not only consider individual components of the research process but also understand their interactions and relationships. By integrating data science methods across the entire research lifecycle, research institutions can ensure that data is effectively utilized in every phase of the process to make informed decisions and drive scientific progress.

Moreover, the application of data science methods in RIS provides an opportunity to make research findings transparent and comprehensible. By employing data visualization techniques and providing dashboards, researchers and decision-makers can better understand and interpret research data, leading to improved collaboration and communication within the research community.

Overall, advancements in data science and its integration into RIS paint a promising future for research management. By fully harnessing the capabilities of data science methods and adopting a holistic approach to leveraging research data, research institutions can strengthen their knowledge generation capacity and make a sustainable contribution to scientific development.

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How to Promote the Coordinated Development of Beijing, Tianjin and Hebei Under the Background of Digitalization?

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Abstract. The digitalization of the economy has promoted the further transformation of regional coordinated development. In 2014, the coordinated development of the Beijing-Tianjin-Hebei region became a major strategy of China. It is the core strategy to ease the capital's non-core functions. Beijing in the wholesale market, regional logistics base as the main content of management has made great progress and a variety of non-core functions of ease is an important indicator of logistics related changes since 2014. Based on the improved gravity model of logistics, we through the comprehensive quality and logistics radiation range of each city in the region of Beijing Tianjin Hebei, the overall spatial layout of Economic Zone regional center city logistics spatial contact occurred in 2018-2022 years. We found that the non-core functions of the capital reduced the freight and traffic burden in Beijing and the volume of logistics connections decreased from 4.54 to 4.39 in 2018. The main logistics of Beijing are Langfang, Tianjin, Shijiazhuang and Tangshan. the degree of connection with Langfang increased by 0.5, with Tianjin increasing by 0.14, and the connection with Shijiazhuang increased by 0.05, and the logistic connection with Tangshan increased by 0.11 from 2021 and 2022. Comparatively speaking, the degree of logistics connection between Beijing and other cities has declined. The problems of uneven logistics linkage in each city are prominent, and the logistics function of Baoding and Zhangjiakou is relatively weak, showing the phenomenon of logistics development, fracture and collapse, and being marginalized in the logistics development of Beijing Tianjin Hebei Economic zone. Accordingly, we put forward policy recommendations to promote the integration of logistics development in Beijing Tianjin Hebei Economic zone under the background of digitalization.

Keywords. Digitization, Beijing Tianjin Hebei, gravity model, non-core function, ease

1. Introduction

Coordinated development of the Beijing, Tianjin and Hebei region has become a major national strategy since 2014. The central government set up a leading group for the coordinated development of the Beijing, Tianjin and Hebei region to strengthen

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centralized and unified leadership over related work. Over the past decade, the coordinated development of the Beijing, Tianjin and Hebei region has been deepened, and the economic aggregate of the three regions has exceeded 10 trillion yuan. Among them, more than 3000 general manufacturing enterprises in Beijing have withdrawn, nearly 1000 regional professional markets and logistics centers have been relocated and upgraded, and the distribution of public service resources has been continuously optimized. Eight municipal universities and 15 municipal medical and health institutions have been relocated to the outside world, more than 7700 commercial outlets for the convenience of the people have been precisely renovated, and more than 9200 hectares of green space have been used to remove non-core functions of the capital, urban and rural construction land was reduced by 130 square kilometers. The main framework of the Beijing, Tianjin and Hebei region on track has basically taken shape, and an interconnected highway network has been fully built, the core area of Beijing, Tianjin and Xiongan can be reached in half an hour, and the traffic circle of major cities in Beijing, Tianjin and Hebei has been formed in 1 to 1.5 hours, a new regional traffic pattern with four vertical, four horizontal and one ring transportation channel as the main skeleton, multi-node and grid-like has been basically formed, and a modern high-quality comprehensive three-dimensional transportation network has been initially constructed.

The digitalization of the economy has promoted the further transformation of regional coordinated development. Orderly dispersal of non-capital functions of Beijing and continuous optimization of spatial development pattern of Beijing, Tianjin and Hebei region. So, what is the impact of the logistics link and layout between Beijing, Tianjin and Hebei? What are the trends affecting logistics links and spatial layout? Based on this, this paper sorts out the current situation brought by the deregulation of non-core functions of the capital, and then selects 13 samples from Beijing, Tianjin and 11 cities in Hebei province. Then, this paper uses the relevant data from 2014 to 2022, according to the gravity model, empirically analyses the changes brought by the non-core function evacuation, especially the logistics related industry evacuation, to the Beijing-Tianjin-Hebei logistics connection and spatial layout and makes the trend prediction. Finally, the paper puts forward some policy suggestions on the non-capital core functions and the integrated development of Beijing, Tianjin and Hebei logistics under the background of digitalization.

2. Review of literature

As the core of the coordinated development strategy of the Beijing-Tianjin-Hebei region, the alleviation of non-capital functions is of great significance to solve the problems of Beijing's big city and realize the sustainable development of the Beijing, Tianjin and Hebei region (Liu Xiaoxiao and Wu Kang, 2020). [1] Liu Na and Wang Hongpeng (2023) pointed out that based on the new development stage, in order to promote the coordinated development of the Beijing, Tianjin and Hebei region to continue to expand in depth and reach a higher level, it is necessary to firmly grasp the trunk of the non-capital function of Beijing, and work hard to innovate the mode of industrial transfer and docking and cultivate new driving forces by agglomeration. [2] Sun Jiuwen (2023) emphasized that the evacuation of the headquarters of central enterprises is the top priority, through marketization and rule of law to enhance the endogenous power of outward mobilization, we will continue to leverage the advantages of the Beijing, Tianjin and Hebei region and form synergy for coordinated development. [3] Li Guoping and Lu Shuang (2024) proposed that joint efforts should be made in both alleviation and undertaking to create a new spatial pattern of one core and two wings. [4] In April 2015, the Outline of the Beijing, Tianjin and Hebei Coordinated Development Plan emphasized that the Beijing, Tianjin and Hebei region has a clear positioning and coordinated development, and one of the important tasks is to alleviate and solve the urban disease in Beijing. Wen Kui (2014) believed that Beijing can mainly relieve non-capital core functions, but not all non-capital core functions can be relieved, it is necessary to see not only its removability, but also the problems and challenges that may be brought by its removability. [5]

How to relieve the non-capital functions of Beijing has attracted more and more attention and become a research hotspot. Wu Jianzhong and Zhan Shengze (2018) emphasized the importance of the central government's top-level design and implementation of the integrated plan for the Beijing, Tianjin and Hebei region, scientifically establishing the strategic focus of evacuation, coordinating and regulating the development of Beijing's urban area, and scientifically implementing the mechanism of industrial upgrading, transfer and exit. [6] Zhang Keyun and Shen Jie (2017) believed that there was a ladder fault structure in the economic development of Beijing, Tianjin and Hebei, with a large gap within the region, so the mode of industrial gradient transfer at the present stage is more suitable for the development of the Beijing, Tianjin and Hebei region. [7] Liang Shuang (2020) believes that the decentralization of non-capital functions is a long-term and comprehensive project involving more stakeholders, which cannot be adjusted only through simple administrative measures, but also needs to do a good job in the decentralization of top-level design and docking with the surrounding bearing sites. [8] Zhu Jing (2023) believes that under the new development pattern, Beijing should grasp the strategic positioning of the capital city and optimize the function layout of Beijing, strengthen core functions, accelerate the construction of an international science and technology innovation center, promote the digital transformation of the service industry, increase the density of rail transit in the core area, adhere to the combination of centralized and decentralized decentralization, overall planning and classified policies, adjust the economic structure and spatial structure, and find a new way to optimize the development of densely populated areas. [9]

Many scholars have proposed that the Beijing-Tianjin-Hebei coordinated development of transportation and logistics should take the lead (Zhu Xianying, Dun Lei, Liu Na, 2017). [10] Chen Shuzhi (2017) pointed out that as the Beijing, Tianjin and Hebei coordinated development strategy entered the implementation stage, the establishment of an efficient and convenient regional integrated transportation service system was an important basis for promoting industrial cooperation and realizing industrial upgrading in the Beijing, Tianjin and Hebei region. [11] Li Hui, Ren Qilong and Zhang Chunmai (2022) believed that Beijing gradually distributed non-core functions of the capital including logistics to surrounding areas, which was a process of logistics pattern reconstruction for the Beijing, Tianjin and Hebei region, and proposed to formulate reasonable regional logistics development plans to guide the coordinated and mutual development of regional logistics. [12] Liang Chen (2021) proposed that efficient and smooth logistics channels are an important support for regional economy and the coordinated development of Beijing, Tianjin and Hebei. Emphasis should be placed on speeding up the construction of regional logistics channels, strengthening regional logistics cooperation in Beijing, Tianjin and Hebei, and promoting regional coordinated development. [13] Li Yanwei and Chen Rong (2022) pointed out that in order to further improve the agglomeration degree of the Beijing, Tianjin and Hebei logistics industry, all cities should strengthen regional linkage development, reasonably adjust the industrial structure, strengthen the construction of logistics information platform and the construction of logistics talent training mechanism. [14] Bing Xingguo (2024) proposed that in promoting the coordinated development of Beijing, Tianjin and Hebei region, the construction of transport infrastructure should be vigorously promoted, the integrated development of transport ecological industry should be promoted, and new breakthroughs should be made in the coordinated development of key areas. [15]

Digital development plays an important role in promoting the synergy of urban agglomeration (Ke Yang, Qi Han, Bauke de Vries, 2024). [16] Relevant studies have analyzed digitalization and regional development. Kai Yuan et al (2023) point that Exploring the interaction and coupling effects within the digital economy and eco-economic system resilience in urban agglomeration areas is conducive to promoting high-quality sustainable urban development. [17]Yangyang Yang et al (2023) based on the panel data of 13 cities in the Beijing-Tianjin-Hebei (BTH) region from 2011 to 2019, this study investigates the direct effect, intrinsic mechanism, and spatial spillover effect of digital technology development (DTD) on urban green development efficiency (GDE).[18] Runde Gu et al (2023)reveals the influence mechanism of industrial digitalization and regional collaborative innovation on urban green development efficiency (GDE) and show that industrial digitalization significantly improves urban GDE and regional collaborative innovation can directly enhance urban GDE.[19] Yuxing Yan et al (2024) taken the Beijing-Tianjin-Hebei (BTH) region of China as a typical case, this study measures the URT(urban-rural transformation) from the population-land-industry perspective and elucidates the influence of each index of URT on ESs (ecosystem services) at different stages.[20]

To sum up, the research on the coordinated development of Beijing, Tianjin and Hebei region and the alleviation of non-core functions of the capital has achieved rich results. However, more focus on the connotation definition, policy suggestions and qualitative description of non-core function allocation, lack of quantitative analysis of the effect of non-core function allocation of the capital and need in-depth theoretical analysis of the transfer and undertaking process among Beijing, Tianjin and Hebei. Based on the improved logistics gravity model theory, this paper empirically calculates the comprehensive quality of logistics and the scope of logistics radiation of each city in the Beijing, Tianjin and Hebei Economic Zone from 2018 to 2022, and plans the spatial pattern change of logistics links in the Beijing, Tianjin and Hebei Economic zone, especially quantitatively analyzes the logistics links between Beijing, Tianjin and 11 cities in Hebei. To preliminaries the effect of non-core function easing and the integrated development of Beijing, Tianjin and Hebei, and provide reference for promoting the integrated development of Beijing, Tianjin and Hebei under the background of digitalization.

3. Current Situation of Logistics under the Background of Beijing, Tianjin and Hebei Integration

In the context of Beijing, Tianjin and Hebei integration, since 2014, the Beijing Municipal Party Committee and government have attached great importance to the decentralization of non-capital functions and introduced relevant decentralization measures according to the Outline of the Beijing, Tianjin and Hebei Coordinated

Development Plan, focusing on four categories of decentralization subjects such as the commodity market, and achieved positive results. According to statistics, since 2014, the number of commodity trading markets has decreased from 728 to 422, especially in the core area of the capital (Table 1). Moving batch, Da Hongmen and other commodity trading markets have mostly completed the overall relocation. Moreover, fixed asset investment in wholesale and retail was only 1.7 billion yuan in 2019, down 46.1% (Table 2). At the same time, Beijing has formulated and implemented the country's first list of new industry bans and restrictions aimed at controlling the big city disease, with 55% of the city and 79% of the city's six districts banned. Since the catalogue was implemented in 2014, the total number of industrial and commercial registration businesses not handled in the city has reached 25,000. Complete the task of withdrawing 3,200 general manufacturing and polluting enterprises. Implement the policy of controlling people by industry and transfer low-end industries to the outside, Through the Beijing, Tianjin and Hebei coordination mechanism, the enterprises that have been dispersed out find corresponding development space in Hebei and Tianjin.

The cumulative permanent resident population of Beijing has shown a steady decline, and the permanent resident population of the city's six districts has achieved the target of decreasing by 15% compared with 2014. By the end of 2021, the number of market players in the city's six industries related to deregulation, such as manufacturing, wholesale and retail, decreased by 17.8% compared with the same period in 2016, among which the number of market players in the city's six districts decreased by 35.3%, twice the city's average decline, the proportion of newly established business entities in science and technology, commerce, culture and information increased from 40.7% in 2013 to 65.6% in 2022, achieving remarkable results.

Table 1. Changes in the number of commodity trading markets in Beijing, Tianjin and Hebei from 2014 to 2022

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Number of commodity markets in Beijing	728	719	612	631	529	483	453	430	422
Number of commodity trading markets over 100 million yuan in Beijing	131	125	136	114	94	86	88	73	65
Number of commodity trading markets over 100 million yuan in Tianjin	65	56	55	44	43	42	41	47	44
Number of commodity trading markets over 100 million yuan in Hebei Province	244	236	225	217	200	190	178	168	161

Data source: the 2014-2022 statistical yearbook of the Beijing, Tianjin and Hebei region and the statistical communiques of the central cities of the region for 2014-2022.

Table 2. Changes in fixed investment in wholesale and retail in Beijing, Tianjin and Hebei from 2014 to 2022

(Unit: RMB 100 million)

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Beijing wholesale and retail fixed asset investment	33.9	60.8	30	30.7	31.5	17.0	10.2	10.6	10
Year-over-year growth rate	-34.1%	79.3%	-50.7%	2%	2.5%	-46.1%	-40.0%	3.9%	-5.9%
Tianjin wholesale and retail fixed asset investment	323.74	471.45	868.67	740.7	572.56	341.82	323.7	193.25	142.43
Year-over-year growth rate	25.6%	45.6%	84.3%	-0.9%	-22.7%	-40.3%	-5.3%	-40.3%	-26.3%

Hebei wholesale and retail fixed asset investment	875.89	967.4	851.67	795.28	913.78	830.62	675.3	574	625.66
Year-over-year growth rate	4%	10.4%	-12%	-6.6%	14.9%	-9.1%	-18.7%	-15%	9.0%

Data source: the 2014-2022 statistical yearbook of the Beijing, Tianjin and Hebei region and the statistical communiques of the central cities of the region for 2014-2022.

With the rapid development of non-capital core functions, it can be inferred that the absolute amount of freight in Beijing should decrease, and the relative total amount of logistics will also decrease. The freight volume of Hebei and Tianjin, where the industry is mainly undertaken, should increase, and the relative total logistics volume will also increase. The total freight volume in Beijing from 2014 to 2022 shows a downward trend on the whole, especially the railway and road transportation. That is to say, with the transfer of backward production capacity and market, freight volume, especially road freight volume, has decreased significantly. Of course, in fact, Beijing's GDP and total retail sales of consumer goods have steadily increased, which further highlights the role of non-core functions (Table 3).

Beijing is mainly to ease the non-core functions of the capital, accelerate industrial transfer and population diversion, while Tianjin and Hebei are to do a good job in the relocation of functions and industrial transfer undertaking and cooperation. The enthusiasm of Tianjin and Hebei to undertake the urban functions and industrial deregulation of Beijing is very high. The implementation of the coordinated development strategy of Beijing, Tianjin and Hebei, on the one hand, effectively alleviates the non-capital functions, and on the other hand, it also brings huge development dividends and far-reaching impacts to Hebei and Baoding. Cities in Hebei Province, such as Baoding, Shijiazhuang and Tangshan, are striving to build industrial undertaking parks and platforms. In the coordinated development of the Beijing, Tianjin and Hebei region, Tianjin will undertake the main functions of the capital and take advantage of Beijing's technological advantages and its own advanced manufacturing capabilities to develop high-tech industries, producer services, high-end equipment manufacturing, biomedicine, port industry, financial industry and other industries. From 2014 to 2022, the total volume of freight transport in Tianjin showed an overall upward trend. In fact, Tianjin has made great progress in eliminating backward production, and the annual reduction task of 3.7 million tons of crude steel production capacity in the iron and steel industry has been completed ahead of schedule by overcapacity reduction (Table 3).

Hebei's freight volume has not changed much in recent years, one is Hebei's efforts to reduce capacity. Since 2013, Hebei has reduced steel, cement, coal and glass production capacity. In 2015, Hebei province closed down 58.9 percent of the country's iron making capacity and 76.6 percent of the country's steelmaking capacity. In 2016, Hebei reduced its steelmaking capacity by 16.24 million tons, iron making by 17.61 million tons, cement by 2.86 million tons and flat glass by 21.89 million weight boxes, shut down 54 coal mines and reduced its coal production capacity by 14 million tons. Compared with the reduction of freight volume caused by overcapacity reduction, the increase of freight volume caused by the dredging of non-core functions of Hebei's capital is insignificant. As a result, Hebei's freight volume has decreased since 2014 (Table 3).

Table 3. Changes in total freight volume in Beijing, Tianjin and Hebei from 2014 to 2022

(unit: ten thousand tons)

	City	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total amount of transportation	Beijing	26551	20078	20734	20110	20873	22808.4	22202.9	23424.8	18918
	Tianjin	49753	48779	50506	51800	52221	50093.3	52519.2	56435.4	52898
	Hebei	238749	199192	210994	229211	249650	242866	247783	261679	232136
railway	Beijing	1135	1034	762	736	596	483.6	413.9	349.7	368
	Tianjin	8874	8378	8149.16	8736	9249	9888.2	11124.2	11749.7	11754
	Hebei	48063	17843	16313	17100	19580	26823	30806	29205	30212
highway	Beijing	25416	19044	19972	19374	20278	22324.8	21789	23075.1	18549
	Tianjin	31130	30551	32841	34720	34711	31250.2	32261	34527	30382
	Hebei	185286	175637	189822	207309	226334	211461	211942	227203	196727
water transport	Tianjin	9749	9850	9514.53	8345	8261	8954.9	9134	10158.7	10761
	Hebei	4041	4542	4458	4413	3352	4160	4575	4800	5197
civil aviation	Hebei	2.52	2.60	2.33	2.10	2.19	2.58	2/48	2.67	2.41
pipeline	Hebei	1356	1168	399	386	382	419	455	469	485

Data source: the 2014-2022 statistical yearbook of the Beijing, Tianjin and Hebei region and the statistical communiques of the central cities of the region for 2014-2022.

In general, the coordinated development of Beijing, Tianjin and Hebei and the relaxation of non-core functions of the capital will eventually be reflected in the change of logistics pattern, which will also lead to great changes in the logistics pattern of cities in Beijing, Tianjin and Hebei. However, it is difficult to see what effect Beijing, Tianjin and Hebei integration and non-core functions of the capital city have achieved from the deregulation of market players and the change of freight volume. How does the logistics pattern between Beijing, Tianjin and Hebei change after all? What kind of changes have taken place in the logistics links between various cities in Beijing, Tianjin and Hebei and so on. The laws and processes of these changes have not received in-depth discussion and attention. Therefore, based on the improved logistics gravity model theory, this paper empirically calculates the comprehensive quality of logistics and the scope of logistics radiation of each city in the Beijing, Tianjin and Hebei Economic Zone from 2014 to 2022, and plans the spatial pattern changes of logistics links in the Beijing, Tianjin and Hebei Economic zone, especially quantitatively analyzes the logistics links between Beijing, Tianjin and 11 cities in Hebei. This paper preliminarily explores the effect of non-core function easing and the integrated development of Beijing, Tianjin and Hebei, and gives evidence of promoting the integrated development of Beijing, Tianjin and Hebei under the background of digitalization.

4. Data Sources

The Beijing, Tianjin and Hebei region is an important part of Beijing and its strategic position is very important, but it is also faced with prominent problems such as the continuous deterioration of the ecological environment, the imbalance of the development of urban system, and the widening gap between regional and urban development. To realize the coordinated development of Beijing, Tianjin and Hebei region and innovation-driven development, and to promote the innovation of regional development system and mechanism, it is necessary to build a new capital economic circle and realize the national development strategy in the future. The Beijing, Tianjin and Hebei urban agglomeration covers two municipalities directly under the Central Government, Beijing and Tianjin, and 11 cities in Hebei, namely Tangshan, Shijiazhuang, Handan, Xingtai, Hengshui, Cangzhou, Zhangjiakou, Chengde, Qinhuangdao, Langfang and Baoding. The land area is 218,000 square kilometers, and the resident population is about 140 million, of which 17.5 million are migrants. The Beijing, Tianjin and Hebei urban agglomeration accounts for 2% of the country's land area, but 7.98% of the country's total population. In 2022, the total GDP of the Beijing, Tianjin and Hebei urban agglomeration will reach 10,029.3 billion yuan, accounting for 8.3% of the country's GDP.

Considering the actual development of each city, district and county, we select two core cities in the Beijing, Tianjin and Hebei urban agglomeration: 16 districts each of Beijing and Tianjin, and 11 prefecture-level cities such as Baoding, Tangshan, Langfang, Qinhuangdao, Zhangjiakou, Chengde, Shijiazhuang, Cangzhou, Handan, Xingtai and Hengshui in Hebei Province, so there are 13 regional research objects in total. The research data were derived from the 2014-2022 statistical yearbook of the Beijing, Tianjin and Hebei region and the statistical communiques of the central cities of the region for 2014-2022. The traffic distances and freight modes between the regions were derived from Google Maps and the Beijing, Tianjin and Hebei Traffic Information Network, respectively, and the data were dimensionless processed by using the range method.

5. Research Methods

This paper adopts the modified gravity model, which is derived from Newton's classical physics law. With the continuous expansion of model significance, this model has been widely used in the study of economic spatial connection, such as the study of urban economic connection pattern, the analysis of spatial structure of metropolitan circle and the study of regional development pattern, etc. Most of the above studies use indicators such as economic aggregate, population and fixed asset investment as the quality of the research objects, take the linear distance or economic distance between the two objects as the distance between the research objects, and make use of the improved gravity model to obtain a series of empirical research results.

It is necessary to measure the quality of logistics and the distance of logistics between cities to calculate the value of logistics connection between cities by using gravity model. In order to ensure the accuracy of the research, this paper revises the gravity model of inter-city logistics connection on the basis of literature review and reference to existing achievements, so as to make it more reasonable to evaluate the comprehensive strength of regional logistics and make the estimation of logistics distance more realistic.

5.1. Logistics quality evaluation

The quality of logistics represents the comprehensive strength of regional logistics development. At present, researchers mainly use factor analysis, entropy value, central function strength evaluation and AHP to evaluate the development level of logistics. Among them, the center function strength evaluation method can not only realize the multi-index measurement of logistics quality, but also can be used to evaluate the city centrality and comprehensive strength level. Therefore, this paper adopts this method to measure logistics quality and divide the spatial pattern of logistics connections in the central cities of Beijing, Tianjin and Hebei economic zone. Based on the actual development of 13 cities and districts and considering the principle of comparability, this paper selects six indicators: per capita GDP, per capita freight turnover, market prosperity (ratio of total retail sales of consumer goods to total regional economy), highway network density, per capita number of mobile phones, and average number of households with Internet access to calculate the functional strength of urban centers. K_i represents the quality value of regional logistics, calculated as follows:

$$K_i = (K_{1i} + K_{2i} + K_{3i} + K_{4i} + K_{5i}) / 5 \quad (1)$$

Where, K_{1i}, K_{2i}, K_{3i}, K_{4i} and K_{5i} represent the economic development level index, logistics supply level index, logistics demand level index, logistics basic development index and informatization level index of the city respectively. The average per capita GDP, per capita freight turnover, market prosperity, road network density, per capita number of mobile phones and average number of Internet access households are taken for calculation respectively. See reference for the calculation process. K_i represents the intensity of regional center functions, and this value is used as the quality value of urban logistics.

5.2. Logistics distance measurement

The logistics distance between two cities should not only consider the length of the spatial distance between them, but also consider the influence of the transportation mode and economic gap between the two cities. In order to measure the logistics distance between two cities, correction weights α and β are introduced to correct the spatial distance between cities.

The calculation formula is as follows: $R = \alpha \times \beta \times d$ (2)

Where, d is the spatial distance between the two cities, α is the modified weight of transportation mode, β is the economic gap between the two cities, and R is the logistics distance between the two cities. The values of the two weights are shown in Table 4 below:

Table 4. List of correction weights for distance of logistics between cities

Mode of transportation	train	automobile	steamship	train, automobile	train, steamship	automobile, steamship	train, automobile, steamship
α	1	1.2	1.5	0.7	0.8	1.1	0.5

5.3. Modified gravity model of logistics linkages

According to the above description of logistics quality and logistics distance, the revised gravity model of logistics connection can be expressed as:

$$F_{ij} = {GK_iK_j}/{R^2} \tag{3}$$

In the above formula, F_{ij} represents the quantity of logistics connections between two cities i and j, K_i and K_j respectively represent the logistics quality of cities i and j, R represents the logistics distance between i and j, and the coefficient G is set as 1 for convenience of calculation because it does not affect the comparison result.

5.4. Logistics quality measurement

By referring to the Statistical Yearbook of Chinese Cities from 2013 to 2016 and the statistical bulletin of each district and county from 2012 to 2016, the square of logistics quality (K) value of 13 cities was calculated by substituting formula (1), as shown in Table 5 below:

Table 5. List of logistics quality K of each city

The year	Bei jing	Tian jin	Shi Jia zhuang	Cheng de	Zhang Jia kou	Qin Huang dao	Tang shan	Lang fang	Bao ding	Cang zhou	Heng shui	Xing tai	Han dan
2018	4.14	7.39	5.75	4.70	4.28	4.84	10.58	5.37	3.92	7.91	2.88	4.07	6.90
2019	4.19	7.20	6.91	5.23	4.49	5.24	11.93	6.04	4.59	8.96	3.29	4.36	7.35
2020	4.54	7.71	6.91	5.17	4.50	5.20	11.85	6.07	4.73	8.92	3.32	4.37	7.33
2021	4.16	7.58	7.09	2.92	5.07	3.95	9.46	5.06	2.38	5.53	3.23	5.01	7.82
2022	4.39	7.89	7.75	1.01	3.41	5.87	10.14	5.26	1.85	5.92	2.71	5.81	7.32

From the above data, it can be analyzed that Tangshan, Tianjin, Handan, Cangzhou, Shijiazhuang and other cities in the Beijing, Tianjin and Hebei urban agglomeration have a high proportion of secondary industries dominated by manufacturing, good logistics infrastructure conditions, strong demand for logistics services, and a high value of logistics quality K, among which Tangshan has the most fully played its logistics function. On the one hand, Tangshan has a large freight volume of steel, coal, agricultural products and other bulk commodities, and on the other hand, Tangshan has formed a logistics industry cluster area including ports and logistics parks. However, Tangshan's logistics function was relatively weakened in 2021 and 2022, which may be related to the macro economy. The logistics function of Tianjin begins to become prominent, especially under the background of Beijing, Tianjin and Hebei integration, the logistics function of Tianjin reaches the highest value of 7.89 in recent years in 2022, which shows that Tianjin benefits significantly from the Beijing, Tianjin and Hebei integration process. The logistics function of Cangzhou declined after 2020 and turned to a growth trend in 2022. Tangshan, Tianjin, and Cangzhou together constitute the eastern logistics corridor of the Beijing-Tianjin-Hebei region, becoming the eastern logistics base of the Beijing, Tianjin and Hebei region. Handan's logistics function is also fully played, and together with Xingtai, it forms the logistics corridor in the southwest of Beijing, Tianjin and Hebei. In recent years, the logistics function of Shijiazhuang has been gradually strengthened, surpassing Handan and closing in on Tianjin. According to speculation, Shijiazhuang is also a beneficiary of the integration of Beijing, and a large part of the logistics function transferred from Beijing has been transferred to Shijiazhuang. In contrast, the logistics functions of Langfang, Zhangjiakou and Baoding around Beijing have been significantly weakened, and they have not been able to effectively undertake the logistics functions of Beijing. In general, under the background of Beijing, Tianjin and Hebei integration, Beijing, Tianjin and Hebei presents a dumbbell logistics function layout with strong at both ends and weak in the middle. It is a logistics industry gathering area dominated by the east and west axes, with Tangshan, Tianjin and Cangzhou as logistics nodes in the east and Shijiazhuang, Handan and Xingtai as the main logistics nodes in the west. The logistics functions of Langfang, Zhangjiakou and Baoding centered on Beijing have been significantly weakened, and Beijing has become a logistics node. Since 2014, the logistics function of Beijing has been significantly relieved, but Baoding, Zhangjiakou and other places have not effectively undertaken the logistics function of Beijing.

5.5. Calculation of logistics spatial connection quantity

The spatial distance between the 13 cities is consulted through Google Map, and the square of the logistics distance between the 13 cities can be calculated by Formula (2) considering the economic gap and freight mode between the cities. By substituting the logistics quality and logistics distance calculated above into Formula (3), the third power of the amount of logistics links between cities can be obtained. Table 6 shows the amount of logistics links between Beijing, Tianjin and 11 cities in Hebei Province.

Table 6 show that under the background of Beijing-Tianjin-Hebei integration, the distribution of logistics links among central cities is obviously unbalanced, roughly forming the following trends: (1) Beijing and Langfang have the closest logistics links, followed by Tianjin, Tangshan and Shijiazhuang. That is to say, the logistics function of Beijing is mainly dispersed in Langfang, Tianjin, Shijiazhuang and Tangshan. In 2021 and 2022, the connection degree with Langfang increased by 0.5, the connection degree with Tianjin increased by 0.14, the connection degree with Shijiazhuang increased by 0.05 and the logistics connection degree with Tangshan increased by 0.11. In contrast, the logistics connection degree between Beijing and other cities has decreased. (2) Tianjin has a close logistics connection with Tangshan, Langfang and Cangzhou, and its logistics connection degree with Tangshan and Langfang increased in 2021 and 2022, but the connection degree with Cangzhou decreased. In fact, Tianjin, Tangshan and Cangzhou constitute the eastern logistics industry base of Beijing, Tianjin and Hebei. (3) Shijiazhuang has a close logistics connection degree with Baoding, Xingtai and Handan, but a low logistics connection degree with Tianjin, Zhangjiakou and Chengde. Shijiazhuang, Baoding, Xingtai and Handan constitute the western logistics industrial belt of Beijing, Tianjin and Hebei. (3) In the central part of Beijing, Tianjin and Hebei Economic Zone, the large-scale logistics network structure has not been formed, and the logistics connection among cities is loose, which makes the development of logistics in the economic zone show an obvious central break phenomenon. Beijing played the role of central logistics hub in the past, under the background of relieving non-core functions, it is necessary to clarify the layout of logistics industry in the central part. (4) The logistics connection degree among cities in northwest China, mainly Chengde and Zhangjiakou, is small, and the logistics development is seriously collapsed, which is the weak area of logistics integration in Beijing, Tianjin and Hebei Economic Zone.

Table 6. The number of logistics links between Beijing and Tianjin and 11 cities in Hebei Province

The year	Tian jin	Shi Jia zhuang	Cheng de	Zhang Jia kou	Qin Huang dao	Tang shan	Lang fang	Bao ding	Cang zhou	Heng shui	Xing tai	Han dan
2018	1.42	0.24	0.37	0.48	0.06	0.97	5.53	0.54	0.64	0.13	0.09	0.14
2019	1.40	0.29	0.41	0.51	0.07	1.11	6.30	0.64	0.74	0.16	0.10	0.16
2020	1.62	0.31	0.44	0.55	0.07	1.20	6.86	0.72	0.79	0.17	0.11	0.17
2021	1.46	0.29	0.23	0.57	0.05	0.88	5.24	0.33	0.45	0.15	0.12	0.17
2022	1.60	0.34	0.08	0.41	0.08	0.99	5.74	0.27	0.51	0.13	0.14	0.16

6. Conclusions and Suggestions

6.1. Discussion

During the COVID-19, due to the impact of epidemic prevention policies, the integration of Beijing Tianjin Hebei logistics into the city was limited at the initial stage. In the later stage, due to the needs of economic development, especially material support, the three regions have increased logistics integration cooperation. Overall, the epidemic has had little impact on the integration of logistics in the three regions. On the contrary, digital construction has greatly promoted the integration of logistics in the three regions.

6.2 Conclusions

The integration of Beijing, Tianjin and Hebei, especially the non-core functions of the capital, has brought new adjustments and changes to the integration of Beijing, Tianjin and Hebei logistics. The changes of logistics connection degree and logistics function can also fully reflect the changes of non-core function of the capital. Since 2014, the logistics function of Beijing has indeed changed, and the logistics quality K value, which represents the logistics function, has undergone positive changes and adjustments. In 2021, it decreased by 0.38 compared with 2014, and in 2022, it recovered somewhat, but it is also less than that in 2020. The main reason for the improvement is the advance of logistics function brought by the digitalization of the economy. The main undertaking of logistics dredging in Beijing is Tianjin, Shijiazhuang and Tangshan. That is to say, the logistics function of Beijing is mainly dispersed in Langfang, Tianjin, Shijiazhuang and Tangshan. In 2021 and 2022, the connection degree with Langfang increased by 0.5, the connection degree with Tianjin increased by 0.14, the connection degree with Shijiazhuang increased by 0.05 and the logistics connection degree with Tangshan increased by 0.11. In contrast, the logistics connection degree between Beijing and other cities has decreased. The northwest of Beijing, Tianjin and Hebei region shows the phenomenon of logistics development fracture and collapse and is gradually marginalized in the logistics development of Beijing, Tianjin and Hebei Economic Zone.

6.3. Suggestions

Therefore, in order to relieve the non-core functions of the capital, promote the integrated development of logistics in the Beijing, Tianjin and Hebei Economic Zone and give full play to the urban cluster effect of the economic zone, we can start from the following aspects:

(1) Focus on creating a strategic digitalization framework of overall layout.
The integrated development of logistics and the coordinated digitalization planning and construction of urban agglomeration are complementary to each other, and the construction and development of urban agglomeration have an important impact on regional industry driving and economic growth mode transformation and are an important driving force for the coordinated development of regional logistics. By improving the four Beijing, Tianjin and Hebei logistics centers in Tianjin, Tangshan, Langfang and Shijiazhuang, we will create three logistics industrial belts in the east, west and middle. Through the construction of four logistics centers, the non-core functions of Beijing can be alleviated, and the industrial cluster advantages of the industrial belt can stimulate the development vitality of the logistics industry in the Beijing, Tianjin and Hebei Economic Zone, and enhance the cohesion of the development of logistics within the region.

(2) Pay attention to the realization of logistics multi-format development.
Multi-format refers to the diversification of modern logistics formats. As far as the current situation is concerned, the logistics of many areas in the Beijing, Tianjin and Hebei Economic zone still stays in the traditional business mode of material transportation, and the level of logistics development is low. In the future, Langfang, Shijiazhuang and Tangshan should seize the strategic opportunity of industrial transfer in the Beijing, Tianjin and Hebei region, carry out procurement, packaging, transit, export, warehousing and other kinds of logistics business, and realize the diversification of regional logistics development. This can not only improve the overall benefits of the logistics industry in the Beijing, Tianjin and Hebei Economic Zone, but also further enhance the status of the regional logistics center of the above cities, expand the scope of logistics radiation, make the logistics link between regions closer, so as to promote the integration of regional logistics.

(3) Actively integrate into the industrial chain to improve the strength of logistics development.
The economic level of cities in the Beijing, Tianjin and Hebei Economic Zone is extremely uneven, especially Chengde, Zhangjiakou and other central and northern cities are relatively backward in economic development and low in logistics development. We should take active measures to make full use of the characteristics of the market close to Beijing and Tianjin, do well in the upstream market of the supply chain, form the supporting manufacturers of the core enterprises of the supply chain of Beijing and Tianjin, and according to the comparative advantages of the regional central cities, carry out the division of labor, cooperation and complementary development in the industrial chain, and gradually eliminate the boundary with the core area from passive to active, so as to promote the integration of the whole region.

(4) Break through administrative boundaries to carry out comprehensive planning for logistics development.
With the continuous development of Beijing, Tianjin and Hebei Economic Zone, the competition among cities in the region is becoming increasingly fierce, and many cities are scrambling to become the central city of regional development. Under the background of the integration of Beijing, Tianjin and Hebei and the easing of non-core functions of the capital, the Beijing, Tianjin and Hebei Economic Zone should carry out

the alliance according to the principle of geographical proximity rather than administrative boundaries, establish the concept of resource sharing and win-win cooperation, establish the coordination mechanism of equal distribution of interests, coordinate the development of the opening and construction of routes and railways.

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Research on the Competitiveness Evaluation of Pupu Supermarket in the Context of Digitalization

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Abstract. This paper, analyzes the development status as well as competitive advantages and disadvantages of Pupu Supermarket in Wuhan in the context of digitalization. In the empirical research part, the competitiveness evaluation of Pupu supermarket was divided into five first-level indicators. Based on the questionnaire survey, the data were studied by analytic hierarchy process and fuzzy comprehensive evaluation method. Based on the empirical research, combined with the actual development of Pupu supermarket in Wuhan, this paper analyzed consumers' purchase intentions, and put forward countermeasures and suggestions to enhance competitiveness and increase the attractiveness to consumers.

Keywords. Pupu supermarket, digitalization, competitiveness, fuzzy comprehensive evaluation

1. Introduction

The development of the digital economy has brought new models such as e-commerce, sharing economy, and platform economy, which have had a disruptive impact on traditional industries. The fresh e-commerce industry needs to undergo digital transformation and deeply integrate digital technologies to enhance competitiveness[1].

Founded in 2016, Pupu Supermarket is characterized by "pure online operation + pre-warehouse distribution", providing 30-minute express delivery service. The company has developed its own APP and WeChat mini-program to provide online ordering and instant delivery services. Pupu Supermarket cooperates with more than 2,000 suppliers and uses the digital middle platform to provide timely feedback on sales data as well as optimize the supply chain. Pupu Supermarket's digital transformation encompasses multiple aspects such as technology, business model, marketing, and user experience. In order to maintain competitiveness in the fierce market, Pupu Supermarket needs to continue to build on its own competitive strengths and make up for their shortcomings and improve its competitive strategy through competitiveness evaluation research. How can the fresh food e-commerce industry improve its competitiveness? The fresh food industry is developing rapidly. In the context of the continuous expansion of the scale of the fresh food market, scholars' research for the fresh food e-commerce industry began to appear, mainly focusing on marketing and service, such as the

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transformation of marketing strategies for graduate fresh food e-commerce companies, and the improvement of online and offline service levels. Meanwhile, research on competitiveness is more in the manufacturing industry, tourism industry, etc., and less for the fresh food e-commerce field. With the changes in the market context, the existing research based on the competitive context is still in its infancy. This paper investigated the competitiveness of Pupu Supermarket based on its competitiveness evaluation indexes in order to analyze the important factors that affect the competitiveness of Pupu Supermarket. The research objective of this paper is to find the factors affecting the competitiveness of Pupu Supermarket, analyze the consumers' purchase intention and propose countermeasures to increase the attractiveness to consumers. This paper filled the relevant research gaps, thus helping Pupu Supermarket to improve its competitiveness in the future competition and providing references for other fresh food e-commerce enterprises.

2. Theoretical analysis

Pupu Supermarket is growing rapidly in Wuhan thanks to ultra-fast delivery and high customer adhesion. Since its arrival in Wuhan, Pupu Supermarket has seen a rapid growth in users, thanks to Pupu Supermarket's ultra-fast delivery, which greatly facilitates consumers' lives and reduces their waiting time. The delivery staff of Pupu's Supermarket is highly qualified, with enthusiastic and polite service, and will thoughtfully provide some convenient services to create a warm and considerate experience. High customer bonding is one of the major advantages of Pupu Supermarket. Pupu Supermarket platform often carries out some preferential activities. For example, by issuing coupons and other marketing strategies, it stimulates consumers' enthusiasm for consumption, so as to increase their loyalty to the platform. At the same time, the platform users can forward the coupons to their friends and relatives to use, thus implementing the publicity mode of "one band with many, old with new, loyal users drive non-loyal users". This way of publicizing is low-cost and highly effective. The operation model of Pupu Supermarket is pre-warehouse + online traffic + business closed-loop. Figure 1 below shows Pupu's operating model[2].

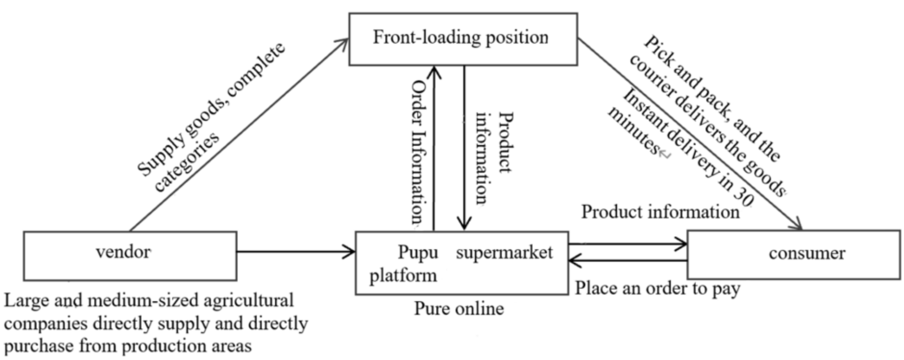

Figure 1. Pupu operation mode

Foreign scholars have conducted research on competitiveness evaluation, and put forward reference strategies and suggestions for retail industry to enhance competitiveness. Fresh food e-commerce is rapidly penetrating into customers' lives.

Scholars have analyzed the current situation of the scale of fresh food e-commerce, the evolution of the development stage model and the development trend. Taking Daily Fresh and JD to Home as examples, their specific warehousing and logistics, user promotion, management, cost and profitability are discussed in detail from the aspects of users and platforms, so as to explore their competitive advantages[3]. Logistics distribution have an important impact on the competitiveness of fresh food e-commerce enterprises. The intensification of competition in the e-commerce industry and the improvement of the logistics supply chain system of fresh food can enhance the competitiveness of e-commerce retail enterprises in the industry.

In recent years, consumer demand in the field of fresh food e-commerce has surged, forcing many middle-aged and old-aged groups to become new customers. Retaining market share and new customers will help fresh food e-commerce enterprises to stand firm in the competition in the industry. The speed of delivery, freshness of products, hygiene services up to standard, strength of offers and after-sales service attitude all have an impact on competitiveness. For the operation mode of Pupu Supermarket, analyze the core strengths that form the development of the enterprise in order to fundamentally improve its core competitiveness.

3. Competitiveness evaluation of Pupu supermarket

3.1. Construction of competitiveness evaluation index system

3.1.1. Construction of evaluation index system

Drawing on the pre- research as well as previous studies, evaluation indicators were identified. Brand trust affects eWOM, which in turn affects consumers' propensity to repurchase[4]. Electronic word-of-mouth spread by social media has a great influence on the purchasing decisions of customers, which rational information has a greater impact than emotional information. At the same time, a customer's personal perceptions on social media likewise influence his or her purchasing behavior[5].The competitiveness evaluation index system of Pupu supermarket is shown in Table 1. This paper hypothesizes that the following indicators will have an impact on the competitiveness of Pupu Supermarkets.

Table 1. Pupu supermarket competitiveness evaluation index system [6-9]

Target layer	Criterion layer	Indicator layer
Pupu supermarket competitiveness evaluation index system A	The core competitiveness of the product is B_1	Product qualityC_1 Richness of product varietyC2 Reasonableness of product pricesC_3
	Customer perception B_2	The perfection of the platform interfaceC_4 Ease of shoppingC_5 Service satisfactionC_6
	Supportive Services B_3	APP technical supportC_7 The ease of return or exchangeC_8 Professionalism in after-sales serviceC_9
	Market conditions B_4	BrandingC_{10} Customer preferencesC_{11} The degree of promotion of fresh e-commerceC_{12} Discount strengthC_{13}
	Delivery servicesB_5	The punctuality of the delivery personC_{14} The service attitude of the delivery staffC_{15}

		Satisfaction with takeaway packagingC_{16} Rationality of deliveryC_{17}

3.1.2. Description of evaluation indicators

Product Core Competitiveness B_1: The core competitiveness of the fresh food industry refers to the products that can provide the company with relative competitive advantages, the abundance of products and the reasonableness of product prices. Customer perception B_2: Customer perception refers to the evaluation based on the cognitive understanding of the customer's intuitive response to the interface of the Pupu Supermarket shopping platform when using the Pupu Supermarket shopping platform, as well as the reflection of the profile of the degree of shopping convenience and service satisfaction it brings. Supportive services B_3: APP technical support, ease of return and exchange, and after-sales service professionalism. Market conditions B_4: There are producers, consumers, participants, market and demand, i.e., customer preference, degree of fresh food e-commerce publicity, and discount strength. Delivery service B_5: the degree of punctuality and service attitude of delivery staff, takeaway packaging and delivery fee.

3.2. Questionnaire and data analysis

Regarding the questionnaire designed for the evaluation of the competitiveness of Pupu Supermarket, the first part of the questionnaire contains the basic information of the subjects, i.e., gender, age, and the number of purchases, and the second part of the questionnaire is an evaluation of each evaluation index in the competitiveness evaluation system of Pupu Supermarket utilizing the Likert five-level quantitative scale. Through the judging of the evaluation indexes, the subjects select one out of the five different scoring criteria. On the whole, this questionnaire was designed to be easy to understand and easy for the subjects to fill in.

A total of 113 valid questionnaires were collected. As shown in Table 2 below, the alpha coefficient of each index is more than 0.8, and the overall reliability is 0.960, indicating that the questionnaire data is highly credible and the competitiveness evaluation index system is relatively perfect.

Table 2. Results of reliability test

index	Number of projects	α coefficients
The core competitiveness of products	3	0.895
Customer perception	3	0.840
Supportive Services	3	0.852
Market conditions	4	0.875
Delivery services	4	0.898
Overall reliability	17	0.960

Through SPSS analysis, the validity results were summarized in Table 3, the KMO value was >0.8, the P-value=0, and the coefficient of each factor exceeded 0.7, indicating that all indicators were well verified.

Table 3. Results of validity test

Level 1 indicators	Secondary indicators	Factor load	KMO value	P-value
The core competitiveness of products	Product quality	0.897	0.748	0
	Richness of product variety	0.918		0
	Reasonableness of product prices	0.911		0

Customer perception	The perfection of the platform interface	0.862	0.727	0
	Ease of shopping	0.871		0
	Service satisfaction	0.879		0
Supportive Services	APP technical support	0.859	0.723	0
	The ease of return or exchange	0.878		0
	Professionalism in after-sales service	0.901		0
Market conditions	Branding	0.865	0.798	0
	Customer preferences	0.895		0
	The degree of promotion of fresh e-commerce	0.815		0
	Discount strength	0.840		0
Delivery services	The punctuality of the delivery person	0.892	0.842	0
	The service attitude of the delivery staff	0.861		0
	Satisfaction with takeaway packaging	0.890		0
	Rationality of delivery	0.855		0

3.3. Index evaluation and analysis

3.3.1. Analytic hierarchy process

Table 4. Judgment scale definition

scale	Importance level
1	The first element is equally important as the second
3	The first element is slightly more important than the second
5	The first element is significantly more important than the second
7	The first element is more strongly important than the second
9	The first element is extremely important than the second
1/3	The first element is slightly less important than the second
1/5	The first element is significantly less important than the second
1/7	The first element is stronger than the second element and is not important
1/9	The first element is extremely unimportant than the second

Note: {2,4,6,8,1/2,1/4,1/6,1/8} indicates that the importance is {1,3,5,7,9,1/3,1/5,1/7,1/9}.

In this paper, the analytic hierarchy process (AHP) method is used to establish a pairwise comparison discriminant matrix based on the 1-9 scale method based on the 1~9 scale method (Table 4), and the weight calculation is carried out. Combined with the actual situation of Pupu supermarket, the first-level indicators of competitiveness evaluation were compared in pairs, and the judgment matrix was obtained as shown in Table 5 [10].

Table 5. Total Goal Judgment Matrix

Competitiveness evaluation	The core competitiveness of products	Customer perception	Supportive Services	Market conditions	Quality of staff	wi
The core competitiveness of products	1	2	1	1/2	1/5	0.1105
Customer perception	1/2	1	1/2	1/3	1/6	0.0654
Supportive Services	1	2	1	1/2	1/5	0.1105
Market conditions	2	3	2	1	1/3	0.1997
Delivery services	5	6	5	3	1	0.5140
Consistency checks	$\lambda_{max} = 5.037, C.R. = 0.008 < 0.1$					

The subordinate indicators of the five first-level indicators were compared in pairs, and the judgment matrix was obtained, as shown in Table 6-10.

Table 6. Judgment matrix based on the core competitiveness of the product

The core competitiveness of products	**Product quality**	**Richness of product variety**	**Reasonableness of product prices**	wi
Product quality	1	1/2	2	0.2973
Richness of product variety	2	1	3	0.5390
The price of the product rationality	1/2	1/3	1	0.1628
Consistency checks	$\lambda_{max} = 3.009, C.R. = 0.009 < 0.1$			

Table 7. Judgment matrix based on customer perception

Customer perception	**The perfection of the platform interface**	**Ease of shopping**	**Service satisfaction**	wi
The perfection of the platform interface	1	1/4	1/3	0.1226
Ease of shopping	4	1	2	0.5571
Service satisfaction	3	1/2	1	0.3202
Consistency checks	$\lambda_{max} = 3.018, C.R. = 0.018 < 0.1$			

Table 8. Judgment matrix based on supporting services

Supportive Services	**APP technical support**	**The ease of return or exchange**	**Professionalism in after-sales service**	wi
APP technical support	1	2	3	0.5390
The ease of return or exchange	1/2	1	2	0.2973
Professionalism in after-sales service	1/3	1/2	1	0.1638
Consistency checks	$\lambda_{max} = 3.009, C.R. = 0.009 < 0.1$			

Table 9. Judgment matrix based on market conditions

Market conditions	**Branding**	**Customer preferences**	**The degree of promotion of fresh e-commerce**	**Discount strength**	wi
Branding	1	1/3	3	1/4	0.1362
Customer preferences	3	1	5	1/2	0.3093

The degree of promotion of fresh e-commerce	1/3	1/5	1	1/6	0.0626
Discount strength	4	2	6	1	0.4919
Consistency checks	$\lambda_{max} = 4.080, C.R. = 0.030 < 0.1$				

Table 10. Judgment matrix based on delivery service

Delivery services	The punctuality of the delivery person	The service attitude of the delivery staff	Satisfaction with takeaway packaging	Rationality of delivery	wi
The punctuality of the delivery person	1	1/3	3	3	0.2517
The service attitude of the delivery staff	3	1	5	5	0.5550
Satisfaction with takeaway packaging	1/3	1/5	1	1	0.0967
Rationality of delivery	1/3	1/5	1	1	0.0967
Consistency checks	$\lambda_{max} = 4.044, C.R. = 0.016 < 0.1$				

The weights of the indicators at each level relative to the overall target are calculated comprehensively, as shown in Table 11.

Table 11. Weights of indicators at each level based on the overall goal

Level 1 indicators	Based on the total goal weight	Secondary indicators	Based on first-level indicator weights	Based on the total goal weight
The core competitiveness of products	0.1105	Product quality	0.2973	0.0329
		Richness of product variety	0.5390	0.0596
		Reasonableness of product prices	0.1628	0.0180
Customer perception	0.0654	The perfection of the platform interface	0.1226	0.0080
		Ease of shopping	0.5571	0.0364
		Service satisfaction	0.3202	0.0209
Supportive Services	0.1105	APP technical support	0.5390	0.0596
		The ease of return or exchange	0.2973	0.0329

		Professionalism in after-sales service	0.1638	0.0180
Market conditions	0.1997	Branding	0.1362	0.0272
		Customer preferences	0.3093	0.0618
		The degree of promotion of fresh e-commerce	0.0626	0.1250
		Discount strength	0.4919	0.0982
Delivery services	0.5140	The punctuality of the delivery person	0.2517	0.1294
		The service attitude of the delivery staff	0.5550	0.2853
		Satisfaction with takeaway packaging	0.0967	0.0497
		Rationality of delivery	0.0967	0.0497

3.3.2. Fuzzy comprehensive evaluation method

Based on the results of the above reliability and validity analysis, the fuzzy comprehensive evaluation method was used to evaluate the statistical index results of the competitiveness evaluation data of Pupu supermarket, as shown in Table 12 below.

Table 12. Statistical results of the competitiveness evaluation of Pupu supermarket

Evaluation Rating	Very bad	Not good	Average	Good	Very good
The core competitiveness of products	2.06%	4.13%	27.14%	42.77%	23.90%
Customer perception	1.77%	5.31%	28.02%	45.43%	19.47%
Supportive Services	1.47%	5.01%	25.66%	46.02%	21.83%
Market conditions	2.21%	11.06%	23.67%	41.59%	21.46%
Delivery services	1.77%	4.42%	25.66%	44.47%	23.67%
Converted total	1.86%	5.99%	26.03%	44.06%	22.07%

Note: Market conditions are rated as Very Little, Small, Average, Large, and Significant.

First, establish the evaluation factor set of Pupu supermarket's competitiveness: U= {Product core competitiveness, customer perception, supportive services, market conditions, distribution services}

Second, create a collection of comments: V= {Very bad, not good, average, good, very good}

Thirdly, based on the calculation results of AHP, the weight set of each factor is established, and the weights of the first-level indicators are:

W= {Product core competitiveness, customer perception, supportive services, market conditions, distribution services} = {0.111,0.065,0.111,0.200,0.514}

Fourth, establish a fuzzy evaluation matrix:

R_1(The core competitiveness of products) = {0.020,0.041,0.271,0.428,0.239}
R_2(Customer perception) = {0.018,0.053,0.280,0.454,0.195}
R_3(Support Services) = {0.015,0.050,0.257,0.460,0.218}
R_4(Market Conditions) = {0.022, 0.111, 0.237, 0.416, 0.215}
R_5(Delivery service) = {0.018,0.044,0.257,0.445,0.237}

Combining the above set of one-factor evaluations and omitting the comments, we can obtain a one-way evaluation matrix, which is the fuzzy relation matrix R:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \end{bmatrix} = \begin{pmatrix} 0.020 & 0.041 & 0.271 & 0.428 & 0.239 \\ 0.018 & 0.053 & 0.280 & 0.454 & 0.195 \\ 0.015 & 0.050 & 0.257 & 0.460 & 0.218 \\ 0.022 & 0.111 & 0.237 & 0.416 & 0.215 \\ 0.018 & 0.044 & 0.257 & 0.445 & 0.237 \end{pmatrix}$$

The results of the comprehensive objective evaluation are as follows:

$$B = W \times R = (0.111 \quad 0.065 \quad 0.111 \quad 0.200 \quad 0.514) \times \begin{pmatrix} 0.020 & 0.041 & 0.271 & 0.428 & 0.239 \\ 0.018 & 0.053 & 0.280 & 0.454 & 0.195 \\ 0.015 & 0.050 & 0.257 & 0.460 & 0.218 \\ 0.022 & 0.111 & 0.237 & 0.416 & 0.215 \\ 0.018 & 0.044 & 0.257 & 0.445 & 0.237 \end{pmatrix} = (0.0187, 0.0584, 0.2563, 0.4400, 0.2282)$$

4. Conclusions and prospects

4.1. Conclusions

This paper took the fresh food e-commerce shopping platform Pupu Supermarket as the research platform, and chose Wuhan as the specific research site to analyze consumers' evaluation of its competitiveness. Under the rapid development of the fresh food e-commerce industry and the general trend of digitalization, fresh food e-commerce enterprises are coming one after another [11]. The level of competitiveness of the enterprise becomes crucial, and understanding the core of improving competitiveness helps Pupu Supermarket to clarify its own positioning as well as improve the possibility of expanding development [12].

By constructing the competitiveness evaluation index of Pupu Supermarket, the analysis concludes that the distribution service as well as the market conditions have a greater impact on its competitiveness. Pupu supermarket should strengthen its core strength, seize a larger market share, and expand its target group. Pupu supermarket should focus on its distribution services, improve its service convenience, be product-oriented, and take into account the corporate image, so as to enhance the competitiveness of Pupu supermarket. The conclusions of this paper are also useful for other fresh food e-commerce industries to improve their competitiveness and promote the development of related policies. However, the research sample in this paper is rather limited, which may have some impact on the generalizability of the conclusions, and future research can expand the scope of the paper to obtain more universal conclusions.

4.2. Research limitations and future research

This paper relies on data from a specific platform, Pupu Supermarket, and the Wuhan region, which may make it difficult to comprehensively reflect the situation of the entire fresh food e-commerce industry. The paper on the competitiveness of fresh food e-commerce involves a number of disciplines such as supply chain management, consumer behavior, information technology, etc., which is still insufficient in terms of interdisciplinary integration. The fresh food e-commerce market is in the midst of rapid changes, and this paper fails to fully consider the impact of long-term dynamic changes on competitiveness. Although some studies involve the development mode of foreign fresh food e-commerce, overall, international comparative studies are still insufficient, making it difficult to comprehensively draw on international experience. Future refinements will be made in the above-mentioned areas, which will lead to further research conclusions. To summarize, the research on fresh food e-commerce in terms of competitiveness has achieved certain results, but it still needs to be further deepened and improved to better guide the practical development of fresh food e-commerce.

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Research on Synergy Operation of Agriculture Logistics Ecosphere Based on System Dynamics Model

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Abstract. There is a contradiction between extensive agricultural development and sustainable economic development in many countries, so the innovation of agricultural development model has become the mainstream. Agricultural logistics ecosphere (ALE) is a typical model of "integration of primary, secondary and tertiary industries", which is an important starting point of agricultural production, supply and sales under the background of digital economy. Based on the framework analysis of influencing factors of ALE in this research team, a dynamic simulation model of ALE collaborative system was constructed. Based on the analysis of the causal loop of variables, the research context of sensitivity analysis of three order parameters (information technology level, professional level of service providers and Coefficient agriculture logistics investment) on the demand volume for agricultural products, ecosphere integration ability and ecosphere value was determined. The simulation model running results show that: (1) Due to the influence of causality between variables, the three factor coefficients have strong or weak influence on the observed variables at different stages of 0.2-0.5 and 0.5-0.8; (2) The influence of a single factor change on the observed variables may be delayed, and it is difficult to produce a significant impact in a short time. The results suggest that policy makers should understand the differences in ALE in different development stages, comprehensively consider the proportion of investment in each factor, and finally seek a balance between agricultural production development and economic sustainability. By exploring the relationship between the variables of the agricultural logistics ecosphere, we can help agricultural logistics corporate identity identify the key factors in the collaborative process of each subject, and provide suggestions for the green and sustainable development of agriculture.

Keywords. Agricultural logistics ecosphere; Synergy; System dynamics; Digital Economy

1. Introduction

Agricultural logistics, as the main circulation platform in the process of agricultural production, supply and sales, is an important starting point to promote the adjustment of

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agricultural industrial structure and modernization transformation. Since the 21st century, e-commerce and network economy based on Internet technology have reshaped the global industrial structure, which has had an impact on the operation mode and business form of traditional industries. In this context, some countries, especially developing countries, face more and more prominent problems such as poor industrial linkage, weak infrastructure and insufficient industrialization level in the process of agricultural development, and the modernization transformation of traditional agriculture is imminent. Logistics is the main carrier of agricultural products circulation. Under the influence of the rapid development of digital economy and e-commerce, the role of agricultural logistics service has been paid more attention by enterprises and society. As a typical model of the integration of primary, secondary and tertiary industries, the ALE not only reflects the important position of logistics services, but also reflects the great value of the linkage between agriculture and finance, Internet, education, catering and other industries. Therefore, it is of great theoretical and practical significance to conduct empirical analysis and analyze the influence mechanism of variables in the ecosphere collaborative model of agricultural logistics, and put forward the strategy of ecosphere synergy development. From the theoretical level, the analysis of the synergy mechanism of ALE further expands the theoretical framework of industrial ecosphere. From the perspective of practice, the synergy development strategy of ALE is a concrete embodiment of promoting the in-depth development of agriculture to transform the traditional development mode of agricultural logistics.

ALE refers to the function of agricultural logistics, transportation, processing, storage, information processing, etc.), on the basis of organic combination, with the government, financial services, Internet technology services, business consulting and other related industry or organization cooperation, in order to promote agricultural development as the core, the main body to cooperate each other, the industrial symbiosis of ecological network resources and mutual benefit. From the perspective of existing research results, studies on the agricultural logistics ecosphere are rare, mainly focusing on the evolution of the competition and cooperation relationship between the main bodies in the ecosphere [1]-[2], the change of organizational form [3]-[4], the construction of the ecosphere framework system [5]-[6] etc. However, the research on ALE synergy is not only a valuable theoretical problem, but also a practical problem related to agricultural development. Based on the research basis of the author's framework of influencing factors of ALE synergy and combined with the development data of agricultural logistics in China, a simulation model of ALE system dynamics was constructed, and the influencing mechanism of variables in the model on agriculture logistics ecosphere synergy was analyzed. It can not only put forward suggestions for exploring the leapfrog development of agricultural logistics, but also provide new ideas for the dynamic analysis of the development mode of agricultural logistics.

2. Methodology

2.1. Variable selection

The construction of the system dynamics model has certain requirements for the feedback mechanism and dynamic structure of the system itself. On the one hand, the boundary of the system is relatively clear and far from equilibrium dissipative structure [7]-[8]. On the other hand, the dynamic changes of the system are regular and predictable.

Therefore, the ALE model should be a bounded circular feedback system, which requires that the more quantities considered in this model, the better. The more variables studied, the easier it is to blur the boundary of the system dynamics model, which makes it difficult to analyze the explained variables. Based on the analysis of the theoretical framework of ALE synergy by the research team and the possibility of obtaining relevant data, the main variables in the ALE system dynamics model were determined from three aspects: synergy environment, synergy capability, and disturbance factors. Synergy environment layer contains four variables: agricultural logistics investment, information technology level, transportation capacity and demand volume of agricultural products. Synergy capability layer contains four variables: Volume of agricultural products supply, business development capability, organization and coordination ability, and ecosphere integrity. Disturbance factors layer contains two variables, storage and transport natural loss.

2.2. Model assumption

In order to ensure the effectiveness of the model and the rationality of the operation results, four basic assumptions are put forward: (1) ALE is a continuous and circular system composed of the ecosphere operators, agricultural logistics service providers, government and service providers; (2) ALE constructed in this paper is constructed under normal economic, environmental, political and other circumstances, without considering the influence of economic fluctuations, political turbulence, extreme weather and other accidental or complex factors; (3) For the variables that are difficult to quantify in the model, such as information technology level, integration ability, coordination ability, natural loss, etc., this paper uses utility function to define the quantitative changes of these variables in the process of agricultural products from supply to ecosphere value realization. (4) In order to simplify the professional service providers, government agricultural products such as suppliers, ecosphere operators, the main body of the calculation of income, regardless of the ecosphere operators in organization operation process of equipment purchase, depreciation, fixed assets investment and loss. Ecosphere value variable on behalf of the ALE of profit-making realized by operating income.

2.3 Causality analysis

In order to describe the relationship between the variables in the ALE system dynamics model clearly, will be based on the ALE framework structure [5], from three aspects to discusses the interrelation between the variables respectively: the agricultural logistics upward circle, downward circle as well as the external support circle. Then analyzes the causal loop between the variables in order to show the causal relationship between the variables in the ALE model more clearly.

2.4 Causality and feedback analysis

Based on the above analysis, the causal relations of the three sub-systems in the three circles are integrated to construct the overall causal loop of the ALE (as shown in Figure 1).

Variable and feedback mechanism to balance the relations between ALE every main body and is beneficial to the stable development of the ecosphere, namely synergy process of agricultural logistics upward circle, downward circle and external support subsystem, can through the interaction between the variables of self-regulation to adapt to the constantly changing agricultural logistics external environment. There are many causal loops involved in the ecosphere dynamics model of agricultural logistics, but the causal loops are mainly composed of three variables, namely demand volume of agricultural product, ecosphere integration ability and ecosphere value. Among them, there are 14 causal loops starting from the demand volume of agricultural products, 12 causal loops starting from the integration ability of the ecosphere, and 15 causal loops starting from the ecosphere value. Limited by space, this paper will not list the causal loops of the ALE system.

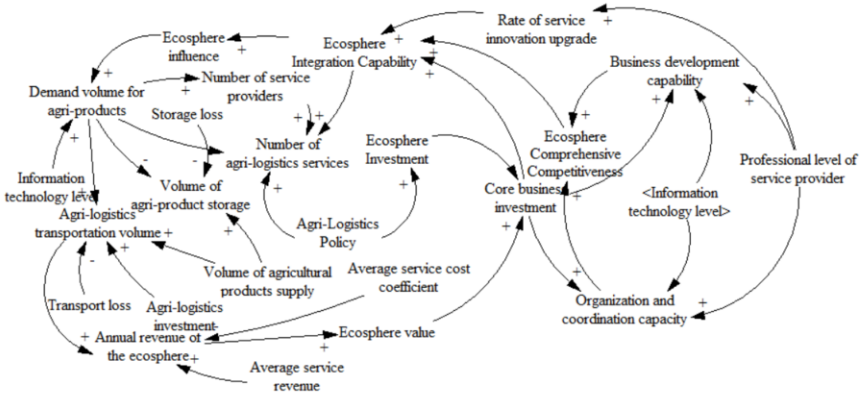


Figure 1. Causality of agriculture logistics ecosphere system dynamics

2.5 Variable equation setting

Based on the causal analysis of ALE synergy, this paper further constructs the system dynamics dynamic flow diagram of ALE synergy (as shown in Figure 2). Based on the long history of agricultural development in Jiangxi Province and the research basis of the author, the initial values and table functions of the system dynamics model were set up by selecting relevant data of agricultural logistics development in Jiangxi Province. The data were obtained from China Statistical Yearbook, Jiangxi Statistical Yearbook and China Logistics Yearbook. In combination with the setting of system dynamics model variables by relevant scholars [9]-[10], the equation expressions of variables in the ALE synergy model are determined.

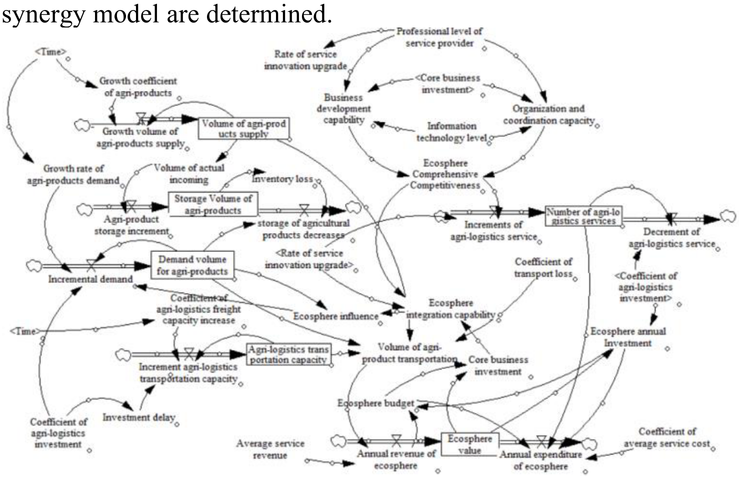


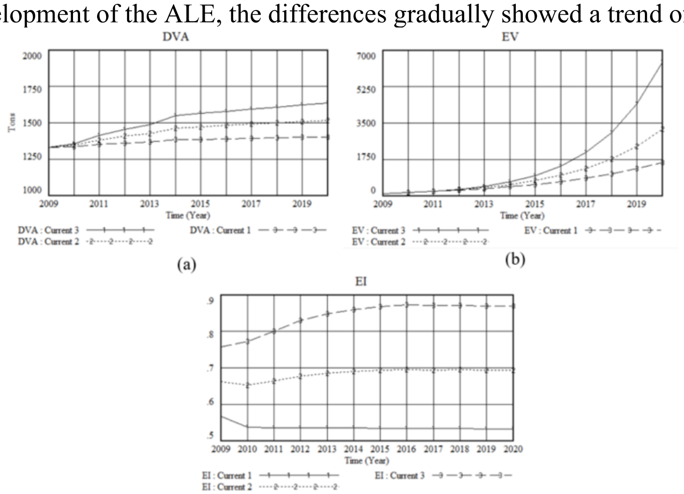
Figure 2 Dynamic flow diagram of agriculture logistics ecosphere system dynamics model

3. Analysis of simulation result

On the premise of keeping the parameter values of other variables unchanged, the parameter values of variables of different levels are changed successively for simulation. Under the condition of dynamic changes of horizontal variables, the development trend of ALE observation variables is analyzed. From variables causal loop, the demand volume of agricultural product(DVA), ecosphere integration capability(EI), ecosphere value(EV) three variables as the starting value of causal path covering most of the variables in the model, taking into account the ALE three subsystems relationship between variables, the article most decided by information technology level(ITL), professional level of service provider(PLS) and coefficient agricultural logistics investment(CAFI) as sensitive variables, The sensitivity analysis of DVA, EI and EV was carried out. The output result figure consists of three curves, each of which represents the output of the variable at different values, as shown in Figure 3-5. Curves 1, 2 and 3 represent the output of the three factors at 0.2, 0.5 and 0.8 respectively.

3.1 Sensitivity analysis of ITL

As shown in Figure 3a, for the demand for agricultural products, the coefficient of information technology level increased from 0.2 to 0.8 (marked by Current 1, Current 2 and Current 3 respectively in the legend, the same below), which made the demand volume for agricultural products break the limit of 1600 units in 2020, with a significant increase. It shows that the DVA is sensitive to the difference of information technology level. According to Figure 3b, for the EI, the change of information technology level has a positive impact on the EI on the whole. In the last stage of the simulation cycle (2020), the increase of the information technology level coefficient from 0.2 to 0.8 increases the integration capability by about 25%. But the change of EI is not obvious at the same value of information technology level. As shown in Figure 3c, for the value of the ecosphere, with the increase of the coefficient of information technology level, the value coefficient began to show differences in the fourth stage of simulation (2013). With the further development of the ALE, the differences gradually showed a trend of expansion.



(c)

Figure 3. Sensitivity analysis results of ITL

3.2 Sensitivity analysis of PLS

As shown in Figure4a, the DVA increases with the improvement of the PLS from the third stage of the simulation cycle (2011). When the PLS rises from 0.2 to 0.8, the increase of the DVA is about 3.6%, which is weaker than the level of information technology. Observe Figure 4b, the PLS has a significant impact on the EI at the beginning of the operation of the ALE. The increase of the PLS from 0.2 to 0.8 increases the EI by about 40%, but on the whole, the increase of the EI is relatively gentle in the simulation period. Figure4c shows that as the PLS rises, the EV starts to differ in the fifth stage of the simulation (2013). With the gradual development of the ALE, the change of PLS has a gradually significant impact on the EV.

3.3 Sensitivity analysis of CAFI

According to Figure 5a, there is a positive relationship between the DVA and the change of CAFI. The two-stage change of CAFI from 0.2-0.5 and 0.5-0.8 has a more balanced impact on the demand, and compared with the PLS, the DVA is more sensitive to the impact of CAFI. As shown in Figure 5b, with the increase of investment coefficient, the EI ALEo increases. When the investment coefficient is above 0.5, the EI has reached 0.7. Different from the influence results of the previous two variables, when the CAFI is above 0.5, the EI is significantly stronger than the coefficient at 0.2, but with the increase of investment, the increase of EI ability decreases. As shown in Figure 5c, the EV has a significant change in agricultural logistics investment. When the investment coefficient is 0.5 and 0.8, the EV reaches 4000 and 8000 (million) in the last stage of simulation. In addition, the growth rate of EV in the stage of 0.2-0.5 was lower than that in the stage of 0.5-0.8.

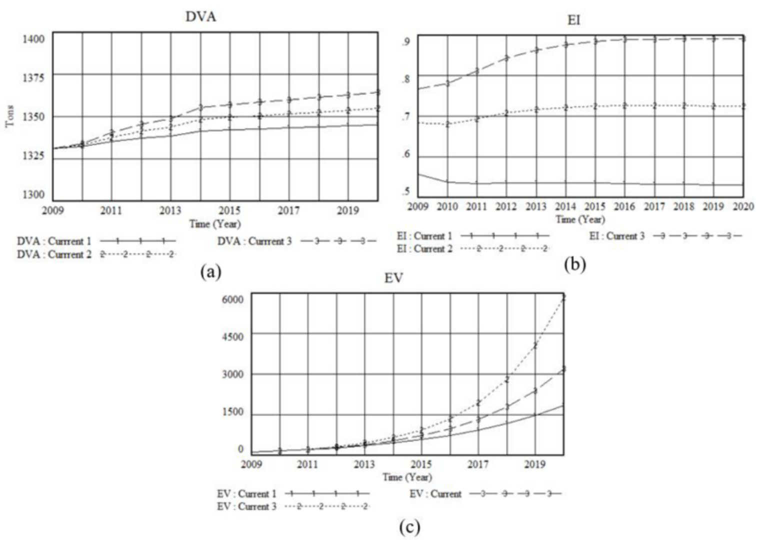


Figure 4. Sensitivity analysis of PLS

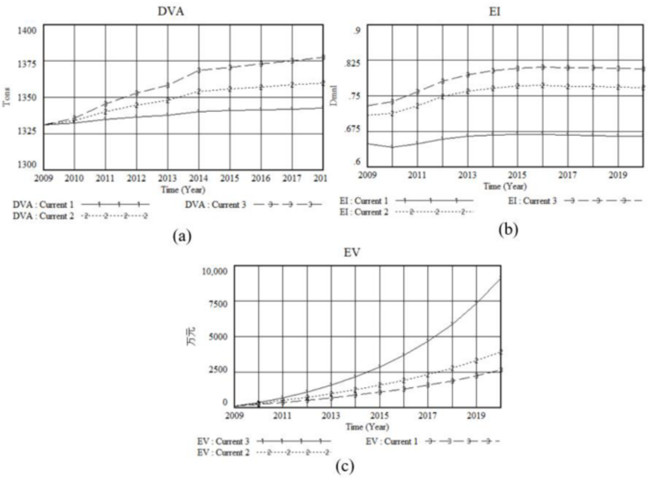


Figure 5. Sensitivity analysis of CAFI

4. Conclusion

Based on the previous research results of the research team and the practical operability of the system dynamics model, the main variables that affect the synergy of the ALE were determined and the system dynamics model of the ALE was constructed. After analyzing the causal loops of the model, it is found that a large number of causal loops are involved when DVA, EI and EV are used as starting variables, and the causal loops can explain the main variables included in the model. Based on the analysis of ALE subsystem, it is concluded that the level of ITL, PLS and CAFI have an important impact on the synergy of ALE, Vensim PLE is used for sensitivity analysis, and the main conclusions are as follows:

Firstly, in the simulation period, the DVA, EI and EV showed positive growth in different degrees for the two-stage changes of the three factors 0.2-0.5 and 0.5-0.8. For the DVA, the order of sensitivity is ITL > CAFI > PLS. For the EV, the sensitivity degree was in the order of CAFI > ITL > PLS. In terms of ecosphere integration ability, the degree of sensitivity was in the order of PLS > ITL > ALE. Second, the two-stage changes of the three factors 0.2-0.5 and 0.5-0.8 will cause different degrees of delay on the influence of variables, that is, the increase of the DVA, EI and EV will not be different until several stages after the simulation cycle. Third, the two-stage changes of 0.2-0.5 and 0.5-0.8 of the three factors have limited influence on a certain variable, that is, enterprises cannot rely on the optimization of a certain variable or factor alone to try to improve the value of the ecosphere in real operation.

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Analysis on the Supply Chain Cost Control of PDD Under the Background of Big Data

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Abstract: With the continuous growth of the national economy and the continuous breakthroughs in Internet technology, a new era of big data has come. Although China's e-commerce industry started late, it has seen rapid development In recent years, it has gradually become an important driving force for China's economic development. In e-commerce, the application of big data lies in mining useful data information for analysis, to reasonably predict the future market, reduce costs, and maximize profits. In modern enterprises, effective supply chain management is a source of profit that can not be ignored. It can produce great profit benefits, which is almost the most important for current e-commerce enterprises. At the same time, the Internet and informatization of supply chain operation is convenient for enterprises to analyze the cost of each link of the supply chain in combination with big data and make favorable decisions. This paper uses supply chain cost control theories, takes PDD as the research object, analyzes the current situation of its supply chain cost control from all links, finds existing problems. Then relevant thoughts & suggestions in the big data context are put forward, including sharing data info, maintaining supplier relationship, using user portraits for consumption stimulation and rational marketing cost planning, eliminating the "copycat" impression and maintaining customer relations, absorbing management talents and rationally allocating personnel for better cost control and profit improvement.

Keywords. Big data, electronic commerce, Cost control, Supply chain, PDD

1. Preface

1.1. Research Background

Since 2019, COVID-19 has affected China and the global economy. This reduction led to decreased household incomes, lower consumer confidence, and slower market consumption growth. Repeated epidemics also dampened work enthusiasm and ability, restricted the supply side, and triggered anti-globalization sentiments and supply chain issues. It had a profound impact on China's economic market and posed challenges to various industries.[1]

China's e-commerce emerged in the 1990s, growing rapidly in recent years. In 2023, its transaction volume increased to 46.83 trillion yuan.[2] Affected by consumer

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[1] Corresponding Author: Jingqiang Li, Beijing Wuzi University, China; Email: lijingqiang@bwu.edu.cn Fund projects: Research on customer relationship management strategies of e-commerce platforms.

[2] Data source: Statistical Bulletin of the People's Republic of China on National Economic and Social Development in 2023.

confidence, it faces a crisis and opportunities. Enterprises need to seize the chance and formulate the right strategy. For any enterprise, effective cost management is the key to improving efficiency and achieving sustainable development. Supply chain cost control is a top priority, but the current methods are not advanced enough. In the era of big data, it is a trend to combine it with e-commerce supply chain cost management.

1.2. Review

- Relevant research on big data technology

Meiyan Du (2022) proposed that the continuous development of communication and computer network technologies has led to the pervasive integration of information technology in all aspects of people's lives.[1] Rogers, R. (2024) thought data management can benefit food manufacturers in the efficiency of their day-to-day operation, while also extending capabilities into the highest levels of company and brand strategy.[3] Zhi Haidan (2023) proposed the future prospect of big data in enterprise management is impressive, running through the whole operation process, but it needs a professional information team for support and guarantee.[4]

- Related research of supply chain cost control

Li Junhua (2022) believes cost management from supply chain perspective helps enterprises ensure production plan accuracy, optimize procurement and sales.[5] Song Chunyan (2023) emphasizes tobacco commercial enterprises need to improve the cost management process in procurement, production, sales, and logistics, and promote deep integration with cost control as per supply chain requirements.[6]

- Relevant research on big data and supply chain cost control

Xianfeng Zhu (2024) proposed the risk management system of e-commerce supply chain based on big data technology r has good risk prediction and risk management effects.[7] Ye Tian (2023) believed B2C e - com enterprises should explore supply chain cost control based on actual conditions and use big data tech to optimize procurement, sales, warehousing, logistics, info security and supplier cooperation.[8]

In conclusion, China has some research on big data and supply chain cost control, but few on its application, especially in the e-commerce industry. This paper integrates them, identifies problems, and analyzes solutions in the big data context.

2. Overview of E-commerce Supply Chain Cost Control in Big Data Context

2.1. Introduction of big data background

Nowadays, info circulation is getting faster, giving rise to big data. McKinsey defines big data as a broad data set with large scale, fast flow, diverse types and low value density. Enterprises must apply data info to adapt to high-growth info, seize big data opportunities and enhance optimization ability. Main big data techs include data preprocessing, mining, cloud computing platform and scalable storage system.

The key to big data app is "useful" for e-commerce. It reflects in marketing, prediction, fault analysis and promotion. But it also brings info leakage problems, posing risks. If not handled well, it brings challenges to customer relationship maintenance.[9]

2.2. The implication of supply chain cost

In this article, the in-cycle costs associated with a firm's supply chain, including procurement, production, and sales costs, are considered supply chain costs. The cost can be categorized into internal and external. Internal includes the costs of departments during production and turnover; external is the cost from collaboration with suppliers, retailers, and consumers.

The supply chain cost involves many enterprises. If information isn't effectively circulated and shared, it causes cost transparency deficiency and lowers control efficiency. This paper starts from the cost composition of each link and analyzes cost control approaches.

2.3. The impact of big data background on supply chain cost control

Big data is closer to people's lives. Our lives and modern enterprises' business rely on it. Supply chain cost control is no exception. The main effect it brings is synergistic effect.

The synergistic effect refers to the scenario where, when groups are combined rationally, they can produce a greater effect than if they were operating independently. In supply chain cost control, it refers to the complementary information advantages between upstream and downstream enterprises to provide better services. In the big data era, upstream enterprises can obtain consumer information to optimize production capacity. Downstream sellers can grasp the market precisely, use data to increase profits.

The big data era influences supply chain cost control. Refined control and other demands offer a new orientation. Enhancing cooperation and fulfilling needs is crucial. E-commerce enterprises can make it more effective if they adapt.

3. PDD Supply Chain Cost Control Case in Big Data Context

3.1. Industry background

Since its inception in 1990, China's e-commerce industry has made great strides, developing into a comprehensive system that includes domestic, overseas, and cross-border transactions. Especially in the past two decades, it has transformed from nothing to something and from a spark to a common consumption mode.

China's e-commerce is closer to the core of the economy. The transaction scale of e-commerce in China is continuously expanding due to the popularity of electronic equipment and the improvement of living standards. In 2023, it was approximately 46.83 trillion yuan, an increase of about 11.00% compared with 2022, related industries are accelerating, further promoting economic development.

After years of development, leading e-commerce enterprises have built their own "ecosystem". The connection between platforms and merchants has become closer, with big data resources emerging as a key factor. The growth and reusability of data provide conditions for sustainable development, like user profiling and precision marketing, and forecasting market changes.

In brief, people's living standards are rising, and their recognition of e-commerce is increasing. The big data environment offers favorable conditions for e-commerce, and its prospects will be brighter.

3.2. Basic situation of PDD

PDD is a C2M group-purchasing social e-commerce platform founded in September 2015. Users can download the software via mobile devices, form groups through social media, and buy goods at lower prices. With its novel social e-commerce thinking, it has created a distinctive concept and attracted many customers.

In the early stages, PDD attracted small merchants, tapped into emerging markets using WeChat, and gained a substantial user base with its unique model. Through user engagement and promotions, it experienced rapid growth by late 2015 with over 12 million users without traditional advertising expenses. In 2019, its active users reached 687 million, and coverage is rising. By the end of 2020, its active users reached 788.4 million, making it the largest e-commerce platform in China with an annual transaction volume of 1,667.6 billion yuan, a 66% increase from 2019.[3]

Low-priced products had a good effect in the early stage but had problems later, and the low-end impression remains. The group mode and subsidy method are easy to imitate, and the competition hasn't improved. To gain the biggest advantage, PDD needs to start with supply chain management.

3.3. Analysis of PDD supply chain cost composition

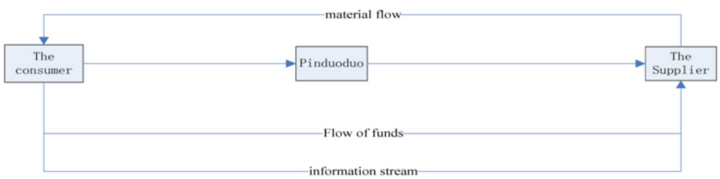

Figure 1. Schematic diagram of PDD's supply chain

Analysis of PDD's supply chain system reveals that consumers are the starting point. Market demand info comes from them and is conveyed to suppliers via the platform. The supply chain's operation depends on meeting consumer requirements and diverse demands. Supply chain optimization and upgrading is an issue to be resolved, and effective cost control will make supply chain management more effective.

As an e-commerce enterprise providing an online shopping platform, PDD's supply chain costs can be roughly divided into internal and external costs.

PDD's internal costs include management cost, research and development cost, and marketing cost, etc. The marketing cost is for attracting users to download, buy and order, and for publicity. The management cost is for internal payment and management. The research and development cost are for enhancing the user experience and fighting counterfeits or optimizing the page.

External costs are from an enterprise's external supply chain, including service and transaction costs. Service cost is for user returns, exchanges, and compensation.

[3] Data source: Collated according to Wande database

Transaction cost is for the collaboration between the supplier and PDD, like getting real-time market info and costs of decision-making, supervision, breach of contract, and execution.[10]

3.4. Current situation of PDD's supply chain cost control

Table 1. Annual revenue and of Pinduoduo 2019-2023[4]

	2019	2020	2021	2022	2023
Gross revenue	30.142 billion yuan	59.492 billion yuan	93.95 billion yuan	130.558 billion yuan	247.639 billion yuan
Purchase cost	6.339 billion yuan	19.79 billion yuan	31.718 billion yuan	31.462 billion yuan	91.724 billion yuan
Marketing, sales, management fees	28.471 billionyuan	42.702 billion yuan	46.342 billion yuan	58.309 billion yuan	86.264 billion yuan
Research and development fees	3.87 billion yuan	6.892 billion yuan	8.993 billion yuan	10.385 billion yuan	10.392 billion yuan

Analysis of PDD's annual report shows costs of each part have risen. Research and development, marketing, and sales management expenses have increased significantly. Over five years, sales and management expenses have risen by over 20 billion yuan, and research and development expenses by about 7 billion yuan.

- Analysis of current situation of PDD's internal supply chain cost control

To compete, PDD has exclusive titles and sponsorships in popular TV programs like "Extreme Challenge" and the 2021 Spring Festival Gala, incurring high marketing costs. To tackle counterfeit goods, it spends a lot on R&D to restore reputation. However, considering the user growth rate, such high marketing and R&D costs are disproportionate, and the allocation lacks scientific basis.

According to survey data, over time, PDD users have gradually saturated. The user growth rate dropped rapidly from 71.02% to -1.48% in six years, and active users increased slowly. High marketing costs and poor growth show that its customer acquisition cost is no longer as good as in the early stage.

- Analysis of current situation of PDD's external supply chain cost control

Low-price quality control has worsened PDD's reputation, like "cut the blade" for rewards, which gets criticized. Consumers often don't get promised rewards, leaving a negative impression of false publicity and low credibility. These dampen consumption enthusiasm and increase service costs.

On the other hand, the negative impression also causes concerns for suppliers. It's hard to have a fixed, long-term cooperation, increasing transaction cost, which is bad for long-term development.

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4 Data source: According to Pinduoduo Annual report。

4. Problems of PDD Supply Chain Cost Control in Big Data Context

4.1. Marketing direction incorrect, marketing cost control inefficient

Marketing cost is a big part of PDD's costs. It mainly includes publicity, design and promotion costs. PDD invested heavily in sponsoring TV programs, but the publicity's effect did not match the investment, and the user growth rate did not increase. Its marketing cost control was inefficient, failing to address key problems. With popularity growth, the marketing cost should be redirected to enhance user experience and reputation for a good word-of-mouth effect.

In the marketing process, the Marketing Department's management staff failed to use user feedback, develop a clear direction and determine accurate objectives, resulting in PDD's overall marketing investment.

4.2. Low research and development cost control effect

PDD has spent a lot on R&D to address counterfeits and improve the user experience. Its R&D costs rose from 3.87 billion yuan in 2019 to 10.392 billion yuan in 2023 but failed to restore users' perception.

For PDD, "shanzhai" gives users a poor experience. "Shanzhai" refers to counterfeit, fake products or behavior, characterized by imitation strong, low cost, quality, intellectual property, reliable quality, but also meets the requirements of spectrum. PDD fails to supervise product authenticity. The Black Cat report shows PDD received over 30,000 complaints but gave a low response rate. This indicates the R&D expenses are poorly managed.

4.3. Neglect to maintain the user-side relationship, service cost control is not in place

Low prices stimulate purchases but ignore the shopping experience, especially in after-sales. Unsatisfactory after-sales deepens the negative impression, increases costs and causes user loss. Complaint statistics show in 2023, the number of complaints against it was 845,621, ranking third, and the response volume was low. This indicates its after-sales service lags behind, and the service cost control is insufficient.

4.4. Unreasonable management cost and lack of management talents

PDD's management costs include administrative expenses, management salaries and education funds. To address the predicament, it recruited highly paid talents, increasing the cost. The proportion of employees shows management personnel are only 7% and basic platform operation personnel are about 28%, indicating redundancy for PDD. High management salaries don't solve issues, and redundant basic staff don't add value, resulting in poor cost allocation and intangible costs. Due to the late development of the domestic e-commerce industry, professional management talents are scarce. PDD has a low proportion of such professionals and needs to attract them.

5. Suggestions for PDD Supply Chain Cost Control in Big Data Context

In summary, PDD has issues in cost control in marketing, R&D, management, and service supply chain: Incorrect marketing orientation lowers efficiency; Unsatisfactory R&D input effect; Low proportion of management talents; Poor customer relationship and service cost control. Considering the big data trend, suggestions are proposed to enhance its supply chain cost control.

5.1. Sharing data, information transparently and maintaining supplier relationships

PDD has many suppliers with inconsistent product quality. Long-term cooperation with outstanding ones is beneficial for cost control. It needs to screen suitable ones based on evaluation criteria by professionals. Suppliers can be evaluated from multiple aspects to select the best. Then, PDD should share information transparently with suppliers, establish and refine the sharing system. Through long-term collaboration and close information sharing, they can achieve a win-win and minimize the supply chain cost.

5.2. User portraits stimulate consumption and reasonably plan marketing costs

JD uses the data technology industry according to different levels of users to customize marketing plan, improving the conversion rate. Alibaba focuses on content marketing, such as "shopping" plate, attracts many brand merchants and talent to participate in, they bring free or low-cost traffic import. It reduces the platform dependence on traditional advertising channels, saving marketing expenses.

Currently, PDD's user base is nearly saturated. The marketing focus should shift from visibility investment to platform construction and user experience. Many users have accounts but rarely purchase, indicating the current marketing approach is wrong. The platform should be optimized to identify low-spending users through data analysis, create personas, and promote the required products. Design tasks or provide discounts to stimulate their consumption.

5.3. Eliminate the impression of "copycat" and maintain customer relations

Alibaba strengthens after-sales services to make users feel at ease during the shopping process. This makes users more willing to shop on the platform, and customer retention rate is further improved. The value of JD brand increases users' trust in JD, reduces users' sensitivity to price, and improves customer retention.

Users are the most crucial element of PDD's supply chain. To maintain a good relationship with them, PDD must foster the "customer is God" notion. It's essential to solve the problems of counterfeit and inferior products and the service attitude, enhance the customer service system, and improve the low-end perception.

Before product sale, assess goods with a high poor rating rate on the data tracking platform, understand the situation, supervise improvement, remove counterfeit links. After the product is sold, efficient settlement of after-sales complaints saves costs, earns trust, and improves the platform's impression. Service cost is correlated with the goods return rate. The service cost is related to the return rate of goods. To reduce it, PDD should improve the after-sales level and subdivide the return conditions to prevent malicious return and avoid unnecessary costs.

In the current big data era, personal information is at risk and consumers are concerned. So, PDD should enhance user information protection, safeguard privacy, establish a security system to protect rights and improve the user experience.

5.4. Absorb management talents and allocate personnel reasonably

In conclusion, supply chain cost optimization needs outstanding management personnel. PDD has the lowest proportion of them. To stay competitive, it can select and train internal candidates or recruit more professionals and enhance incentives.

PDD has too many unnecessary basic staff in the supply chain, resulting in low-cost performance. The assessment system should be improved, efficiency enhanced, outstanding staff rewarded, and layoffs made if necessary. A training system can be set up to optimize employees' knowledge and quality, train talents and reduce brain drain.

6. Research conclusion and enlightenment

Nowadays, big data technology is maturing. E-commerce has advantages in its application. PDD has developed rapidly with its model but has rising costs and ineffective control. Based on data and user experience analysis, its problems include irrational marketing costs, unsatisfactory R&D cost input, shortage of management talents and service cost issues. By integrating data technology approaches in various links, the solutions are: At the marketing level, focus on combating counterfeiting and build user relationships. In management personnel allocation, increase the proportion of administrator and promote talents. Regarding supporting services, foster the "customer is God" concept, handle user problems and reduce return rate and service costs.

This paper endeavors to integrate big data technology with e-commerce supply chain cost control to expand the depth of the supply chain direction in cost control and ultimately promote the upgrading of the consumption structure, economic development and prosperity, as well as the improvement of people's quality of life. In the big data era, not using big data technology reasonably means falling behind. E-commerce enterprises are suitable for using it. If they grasp the opportunity to improve based on their conditions, they will achieve great results.

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Digitalization and Management Innovation III
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A Review of Research on the Impact of the Digital Economy on Automotive Supply Chain Resilience

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Abstract. Today's world is in a situation of significant change unprecedented in a hundred years; changing the complex environment to the stability of the supply chain has brought unprecedented challenges; maintaining the security and stability of the supply chain has become the objective needs of the country to promote high-quality development, supply chain resilience reflects the ability of the supply chain to maintain stability, and to enhance the resilience of the supply chain has become a meaningful way to enhance industrial competitiveness. As a pivotal sector of the national economy, the resilience of the automobile industry's supply chain is crucial for the industry's competitiveness and sustainable development. This paper presents a summary of the factors that influence supply chain resilience, which are classified into four dimensions: supply chain prediction capacity, supply chain reaction capacity, supply chain adaptation capacity, and supply chain recovery capacity. The research methodology employed is a combination of literature research and causal analysis. In light of the dimensions above, this study initiates an investigation into the influence of the digital economy on automotive supply chain resilience. It proposes a mechanism through which the digital economy affects automotive supply chain resilience and offers recommendations for enterprises and the government on leveraging digital technology to enhance automotive supply chain resilience.

Keywords. Digital economy, Automotive supply chain, Supply chain resilience

1. Introduction

China attaches great importance to the development of the industrial chain and supply chain, and the resilience of the supply chain, as well as the ability to maintain the stability of the supply chain, has been paid attention to and emphasized. The 20th CPC National Congress report is clearly put forward to adhere to the theme of promoting high-quality development, focusing on improving the resilience and security level of the industrial chain and supply chain, enhancing the ability to maintain national security, and ensuring the security of the important industrial chain and supply chain. The government report of 2024 will vigorously push forward the construction of the modernized industrial system, accelerate the development of new productive forces, and push forward the optimization and upgrading of the industrial chain and supply chain as one of the government's tasks, which shows the importance of supply chain security in China and the urgency of improving supply chain resilience.

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The digital economy is a new economic form, with the integration and application of information and communication technology and the digital transformation of all elements as the driving force that promotes greater unity of equity and efficiency. The 20th CPC National Congress report also emphasized the need to "accelerate the development of the digital economy and promote the deep integration of the digital economy and the real economy". The digital economy is reshaping the development pattern of various industries at an unprecedented speed and scale. As an important position for the deep integration of the real economy and the digital economy, the level of the manufacturing industry supply chain is an important guarantee for the high-quality development of China's economy. Digital technology, as the core driving force of the digital economy, has become an important way for enterprises to respond to the government's call to promote the modernization and development of the manufacturing industry supply chain [1]. The automobile manufacturing industry is a pillar industry of the national economy. The toughness of the automobile supply chain has become a key factor in determining the competitiveness and sustainable development of the industry. The digital economy through big data, cloud computing, the Internet of Things, and other advanced technologies, real-time sharing of information, and optimal allocation of resources significantly improve the transparency and responsiveness of the supply chain, and supply chain resilience enhancement provides new possibilities. However, at the same time, the development of the digital economy also brings challenges such as data privacy and information security issues, which all pose new challenges to the resilience of the automotive supply chain. Therefore, studying the impact of the digital economy on automotive supply chain resilience can help reveal the potential value of digital technologies in supply chain resilience and also provide suggestions and guidance for the digital transformation and sustainable development of automotive supply chain companies.

2. Analysis of Factors Influencing Automotive Supply Chain Resilience

Maintaining supply chain security and stability is not only a means to cope with the complex and volatile market environment but also an objective need for the country to promote high-quality development. Many emergencies and persistent problems, such as the COVID-19 pandemic, earthquake and tsunami, and energy crisis, have seriously impacted the stability and security of the global supply chain. According to the data, 94% of the world's top 1,000 companies have experienced supply chain disruptions, with the automobile manufacturing industry and the electronics manufacturing industry having the most serious impact [2]. Supply chain resilience refers to the ability of a supply chain to recover to its original or more ideal state after being disrupted [3]. Supply chain resilience reflects a supply chain's ability to resist risk and maintain stability. Supply chain resilience then becomes a recurring topic in the research literature of supply chain risk. Most scholars believe that supply chain risk cannot be completely avoided, so research on the improvement of supply chain resilience capability is the focus of supply chain risk management.

2.1. Research related to factors influencing supply chain resilience

In recent years, scholars have explored supply chain resilience influencing factors from different perspectives, which can be mainly summarized into two aspects: supply chain structure perspective and supply chain capability perspective. Researchers have constructed evaluation index systems based on different perspectives to study the factors that influence supply chain toughness in different industries. Hollnagel believes that supply chain toughness is mainly reflected in the four aspects of forecasting, monitoring, reacting, and learning capabilities possessed by supply chain enterprises [4]. Fan and Lu [5] constructed the index system of supply chain resilience influencing factors from the five dimensions of supply chain prediction capacity, reaction capacity, adaptive capacity, recovery capacity and learning capacity. They carried out a supply chain resilience evaluation. Zhu et al. [6] constructed a comprehensive evaluation index system of the supply chain toughness of China's copper resource industry chain from four dimensions: resistance capacity, recovery capacity, reorganization capacity and renewal capacity. Some scholars divide the supply chain based on the elements contained in its composition structure. Wang Yixin [7] and others analyze the green building supply chain structure and determine the supply chain resilience influencing factors through consulting experts, questionnaire surveys and other ways from eight dimensions, such as the supply chain level, green building materials and equipment suppliers, building construction units, construction units, design technical consulting units, end-users, supervisory agencies and waste recycling enterprises. Zhu Lei et al. [8] introduced supply chain and resilience ideas into assembly building and constructed an evaluation index system of supply chain resilience for assembly building supply chain in six dimensions such as supply chain level, design and supervision units, construction manufacturers, logistics enterprises, and contractors.

2.2. Analysis of Factors Affecting Automotive Supply Chain Resilience

This paper argues that the factors that influence automotive supply chain resilience can be analyzed in four dimensions by reading the literature combined with the connotation of supply chain resilience.

2.2.1. Supply chain prediction capacity

Supply chain prediction capacity is the foundation of supply chain resilience and includes three aspects: risk awareness, security culture and supply chain visibility. Among them, risk awareness refers to the ability of enterprises to avoid and control risks in supply chain operations. In the automotive supply chain, if enterprises can identify and avoid potential risks (such as raw material supply disruption, logistics delays, and market fluctuations) in advance, they can effectively reduce the possibility of supply chain disruption. Security culture includes transportation security of the supply chain, digital information security and security of supply chain partner cooperation. The automotive supply chain involves numerous links, including raw material procurement, parts manufacturing, vehicle assembly, logistics and distribution. Ensuring transportation security, digital information security and the security of supply chain partner cooperation at each link is the key to maintaining the stable operation of the supply chain. Supply chain visibility, on the other hand, is based on the help of a visual information system to obtain timely information and grasp the operation of the whole supply chain. The rate of timely information updating and the rate of demand fulfilment can reflect the supply chain visibility to a certain extent. Timely updating of supply chain information and improved supply chain visualization help enterprises optimize production plans based on the acquired information and better control the supply chain operation process in order to reduce supply chain risks, thus enhancing supply chain resilience.

2.2.2. Supply chain reaction capacity

Supply chain reaction capacity is the ability to react and take action in a timely manner to reduce or eliminate external shocks when risks occur, including the flexibility to make quick adjustments based on environmental changes, the agility to respond quickly to unpredictable demand or supply changes, the flexibility to adjust direction and strategy, and collaborative ability. Flexibility makes the automotive supply chain need to be able to adapt to changes in market demand quickly. When there is a sudden increase in demand for a certain model, the supply chain needs to be able to quickly adjust the production plan to increase production of that model. A high degree of flexibility enables rapid adjustment of resource allocation and production processes. Agility can be reflected in market sensitivity, information transfer speed, production and marketing speed. An agile supply chain reduces production and supply delays caused by market changes and ensures that products are delivered on time. By responding quickly to changes in demand, an agile supply chain can improve customer satisfaction and enhance customer loyalty. It helps companies stay ahead of the curve and seize market opportunities in a competitive market. Information sharing and process integration reduce inventory backlogs and overproduction, thus lowering operating costs. Cooperation and synergy capability reflects the ability of all parties in the automotive supply chain to work closely together to cope with risks. In the event of supply chain disruption, all parties need to make rapid response measures and jointly deploy resources to ensure the continuous operation of the supply chain. Coordination and consistency in all parts of the supply chain can reduce unnecessary delays and duplication of efforts, improve overall operational efficiency, and thus enhance supply chain resilience.

2.2.3. Supply chain adaptation capacity

Supply chain adaptation capacity is mainly the ability of an enterprise to maintain the competitive level of the supply chain at a reasonable level by adjusting the supply chain structure, operation mode and links when it encounters risky shocks, including redundancy, product diversity and outsourcing. In the automotive supply chain, maintaining a certain amount of safety stock and capacity redundancy can cope with possible changes in supply and demand. When a supplier has a problem, companies can utilize redundant inventory and capacity to supplement resources and ensure that production is not affected. Offering a diverse range of automotive products can spread the risk of market demand. When demand for a certain model fall, other models can make up for lost sales and maintain the profitability of the business. Outsourcing non-core business to specialized partners can reduce the enterprise's operating costs and diversify risks. In the automotive supply chain, enterprises can outsource parts manufacturing, logistics and distribution to professional suppliers and logistics companies, thus improving the efficiency and resilience of the supply chain.

2.2.4. Supply chain recovery capacity

Supply chain recovery capacity, which is used to measure the degree of tolerance and resilience after encountering a crisis, includes 4 parts: supply chain structure, financial strength, logistics support, and contingency plan. Supply chain structure represents the complexity of the supply chain, including the number of nodes, the length of the chain, the number of suppliers and distributors and other factors. A complex but flexible supply chain structure can accommodate more nodes and paths, thus enhancing reliability. In the automotive supply chain, firms can increase the complexity and flexibility of the supply chain by establishing a network of multiple suppliers and distributors and by using multiple logistics methods. Financial strength is the economic strength of a firm. Strong economic strength can provide financial support for firms to cope with the financial pressure caused by disruptions in the supply chain. In the automotive supply chain, enterprises need to maintain sufficient cash flow and reserve funds to cope with possible risks and challenges. Logistics support provides enterprises with security in terms of freight transportation. An efficient logistics system can ensure that automotive products are delivered to customers in a timely and accurate manner. In the event of a supply chain disruption, the logistics system needs to be able to quickly adjust distribution routes and methods to ensure that the supply of products is not affected. Contingency planning refers to the contingency mechanism established through supply chain design reconfiguration, information monitoring, technical maintenance and other measures in risk response. Contingency planning can be activated fast when risk occurs to reduce the impact of supply chain disruptions, thus enhancing supply chain resilience.

In summary, automotive supply chain resilience is influenced by four dimensions: supply chain prediction capacity, supply chain reaction capacity, supply chain adaptation capacity, and supply chain recovery capacity, of which the causal relationship is shown in Figure 1.

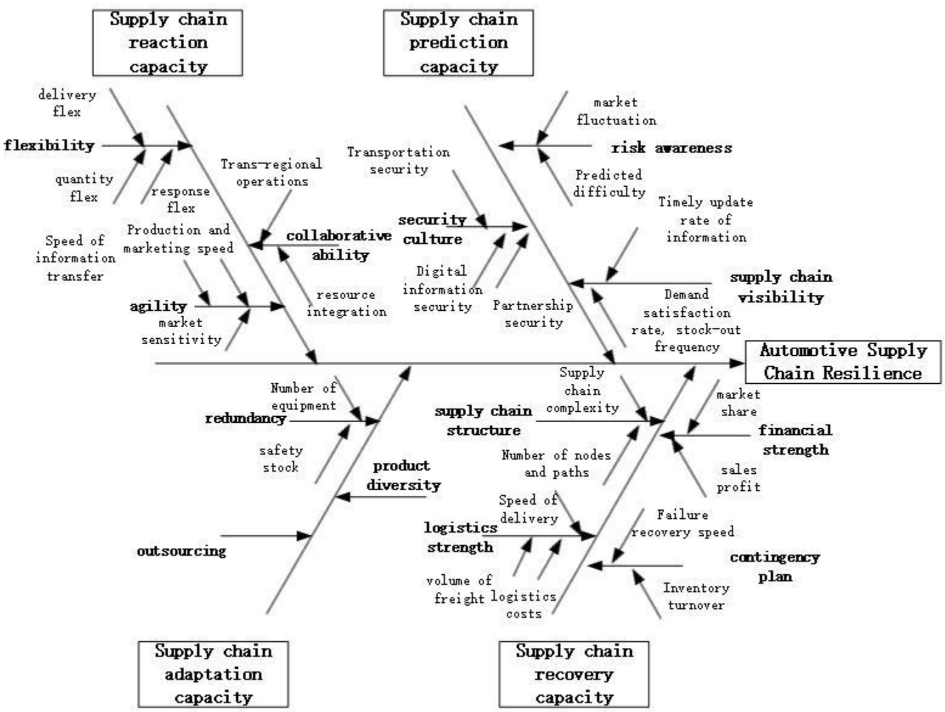

Figure 1. Path diagram of factors affecting supply chain resilience

3. The impact of the digital economy on automotive supply chain capabilities

3.1. Digital economy and supply chain prediction capacity

Qiao Liang and Liu Tao [9] found that by studying three centralized enterprises, China FAW, Dongfeng Enterprises and Chang'an Automobile, the use of big data technology can improve the traceability of all aspects of product production, which is conducive to the improvement of automotive product quality, and also increases the visibility of the supply chain. Gong and Wang [10] digitally upgraded the automotive production off-line detector (EOL), and the upgraded platform became an interactive system for vehicle electrical inspection data across all stages of product development, production and manufacturing, and after-sales. It provides an early warning information module in automobile manufacturing, which facilitates engineers in dealing with on-site problems and avoids the risk of stopping the line. Wang Yi [11], based on the Siemens WinCC OA software platform, uses HTML5 technology for the design and development of an automotive digital workshop production monitoring system, realizing the large-scale collection of vehicle workshop data to achieve timely updating of production capacity data and improve the accuracy of the data and supply chain transparency. He Dazhuang, Zhang Zhikuan, et al.[12] from the display and analysis of engine production quality information, data dimensions and expression methods, display planning and view design, data import and page operation, as well as digitalization results, display, Tableau digital display, the establishment of a systematic expression method, the realization of the data of the high-order and dynamic display, improve the accuracy of statistics and realize the data real-time Update. Yang [13] pointed out that data will become the basic element of automobile products and all parts of the industry, and all parts of the automobile industry can not be separated from the support of data. Blockchain technology provides solutions to the problems of information asymmetry and data tampering in supply chain management through its characteristics of decentralization, non-tampering and traceability. The application of blockchain in the automotive supply chain guarantees the authenticity of data in the supply chain, enhances the transparency of supply chain information, and ensures the accuracy and reliability of information [14]. Lv Yue and Deng Lijing [15] took the automobile industry chain as the entry point and constructed and measured the industry chain security index. They pointed out that the risk of the automobile industry chain has an upward trend and that improving the level of innovation and using digital technology to build a risk early warning platform can reduce the risk of the automobile supply chain brought about by the impact of the epidemic and safeguard the safety of the automobile supply chain in the era of the post-epidemic. Yang Xiaobo and Gao Haiwei [16] take Tesla and Xiaopeng Automobile as the research objects to construct a supply chain network model and discover the potential invisible key risk control nodes in the automotive supply chain so as to prevent the possible risks effectively. Based on the monitoring platform of the automotive supply chain security, Wang Hongzhao, Li Weiqi[17] and others study the risk control model established by using big data technology and other digital technologies, using the Bagging algorithm and stacking algorithm in order to improve the stability of the prediction model and anti-noise capacity, and to improve the accuracy of the early warning, so as to enhance the resilience of the supply chain.

3.2. Digital economy and supply chain reaction capacity

In the traditional supply chain, there exists the phenomenon of information asymmetry between upstream and downstream supply chain enterprises, which restricts the effective docking of inter-enterprise business, affects the matching degree of supply and demand [18], and causes market inefficiency. The accelerated integration of the digital economy and the real economy, the application of artificial intelligence, big data, cloud computing and other digital technologies in the manufacturing industry promotes the improvement of information interoperability, resource sharing, and the level of collaboration and cooperation between the main bodies of the supply chain. Based on big data technology, Ding Nianbo[19] has carried out the overall planning and design of the supply chain control platform to realize data collection, development, management and data sharing, application of the whole process of data services, and to build an analysis system of supply chain data with information accumulation, data self-control, and sharing and unification. Realize dynamic real-time analysis and monitoring for different levels and promote the shaping of resilience in enterprise supply chains. Bi [20] used the case study method to study the electric welding robot workstation of the automobile production enterprise, showing that the digital flexible welding workstation can improve the flexibility and compatibility of the equipment so that the production line has the production digital management and multi-product flexible production capacity. Based on the theory of relational exchange, based on the relationship between manufacturers and distributors in the automotive industry, using bilateral matching survey data and hierarchical regression method, Zhang and Lan [21] concluded that manufacturers can influence distributor agility through digital communication technology and that in the process of long-term relational exchange, the manufacturer's cultivation of distributor agility can bring performance rewards for both parties. Zhu Jinfeng, Xu Chuanzhi[22] and other automobile enterprises as a case, combined with the external environment analysis, concluded that digital technology and procurement management combined to form digital procurement, the establishment of a digital procurement platform can comprehensively improve the supply chain synergy ability, enhance the competitiveness of the supply chain. Huang Xun et al.[23] focus on collaborative manufacturing, intelligent testing and other key digital technologies, with the digital factory and collaborative manufacturing two platforms as the focus point, the formation of the downstream to promote the upstream of the flexible production chain, the construction of the whole chain of customer-centred collaborative manufacturing model, the realization of the vehicle and the supply chain of the whole process of business data interconnectivity, efficient collaboration, data-driven supply chain optimization and improvement to improve the supply chain management control The data-driven continuous optimization and improvement of the supply chain improves the efficiency and stability of the supply chain control and promotes the maximization of the overall industrial chain efficiency. Li Ganlin[24] and others took "Xiaozhi Logistics-SCS Supply Collaboration Platform" developed by FAW-Volkswagen as a case study and found that it realizes the systematization and electronicization of important business and processes, integrates data and system applications, improves the information flow synergy, and comprehensively helps to improve the efficiency of the supply chain.

3.3. Digital economy and supply chain adaptation capacity

Yan et al. [25] FAW-Volkswagen Foshan plant case study found that the factory put into use automated three-dimensional warehouse intelligent storage, the use of AS / RS and SHuttle technology, the realization of the AGL-AKL linkage can be compatible with a variety of sizes of goods so that the plant's inventory capacity to increase several times. Zhang[26] analyzed a number of automotive wire harness manufacturing enterprises' HMES (Harness Manufacturing Execution System) cases and concluded that the HEMS system integrated with the cutting and crimping equipment and control systems can be completed in accordance with the production requirements of the debugging and optimization of industrial processes, but also to monitor and analyze the operating data of the equipment, predicting the maintenance of the equipment Cycle and risk of failure, timely maintenance and repair of equipment to ensure that the system can adapt to the actual needs of production in a timely manner. Tao [27] et al. combined the vertical relationship theory of industrial organization from the perspective of supply chain resilience to examine the impact of digital transformation on enterprise productivity and the transmission mechanism. The study concluded that digital connectivity in the supply chain upstream and downstream business processes helps suppliers and manufacturers to understand the market demand and user dynamics in real-time, according to the changes in demand and joint management of inventories, to ensure that the manufacturing of the punctual and effective to avoid the surplus or shortage of inventory. This ensures on-time manufacturing and effectively avoids over- or under-inventory. There is no lack of high-tech parts and components in the components of automobiles, strengthen the coordination of supply and demand with existing suppliers, increase the supply chain redundant inventory such as high-end chips, and expand the diversified supply chain sources so as to adapt to market changes in a timely manner, and effectively cope with the risk of supply chain disruption [28].

3.4. Digital economy and supply chain recovery capacity

Based on supply chain innovation and pilot work, Zhang Shushan et al.[29] conducted empirical research using data from listed companies and found that supply chain digitization can break the spatial and temporal limitations of geography and chain domains and market segmentation, expand the scope of circulation of products and resource elements, and help enterprises to cooperate without regional limitations, so as to expand the network of supply chain relationships and enhance the supply chain recovery capacity after "disruption", thus improving supply chain resilience. Zhong Tingyong et al. [30] Enterprises use the Internet, Internet of Things and other digital technologies to carry out digital transformation to reduce the concentration of customer resources, effectively mitigate operational risks and surplus manipulation, improve corporate governance, digitally empower the reconstruction of customer resources, improve supply chain resilience, and achieve high-quality development. Wang and He Hongman [31] to automobile manufacturing enterprises as an example of the establishment of the manufacturing enterprise digital transformation evaluation index system, the use of CRITIC-entropy method of combining the weight model, the construction of individual fixed effects model to verify the research hypothesis, the results show that digital transformation has a significant impact on enterprise performance, the enterprise through the introduction of digital technology to achieve digitalization of the production, management, sales and other levels of enterprise operating cost rate, management cost rate, sales cost rate to influence the enterprise financial strength. Wang Haitao [32] analyzed the current situation of digital transformation of the supply chain of automotive enterprises and the trend development issues, pointing out that digital technology helps the enterprise operation from the previous chain structure into a mesh structure and enhances the effect of internal and external communication of the enterprise. At the same time, relying on big data analysis technology through the integration of analysis to achieve the optimization of parts, suppliers, and price adjustment creates the risk of encountering the problem of active response. Liu [33] et al. took the Chongqing New Ecological Logistics Innovation Organization as a case study and creatively used digital technologies such as "SaaS platform+mobile app" and the Internet of Things to build a digitalized logistics collaboration platform, achieving vehicle resource management and integration, transportation allocation, and vehicle transportation status warning. This platform led to an 8% increase in loading rate, a 15% increase in transportation efficiency, and an annual cost savings of over 980000 yuan. The application of the digital platform ensured logistics safety and optimized logistics costs. Through digital and visual means, a low-cost and high-value logistics operation mode was achieved throughout the entire supply chain, providing high-quality logistics support for the supply chain and enhancing its resilience.

3.5. Summary

According to the above literature, it is known that the digital economy affects supply chain resilience by influencing four aspects: supply chain prediction capacity, reaction capacity, adaptation capacity and recovery capacity. First, through the use of big data, blockchain and other digital technologies, enterprises are able to improve the traceability of all aspects of product production and the visibility of the supply chain, conduct large-scale data collection and timely updating, increase the accuracy and transparency of data, and conduct timely monitoring and early warning of risks, so as to optimize the supply chain prediction capacity and enhance supply chain resilience. Secondly, the digital economy promotes information interoperability, resource sharing and collaborative cooperation among the main bodies of the supply chain, improves the response speed of the supply chain, and enhances the competitiveness of the supply chain. The application of digital procurement platforms and digital communication technology drives supply chain optimization and improvement with data, enhances supply chain control efficiency and stability, strengthens supply chain synergy agility and flexibility, and improves supply chain reaction capacity, thus increasing supply chain resilience. Further, the application of digital technology also enhances the supply chain adaptation capacity. Through automated three-dimensional warehouse intelligent storage, HMES system optimization of industrial processes, and digital connection of upstream and downstream business processes, enterprises can control and maintain equipment, can flexibly respond to changes in market demand to adjust equipment and inventory, to ensure on-time manufacturing and effectively avoid the occurrence of excess or insufficient inventory, so that the supply chain enterprises can adapt to market changes in a timely manner, thus enhancing the supply chain adaptation capacity. This enhances the resilience of the supply chain. Finally, the application of digital technology also enhances supply chain recovery capacity. Digital technology helps supply chain enterprises break the time and space limitations of geography and chain domain, expand the supply chain relationship network, reduce the concentration of customer resources, and effectively mitigate operational risks and surplus manipulation. At the same time, digital technology has also helped transform enterprise operations from a chain structure to a mesh structure, enhanced the effectiveness of internal and external communication, and proactively responded to risk issues through the optimization and adjustment of parts, suppliers, and prices. In addition, the application of digital technology in vehicle management, transportation deployment, and early warning of transportation conditions also improves transportation efficiency and loading rate, ensures logistics safety, optimizes logistics costs, provides high-quality logistics support for the supply chain, and enhances supply chain recovery capacity, thus improving supply chain resilience.

4. Mechanisms of the digital economy's impact on automotive supply chain resilience

4.1. Promoting product quality and production levels to strengthen automotive supply chain resilience

The digital economy has greatly improved the quality of automobile production and the level of automobile production through the introduction of advanced technologies such as intelligent manufacturing and the industrial Internet, thereby strengthening the resilience of the supply chain. Supply chain enterprises optimize automotive parts and related products through technological innovation, accelerating product renewal and iteration and enriching product diversity, which not only better meets the needs of enterprises in the automotive supply chain but also adapts to the market environment with increasingly diversified demands, enhancing supply chain adaptation capacity and thus strengthening supply chain resilience. The application of intelligent equipment, such as robots, automated production lines, and intelligent sensors, realizes the automation and flexibilization of production lines, improves the precision and efficiency of production, reduces human errors, ensures the stability and consistency of product quality, and can quickly respond to the changes in market demand, adjust the production plan, improve production efficiency and agility, enhance the supply chain reaction capacity, and strengthen the resilience of the supply chain. The use of big data and other digital technologies for data collection and analysis of production activities provides a scientific basis for enterprise production decision-making, optimizes the production process of supply chain enterprises, reduces costs while improving product quality and production efficiency, improves enterprise financial strength, enhances supply chain recovery capacity, and strengthens supply chain resilience. Automobile manufacturers can use big data technology to build digital manufacturing workshops, design and develop automobile digital workshop production monitoring systems, ensure data accuracy and transparency, realize large-scale collection of enterprise production data, realize real-time monitoring and dynamic adjustment of the production process, discover and solve abnormal situations in the production process in a timely manner, effectively reduce the loss of production capacity, and improve the production efficiency and product qualification rate. At the same time, supply chain enterprises should actively promote internal digital transformation through the optimization of production and management processes, which improves the synergy and management level of the production organization and lays a solid foundation for supply chain resilience.

4.2. Building supply chain data integration and data sharing channels to strengthen automotive supply chain resilience

Information fluency is the key to the efficient operation of the supply chain, the traditional supply chain, due to time, space, and distance constraints, the information system of each supply chain party is not interoperable, can not effectively share information, the formation of "information silos"[34], resulting in the supply chain parties in the delivery of the time limit, inventory management, demand forecasting and other aspects of the lack of transparency of information, which in turn affects the supply chain business efficiency, affecting the overall competitiveness of the supply chain, which affects the efficiency of supply chain operations and the overall competitiveness of the supply chain. Therefore, it is an inevitable trend to open up information silos and build data integration and data sharing channels to enhance the interaction and collaboration between supply chain subjects. Data standardization and normalization are the basis for ensuring data quality and interoperability, including unified data formats, naming conventions, data meta-identification, data security standards and other aspects. Specifically, the automotive supply chain needs to unify industry data formats and standards to ensure that data from different enterprises can be shared and interoperable. Adopt industry-standard naming specifications and data element identification to establish a unified naming specification and data element identification system to ensure the uniqueness and identifiability of data in the entire supply chain, promote enterprise data interaction and sharing, and enhance the interactive and collaborative capabilities of supply chain subjects. Establish a digitally integrated data information platform, make it a centralized storage and exchange centre of supply chain data, and realize data sharing, collaboration and analysis of automotive supply chain enterprises. The platform should be equipped with data integration and sharing functions so that enterprises in each link of the supply chain can obtain the required information in real time, promote the exchange and cooperation between different enterprises, facilitate the matching of supply and demand, and realize the transparency and visualization of supply chain information. In addition to collecting internal data on the supply chain, the platform should also collect relevant external information such as market environment and policies, provide decision support functions such as data visualization report analysis, carry out information screening, and timely feedback useful information to the enterprises in the supply chain, enhance the supply chain prediction capacity, reaction capacity, adaptation capacity and recovery capacity of all parties in the supply chain, and promote supply chain synergy and cooperation as well as overall optimization, and enhance supply chain Resilience.

4.3. Establishing a sound data security and supervision and management system to strengthen supply chain resilience

In the digital era, the supply chain involves a large amount of sensitive data, such as production plans, customer information, and technical information. It is necessary to establish a sound data security supervision and management system and take effective measures to protect the data from malicious attacks and leakage. First of all, enterprises should establish a perfect network security protection system based on advanced technologies such as artificial intelligence, big data, blockchain, and cloud computing. They should adopt technical means such as network firewalls, intrusion detection systems, security authentication and other technical means to monitor the status of supply chain information in real time. Each node enterprise in the supply chain should adopt multi-level data security measures, including data encryption, access control, backup and recovery, to ensure that the data storage, Transmission and processing security should also establish a data security management system, clear data rights and responsibilities, strengthen the monitoring and auditing of key data, timely detection and prevention of hazardous data security events to maximize the protection of data integrity to protect the enterprise production information security. Secondly, build a risk assessment model and digital early warning platform to analyze and evaluate supply chain information data in real-time, help enterprises quantitatively assess the risks in the supply chain, and set corresponding thresholds and trigger conditions to judge the weaknesses of each node of the supply chain and the overall security of the enterprises, and once the risk indicators reach the level of early warning, the platform will issue an alert to the supply chain enterprises to help them make responses in advance. Once the risk indicators reach the warning level, the platform will send alerts to the supply chain enterprises to help them make countermeasures in advance to reduce the probability and impact of risks. When supply chain risk occurs, enterprises can quickly start the emergency plan, mobilize resources to cope with the risk, reduce losses and resume production as soon as possible, and enhance the supply chain's perception, prediction, defence and response capacity of the potential risks of each node, and then enhance the resilience of the supply chain. Finally, the relevant departments should strengthen the supervision and management of the automotive supply chain, establish a sound system of data security laws and regulations, clarify the responsible body and legal responsibility for data security, regularly inspect and evaluate the data security situation of enterprises, find problems and correct them in a timely manner, and ensure the effective operation and continuous improvement of the data security management system. At the same time, the supervisory department should not only supervise the information in the supply chain but also be able to act as a bridge between consumers and enterprises in the automotive supply chain, accept consumer feedback and opinions from consumers, and make inquiries to the supply chain platform in a timely manner according to the consumer feedback, so as to strengthen the supervisory effect of the supervisory department, and also better help enterprises in the supply chain to refer to the opinions of consumers to make adjustments to strengthen the whole Supply chain resilience.

Combining the above three parts of the study, the author has organized the mechanism of the digital economy's impact on the resilience of the automotive supply chain, as shown in Figure 2.

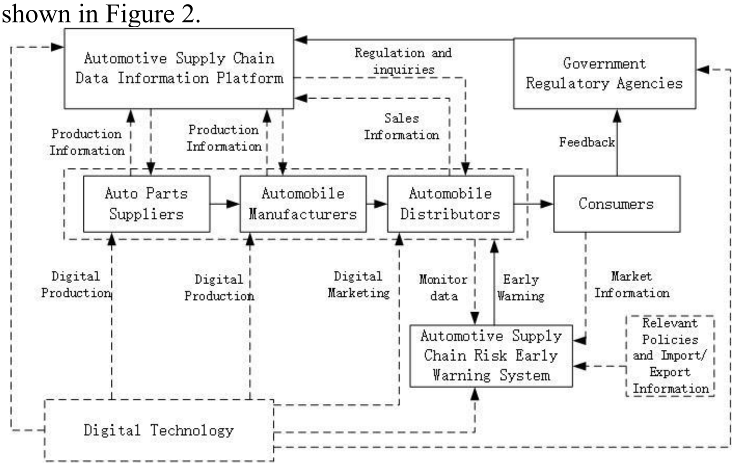

Figure 2. Mechanisms for the impact of the digital economy on the automotive supply chain resilience

5. Challenges posed by the digital economy to the automotive supply chain

The digital economy has brought challenges to the supply chain and the enterprises in the supply chain while enhancing the resilience of the automotive supply chain through the introduction of digital technology. The application of digital technology makes the supply chain data and information more transparent. The transparency and rapid circulation of information alleviate the information asymmetry problem among the supply chain subjects and, to a certain extent, reduce the seller's behaviour of benefiting from the information gap. Consumers' understanding of each link in the automotive supply chain has increased, and their demand for automotive product quality and performance has become higher and higher, which requires each enterprise in the automotive supply chain to accurately grasp the market demand and improve the responsiveness and flexibility of the supply chain. The ever-changing market demand and the increasingly competitive market require automotive enterprises to optimize their supply chain, reduce costs and improve efficiency to enhance their competitiveness in order to cope with the challenges brought about by the improvement of information transparency and the intensification of market competition. In addition, the development of the digital economy has increased the importance of data in the supply chain day by day. The application of digital technology enhances the ability of data collection and the degree of information sharing between the supply chain between the main body to increase, greatly reducing the probability of "information silos", but this also increases the risk of data leakage. Tampering with any of the various links in the supply chain, including replacement, forgery, addition, counterfeiting and other common operations, may cause important data leakage. The difficulty increases in guaranteeing the security and stability of the supply chain data network, and problems in any link of the supply chain may affect the stable operation of the entire supply chain. The security of supply chain data and information is challenged. Network security is a prerequisite for the healthy development of the digital economy, and the digital economy will affect the security and stability of the supply chain, so no matter the government level or the level of each main body of the supply chain, we should pay attention to network information security.

6. Summary and recommendations

The digital economy empowers the automotive supply chain, utilizing big data, artificial intelligence and other advanced technologies to enhance the resilience of the automotive supply chain by improving the supply chain prediction capacity, supply chain reaction capacity, supply chain adaptation capacity and supply chain recovery capacity in four aspects. The development of the digital economy promotes the improvement of product quality and production levels in the supply chain, optimizes the information flow between the supply chain, strengthens the risk control of the supply chain, and enhances the resilience of the supply chain. However, it also brings many challenges to the development of the supply chain. Therefore, the main bodies related to the automotive supply chain should strengthen the digital innovation ability, promote the independent innovation of supply chain digital technology by industry, academia and research, strengthen the construction of data integration and data sharing platforms, establish and improve the governance system of automotive supply chain security, strengthen their production level, strengthen the supply chain enterprises' collaboration and cooperation, and continuously improve the resilience of the automotive supply chain. The government should actively play a guiding role, continue to promote the deep integration of the digital economy and automobile manufacturing industry, firmly implement the innovation-driven development strategy, set up a reward system to encourage scientific and technological innovation, provide policy support to stimulate the innovation enthusiasm of scientific researchers and the potential of scientific and technological innovation of enterprises, and promote the collaborative innovation of large, medium and small enterprises in each link of the supply chain, jointly tackle key technologies, strengthen the autonomy and controllability of the auto supply chain, prevent key technologies from being lost in the supply chain. To strengthen the autonomy and controllability of China's automobile supply chain, prevent the situation of being restricted by others in key technologies and links, so as to strengthen the resilience of the automobile supply chain under extreme challenges and enhance the competitiveness of the entire automobile industry. In view of the data security problem, the government should introduce relevant policies to encourage the research of data security and network security research projects, establish and improve the data security supervision system of the automotive supply chain, and provide a guarantee for the data security and stability of the automotive supply chain. Supply chain enterprises should also increase their investment in data protection work, such as network security and data security under the condition of financial permission and carry out digital security protection for the internal information of the supply chain to ensure that the information is difficult to steal, difficult to leak, and safeguard the information security of supply chain. In short, in the rapid development of the digital economy, the government and the automotive supply chain should grasp the opportunity of the times, the use of digital technology to continuously improve the resilience of the automotive supply chain, promote the sustainable development of the automotive manufacturing industry, and contribute to the development of the real economy.

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Digitalization Practices Flourish Rural Revitalization: Evidence from China

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Abstract. The digitalization practices, driven by economy, innovation, talent, and policies, have emerged as a critical pathway for rural areas. Digital technologies have yielded promising outcomes, ranging from governance to agriculture, e-commerce and culture. This study analyzes the motivation of digital technology development in rural areas, demonstrates the progress of digitalization practices, and extracts the universal experience of digitalization practices flourishing rural revitalization.

Keywords. Digitalization practices, rural revitalization, driven factors, advanced initiatives

1. Introduction

The progression of digitalization has exerted a profound and positive influence on rural areas. Digital technology has significantly contributed to the transformation of rural governance model, expanded the market of rural industries, and enhanced the income of rural residents. With the strategy of rural vitalization and common prosperity, China has come to the formation of advanced experience in integrating digitalization practices in rural area, emerging as a crucial catalyst for rural revitalization.

In recent years, scholars have conducted various research on digital village construction, focusing on the following aspects.

The intrinsic mechanisms and function of digitalization practices in rural areas. Researchers focus on digital technology and the components underlying that empower the modernization of rural areas. The information carried by data is a significant capital of development [1], exerting a bidirectional influence on transformation and reformation of the production [2]. The fundamental value of digitalization practices lies in the realization of high-quality rural development. From the perspective of farmers, the application of digital technology can enhance farmers' sense of access, satisfaction, and happiness [3]. From the perspective of economy, the integration of digital technology can compensate for the shortcomings of the rural agglomeration economy [4], promote the upgrading of rural industries [5], and reduce the income gap between urban and rural areas [6]. From the perspective of household income, the dissemination of digital

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technology can increase the level of household income by promoting household entrepreneurship and non-farm employment [7]. From the perspective of governance, the utilization of digital technology can effectively improve the accessibility and inclusiveness of social services in the countryside, elevating the standard of governance quality [8].

The advanced attempts and outcomes of digitalization practices in rural areas. The case analysis method is used to identify commonalities among villages, which helps figure out the construction of rural digital governance system [9], the development of new rural businesses [10], and the cultivation of talents with modernized insights [11]. The objective is to achieve digital symbiosis and comprehensive development across the economic, political, cultural, social, and ecological spheres [12], which activates the participation of key stakeholders, optimizes the allocation of resources, and safeguards the interests of villagers during digital transformation [13].

In general, academics have recognized digitalization in rural areas from a macro perspective and emphasized the significance and benefits. An analysis of a micro perspective and specific cases provides a valuable supplement to the research. This study focuses on the leading villages in China, analyzing the refined experience of digitalization practices, to provide a general reference for revitalizing rural areas through digital technology.

2. Driven Factors of digitalization practices

2.1. Economy-driven: potential for rural emerging market expanding

China's digital economy has maintained steady growth, with the added value of core digital economy industries accounting for 10% of GDP in 2023. Digital infrastructure continues to expand and accelerate, with total computing power reaching 230 EFLOPS, ranking second globally [14]. The penetration rate of the digital economy in 2023 in China's primary, secondary, and tertiary industries was 10.5%, 24.0%, and 44.7%, respectively [15]. The sophisticated information infrastructure in rural areas, the abundant agricultural and rural big data, and the diverse range of rural new businesses serve as catalysts for expanding the digital growth in rural areas and offer significant potential for the development of a robust rural digital economy. Moreover, improvements in transportation and logistics facilitate the connection between rural and urban areas; 4G popularization and 5G layout strengthen the base of industries and routines. In Zhejiang, leading province in rural revitalization in China, a total of 88,000 5G base stations had been constructed by the end of November 2023[16], broadening resource realization channels, giving rise to new business, and improving rural residents' income levels and happiness index.

2.2. Innovation-driven: impetus for rural industrial transformation

Presently, many technology companies, leveraging their accumulated industry and technological advantages, have joined the effort to empower the transformation and upgrading of rural industries, especially e-commerce. The e-commerce platform, directly connecting the origin and consumers, builds a new circulation system of agricultural products. Information networks and logistics systems expand live broadcasting and other modes to increase the sale of agricultural products, where the sales of agricultural products have experienced continuous growth for seven consecutive years from 2015 to 2022. Digital technology is deepening the connection between the countryside and the market, promoting a more efficient and scientific transformation of rural industries.

2.3. Talent-driven: energy for rural productivity reform

According to the Report on Digital Literacy in China's Countryside, published in 2021 by the Information Research Center of the Chinese Academy of Social Sciences, the digital literacy score of farmers is 18.6, which is 57% lower than the average of the whole sample (43.6) [17]. The urban-rural digital divide is shifting from facility differences to literacy gaps. Talents with a digital perspective and technological expertise, acting as "translators" or "bridges", are the key to the digital reform and industrial upgrading of villages. Talents can help transform digital information into a language that villagers can easily understand, guiding changes in production and living styles, supporting industrial integration and common prosperity, and contributing to rural modernization and rural revitalization.

2.4. Policy-driven: Engine for rural governance enhancement

The Chinese government has implemented comprehensive support in digitalization practices in rural areas among several domains: policy formulation, infrastructure development, technological innovation, talent cultivation, and industrial integration. First, policies clarify the goals, including enhancing the capacity of rural network infrastructure, facilitating the widespread deployment of 5G technology, and establishing a robust foundation for digital village initiatives. Second, the government stimulates innovation in agriculture. For example, the government supports the advancement of intelligent agricultural machinery and encourages the cultivation of digital talent through targeted training initiatives, thereby attracting skilled talents back to rural areas. Third, these policies have fostered the integrated development of rural e-commerce, agriculture, culture, and tourism, while strategically leveraging agriculture-related data to amplify the impact.

Collectively, these driven factors constitute a comprehensive and coordinated system for rural revitalization, promoting sustainable development and ensuring the integration of rural areas into the broader digital economy.

3. Advanced Initiatives of Digitalization Practices

As digital technology and the digital economy continue to evolve, some rural areas have developed generalizable experiences that integrate the nature of rural life with digital efficiency across governance, agriculture, commerce, and tourism. The cases in this research are drawn from rural areas in China, primarily focusing on Zhejiang Province, one of the leading provinces in rural modernization, noted for its rapid progress in modernizing agriculture, thriving rural industries, livable rural environments, affluent rural populations, coordinated urban-rural development, and highly efficient governance [18].

The villages selected for this research have been working on digitalization more than 5 years, almost pioneers in rural revitalization. They demonstrate advanced digital infrastructure, with widespread network connectivity, integrated digital governance and public services, precision agriculture technologies, robust digital economies[19].

3.1 Digitalization Practices in Governance: Promoting Agility

Digitalization practices, combining digital technologies with daily operations of rural communities, transform governance methods and tools and enhance overall process efficiency. The approach effectively addresses challenges such as information asymmetry, inflexibility, lack of transparency, and deficiencies in traditional rural governance structures.

The core of digital governance is the development of a comprehensive "village brain" tailored to the specific needs of each village. Given the complicated and dispersed nature of rural areas, this digital hub unifies governance functions, promotes information sharing, and facilitates multi-village collaboration.

Ensuring data security and privacy protection is essential before full implementation. Current efforts focus on intelligent monitoring, government affairs management, and the establishment of a big data center, which is applied to various aspects such as administrative processing, financial transparency, and epidemic prevention, ultimately mitigating manpower shortages and reducing management costs.

3.2 Digitalization Practices in Agriculture: Unleashing Vitality

Integrating "digital genes" such as artificial intelligence, cloud computing, the Internet of Things, and remote sensing technology into agricultural production can unlock the energy of primary industry, propelling sustainability.

Real-time monitoring of soil, weather, and crop growth through big data and the Internet of Things has been employed in various villages across Zhejiang Province to trace the quality of agricultural products and create an "information map" for visualization and management. Meanwhile, the cloud platform integrates diverse production and publicity systems to realize cooperate operation online and remove barriers of regional communication. Some villages have even established a comprehensive service platform, facilitating the circulation of agricultural products from family farms to broader markets.

3.3 Digitalization Practices in Commerce: Connecting Markets

Modern logistics and e-commerce platforms constitute innovative methods for rural products circulation. The rural e-commerce market is rapidly evolving. By 2020, there were 5,425 e-commerce villages and 1,756 e-commerce towns across China, with online store transactions reaching 1 trillion yuan.

After years of development, intelligent e-commerce promotes rural commercial activities. For example, short video platforms have built the foundation for agricultural business broadcasting, while a strong live-streaming culture has created an environment conducive to the productization and branding of agricultural products. In addition, rural areas that leverage live-streaming e-commerce have formed long-term partnerships with agricultural assistance platforms, which manage the entire process from product launch and pricing decisions to sales channels and logistics distribution. This new rural e-commerce model provides integrated services, effectively coordinating production, warehousing, distribution, and customer service.

The frequency of live-streaming activities positively impacts the acquisition of live-stream traffic. Frequent live-streaming sessions and the vibrant e-commerce atmosphere cultivate modern commercial awareness among villagers, thereby enhancing their digital literacy.

3.4 Digitalization Practices in Tourism: Propagandizing Culture

Digitalization practices enhance the consolidation of rural tourism resources, optimize resource utilization, and infuse new cultural vitality into rural communities. First, rural areas capitalize on their unique resource endowments to design distinctive tourist attractions, using digital media platforms to amplify brand influence and drive rural value creation through a targeted digital promotional matrix. Second, by employing virtual simulation technologies, rural areas create VR experience scenarios for tourist sites, fostering temporal and spatial connections between these rural locations and visitors through cloud-based interactions. Additionally, smart photography systems capture visitors' experiences, generating short videos that offer tourists a memorable and immersive rural tourism experience. The approach not only increases traffic and exposure for rural areas but also entices more visitors to engage with and appreciate rural life.

With the application of new-generation information technology in areas such as agriculture, forestry, animal husbandry, fishery, tourism, culture, education, and wellness in rural settings, new forms of industrial organization are gradually emerging in rural areas. Digital technology also generates both economic and social value for rural industrial operations, cultural dissemination, and rural brand image development.

4. Conclusion

4.1 Discussion

Under the combined effect of economic, innovation drive, talent convergence and policy guidance, digitalization practices have become important to promote rural revitalization. The successful experience of rural development is a great reference for rural development.

Figure 1 presents a comprehensive model of digitalization practices in rural revitalization. Economic development forms the market foundation for rural digitalization, while innovation acts as a powerful engine driving advancements across governance, agriculture, commerce, and tourism. The introduction and training of talent provides essential intellectual support, further enhancing the capabilities of these sectors. Policy guidance ensures the coordination of the elements, facilitating efficient governance, smart agriculture, and the integration of digital technologies into commerce and tourism.

A detailed view of how digital technologies have revolutionized key sectors within rural areas is demonstrated in the model. In governance, digitalization has enabled intelligent systems that facilitate efficient monitoring, improve information sharing across multiple platforms, and leverage big data management to support decision-making processes. These advancements contribute to more transparent, accountable, and cost-effective governance structures in rural communities.

In agriculture, digital branding and promotion strategies have enhanced the visibility and marketability of rural products, and virtual reality technologies have been employed to attract tourism, offering immersive experiences that showcase rural landscapes and farming activities. This not only supports agricultural tourism but also enriches visitor engagement and education. Data-driven management systems can also be employed to monitor and optimize agricultural production, helping to improve resource management and yield outcomes.

In commerce, the implementation of data-driven quality traceability systems ensures that products meet safety and quality standards, while cloud-based integration supports seamless operations across various stages of production and distribution. These technological advancements help to streamline rural commercial activities, making them more efficient and competitive in broader markets.

In tourism, digital technologies have transformed the way rural areas engage with visitors. Live-streaming e-commerce platforms allow local products and experiences to reach a wider audience, while supply chain management technologies enhance the efficiency and reliability of tourism services. Digital literacy initiatives further empower rural populations to participate in and benefit from these digital platforms, fostering a more connected and resilient local economy.

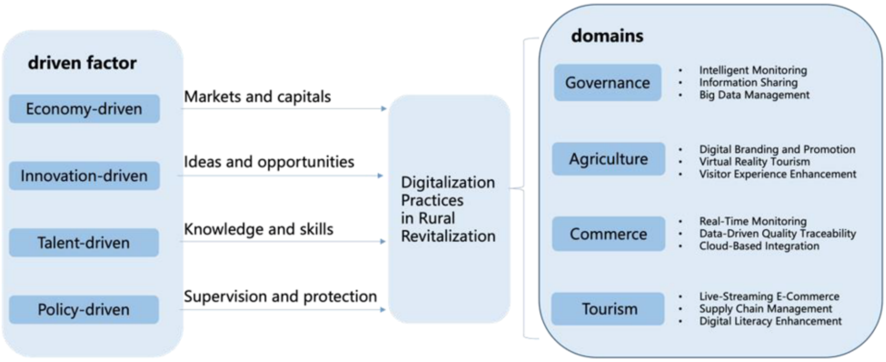

Figure 1. Model of Digitalization Practices in Rural Revitalization

4.2 Future Research

Digital technology is a key driver of rural modernization, and digital village construction should remain a focus for future research, particularly in determining whether the current development model can be standardized and replicated.

In addition, rural construction not only benefits from digital technology but also drives its innovation. The unique needs of rural areas push digital technologies to evolve, fostering tailored solutions in governance, agriculture, and public services. This reverse empowerment stimulates technological innovation, providing vital support for rural revitalization and sustainable development.

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Digital Transformation and the Improvement of Corporate ESG Performance: An Entrepreneurial Perspective

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Abstract: The externality nature inherent in corporate ESG (Environmental, Social, and Governance) endeavors results in suboptimal ESG investment levels. Entrepreneurial endeavors offer a fresh lens through which to capitalize on the digital transformation wave, bolstering firms' capacity to execute ESG practices and harnessing latent internal strengths. Drawing on a cohort of Chinese manufacturing firms spanning 2018 to 2022, this study introduces intermediary constructs encompassing entrepreneurial innovation, societal responsibility, and an entrepreneurial eco-conscious mindset, to scrutinize the effects and underlying mechanisms of digital transformation on corporate ESG outcomes. The findings underscore that digital transformation serves as a catalyst, significantly enhancing corporate ESG performance. Furthermore, the mediation analysis reveals that this enhancement stems from fostering entrepreneurial innovation and societal responsibility, whereas it may be dampened by a diminished entrepreneurial environmental stewardship mindset. These insights offer empirical foundations for shaping digital development strategies and optimizing ESG performance within the entrepreneurial business landscape.

Keywords: digitalization; ESG; Entrepreneurship

1. Introduction

As the global spotlight intensifies on enterprises' environmental, social, and governance (ESG) performance, the fundamental mandate of contemporary corporations is transitioning from profit maximization towards collaborative value creation with stakeholders and society at large. The ascendancy of the ESG concept aligns with this paradigm shift. China, in recent times, has fostered an environment encouraging enterprises to augment ESG investments, fortify ESG practices, and elevate associated information transparency through strategic policy directives. Nevertheless, firms continue to grapple with the hurdle of inadequate incentives when striving to enhance their ESG profiles [1]. To surmount these obstacles, alongside external policy impetus, bolstering corporations' inherent ESG proficiency and fostering internal impetus become

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paramount. By nurturing internal motivation and bolstering ESG capabilities, firms can embark on a more sustainable and stakeholder-centric growth trajectory. For manufacturing enterprises [2], digitalization has emerged as a potent instrument to bolster their ESG implementation capabilities, providing crucial technological underpinnings that propel advancements in corporate ESG development. However, the intricate mechanisms through which this digital transformation exerts its influence remain an area of exploration. Within this context, entrepreneurs emerge as pivotal catalysts for business expansion, functioning as the driving force and the heart of enterprises. By harnessing both internal strengths and external opportunities, entrepreneurs nurture a forward-thinking corporate culture, refine corporate governance structures, and refine innovation strategies, thereby orchestrating substantial strides in ESG performance. This underscores the need to acknowledge entrepreneurs' central role in directing the sustainable growth trajectory of manufacturing enterprises within the ESG landscape.

2. Literature review and research hypothesis

ESG, a pivotal framework for assessing corporate sustainability, underscores the significance of balancing economic gains with environmental stewardship, social responsibility, and robust governance to foster long-term, sustainable development. Drawing upon stakeholder theory, this study delves into the mechanisms through which digital transformation facilitates ESG progress across these three facets. Traditionally, ESG investments were often perceived as resource-intensive and potentially detrimental to corporate competitiveness and shareholder interests [3], leading to reluctance and underinvestment in ESG practices. Furthermore, enterprises grappled with inadequate incentives and faced challenges in enhancing ESG performance due to information asymmetry with stakeholders, resource constraints, and technological lags. However, the burgeoning digital economy offers a novel avenue for sustainable corporate growth. It has significantly accelerated technological innovations, particularly in the realm of green technologies, which have bolstered enterprises' proactive stance towards environmental protection and sustainable development [4]. The profound integration of digital technologies has effectively mitigated information asymmetry [5], minimized transaction costs, and markedly enhanced corporate transparency [6], thereby strengthening their capacity for social responsibility [7-8]. This technological advancement has also fortified enterprises' ability to execute ESG practices and reduced the associated costs [9]. Given these transformative impacts, this paper postulates that the digital transformation of enterprises is a pivotal catalyst for improving their ESG performance. Hence, we formulate the hypothesis is that:

Hypothesis H1: Digital transformation can improve corporate ESG performance.

2.1 The mediating effect of entrepreneurship

Entrepreneurial endeavors and innovative pursuits drive the sustainable evolution and growth of enterprises via diverse pathways, fostering internal creativity and renovation within organizations [10-12]. Embedded within the fabric of entrepreneurship, social responsibility emerges as a vital component, offering robust underpinnings for advancing corporate ESG performance. Manufacturing enterprises, inherently associated with potential environmental repercussions, underscore the paramount significance of an eco-conscious mindset [13]. Digital technologies empower businesses to swiftly address stakeholder demands and align with societal aspirations for environmental stewardship and sustainable progress. By harnessing these advancements, companies can not only mitigate environmental footprints but also demonstrate a proactive commitment to societal welfare, thereby enhancing their overall ESG posture and reputation.

Therefore, this study proposes hypotheses:

HypothesisH2a: Digital transformation promotes ESG by enhancing entrepreneurial innovation.

HypothesisH2b: Digital Transformation Promotes ESG by Enhancing Entrepreneurial Social Responsibility.

HypothesisH2c: Digital Transformation Promotes ESG by Empowering Entrepreneurship to Go Green.

The theoretical model diagram shown in Figure 1 was constructed.

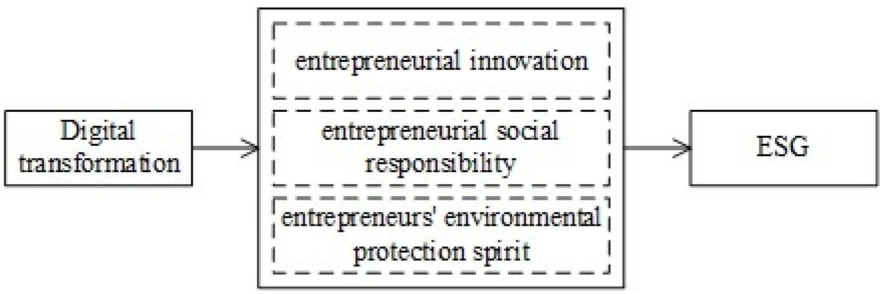

Figure 1. Theoretical model Diagram.

3. Study design

3.1 Sample selection and data sources

From 2018 to 2022, China's listed manufacturing companies in Shanghai and Shenzhen were selected as the initial research samples, the original data of digital transformation and entrepreneurship were from the CSMAR database, and the ESG performance data of enterprises were from the CSMA ESG rating system.

3.2 Measurement of key variables

(1) This study uses the data of the CSI ESG rating system as the explanatory variable in this paper.
(2) Referring to the measurement method of enterprise digital transformation by Wu Fei et al [14] as the explanatory variable in this paper.
(3) Board, Firmage, ROA, BM, and Cashflow are controlled.

(4) Entrepreneurial and innovative spirit (IS): The level of resource investment in innovation practices can reflect the entrepreneurial spirit of innovation.
(5) The spirit of entrepreneurial social responsibility (SS): Referring to Cheng Qiongwen and Ding Hongyi[13], the social contribution value per share of enterprises is used to measure the social responsibility spirit of entrepreneurs.
(6) Entrepreneurial environmental spirit (ES): use environmental protection tax to measure the environmental spirit of entrepreneurs.

3.3 Model settings

This paper sets up the following benchmark regression model:

$$(1)ESG_{i,j,t} = \alpha_0 + \alpha_1 Digital_{i,t} + \sum\alpha_m con_{i,t} + \lambda_j + \lambda_t + \lambda_p + \varepsilon1_{i,t,j}$$

The explanatory variables are corporate ESG performance, λ_j is industry fixed effect, and λ_t is year fixed effect, λ_p is a fixed effect for provinces.

On the basis of equation (1), a mediating effect model was constructed to test H_{2a}, H_{2b} and H_{2c}. The specific model is:

$$(2)IS / SS / ES = \beta_0 + \beta_1 Digital_{i,t} + \sum\beta_m con_{i,t} + \lambda_j + \lambda_t + \lambda_p + \varepsilon2_{i,t}$$

$$(3)ESG_{i,j,t} = \gamma_0 + \gamma_1 Digital_{i,t} + \gamma_2 IS / SS / ES + \sum\gamma_m con_{i,t} + \lambda_j + \lambda_t + \lambda_p + \varepsilon3_{i,t,j}$$

where the sum α_0, β_0 and γ_0 are constant term, $\alpha_1 \sim \alpha_m, \beta_1 \sim \beta_m$ and $\gamma_1 \sim \gamma_m$ are regression coefficient,m =2,...,6 in (1) and (2), m =3,...,7 in (3), $\varepsilon1_{i,t,j}, \varepsilon2_{i,t}$ and $\varepsilon3_{i,t,j}$ are random error term.

4. Empirical results and analysis

4.1 Baseline regression results

Table 1 shows the baseline regression results of digital transformation on ESG. The digital transformation of enterprises has a positive effect on the ESG performance of enterprises.

Table 1. Baseline regression results

variable	**(1)** **ESG**	**(2)** **ESG**	**(3)** **ESG**
Digital	0.041*** (3.77)	0.048*** (4.58)	0.046*** (4.41)
Board		0.119* (2.29)	0.110* (2.13)
Firmage		-0.169*** (-4.67)	-0.151*** (-4.17)
ROA		4.407*** (26.55)	4.293*** (25.91)
Cashflow		0.009 (0.05)	-0.036 (-0.21)

BM		0.102*** (10.28)	0.104*** (10.48)
_cons	2.795*** (3.89)	2.701*** (3.83)	2.804*** (3.99)
Industry fixation	control	control	control
Year-to-year fixed effect	control	control	control
Province fixed effect	control	Not controlled	control
N	10346	10346	10346
Adjusted R2	0.08	0.14	0.15

Note: The data in parentheses are t-statistic, which is significant at the 1% level, ** is significant at the 5% level, *is significant at the 10% level, the same below.

4.2 Mediator effect test

Table 2 shows the results of the mediating effect of entrepreneurship, with the increase of digital transformation, entrepreneurial innovation is promoted, which is conducive to corporate ESG performance, H_{2a} and H_{2b} are Verified, H_{2c} has not been verified.

Table 2. Results of the mediating effect test

variable	**(1) IS**	**(2) ESG**	**(3) SS**	**(4) ESG**	**(5) ES**	**(6) ESG**
Digital	0.003*** (17.69)	0.035*** (3.32)	0.077*** (4.46)	0.043*** (4.14)	-0.001*** (-5.96)	0.038*** (3.64)
IS		3.701*** (6.01)				
SS				0.037*** (6.25)		
ES						-1.842*** (-13.61)
_cons	0.019 (1.71)	2.733*** (3.89)	2.522 0.17	2.806*** (3.99)	1.768*** (34.71)	6.060*** (8.22)
Control variables	control	control	control	control	control	control
Industry/year/province fixed effect	control	control	control	control	control	control
N	10346	10346	10346	10346	10346	10346
Adjust R2	0.38	0.16	0.17	0.16	0.32	0.17

5. Conclusion

Digitalization emerges as a pivotal force in fostering corporate sustainability and enhancing ESG outcomes. To capitalize on this transformative potential, corporations must integrate and leverage cutting-edge digital technologies across strategic planning, R&D for production, marketing strategies, and other critical functions. Furthermore, constructing an enterprise architecture congruent with the digital roadmap is imperative to solidify and amplify the benefits of digitalization, thereby fostering a positive ripple effect on ESG performance. To ensure synergy between entrepreneurial endeavors and the dynamic external landscape, enterprises must prioritize the development of a supportive environment and agilely adapt their strategies to the challenges and opportunities presented by the digital age. Such proactive measures will fortify their position in the digital landscape, reinforcing their commitment to sustainable growth and societal responsibility.

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Research on the Influencing Factors of Low-Carbon Cold Chain of Agricultural Products in Guangxi Under Digital Empowerment

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Abstract. In order to effectively help enterprises identify the digital influencing factors of low-carbon cold chain of agricultural products in Guangxi and accelerate the realization of low-carbonization of agricultural products cold chain enterprises, this paper constructs an evaluation index system of low-carbon cold chain of agricultural products in Guangxi under digital empowerment. Based on the data of cold chain energy of agricultural products in 11 cities of Guangxi from 2013 to 2022, the carbon emissions of cold chain of agricultural products in different cities were calculated. The results show that the consumption of cold chain energy of agricultural products in Guangxi is increasing in general from 2013 to 2022. Subsequently, the correlation analysis between the panel data of agricultural product cold chain carbon emissions and the panel data of digital factors in 11 cities in Guangxi was carried out. The results showed that the highest correlation was the degree of digital investment, and the lowest was the level of employee digitization. However, the correlation degree of all digital factors is higher than 0.6, which proves that digital factors have a high correlation with the low-carbon cold chain of agricultural products in Guangxi. This study provides a reference for how to realize low carbon in the cold chain of agricultural products in Guangxi by means of digitization.

Keywords. Digitalization; Guangxi agricultural products cold chain; low carbon; analysis of influencing factors

1. Introduction

In December 2022, the Guangxi government promulgated the ' Implementation Plan for Carbon Peaks in Guangxi Zhuang Autonomous Region ', which proposed that by 2025, the energy consumption and carbon dioxide emissions per unit of GDP in Guangxi Zhuang Autonomous Region will be reduced to ensure the completion of the national

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target. By 2030, the decline in carbon dioxide emissions per unit of GDP in Guangxi Zhuang Autonomous Region will ensure the completion of the national target and achieve carbon peaks in parallel with the whole country. As a major agricultural province, Guangxi should take the lead in opening a low-carbon wave, which can not only help achieve carbon peaks, but also lead other provinces and provide a reference template for other provinces. However, the cold chain of agricultural products in Guangxi started late, the cold chain facilities and equipment are backward, and the carbon dioxide emissions and cargo damage rates generated during the storage and transportation of agricultural products are high.

The emergence of digitization has brought a new direction to the low-carbon cold chain of agricultural products in Guangxi. How to choose the digital elements suitable for the low-carbon development of enterprises is the key to promote the efficient and green development of agricultural products cold chain. Only by clarifying the relationship between digitization and low-carbon can we effectively help the low-carbon development of agricultural products cold chain. By exploring the logical relationship between digital economy and agriculture, Liu Haiqi [1] initially established the development idea of digital agriculture in China; yang Xiaoli [2] found that technological innovation in the digital economy is an important mechanism affecting the circulation efficiency of agricultural products by measuring the panel data of 29 provinces in China. Chen Zeyun [3] explored the development path and mechanism of e-commerce logistics from the perspective of digital village. Zhang [4] believed that government intervention or exogenous coordination mechanism must be introduced to promote the members of the cold chain supply chain of agricultural products to reach a consensus on the digital transformation based on blockchain. Minghong [5] explored the impact of digital trade on the export efficiency of China 's agricultural products and found that it is necessary to continuously improve digital technology and narrow the digital gap to improve the export efficiency of China 's agricultural products. Yang [6] used the fixed effect model to replace the threshold regression model and clarified the positive impact of digital development on technological progress in the wholesale market of agricultural products. With the promulgation of the " double carbon " policy, more and more scholars have begun to explore the relationship between digitization and low-carbon logistics. Zhong Wen [7] found that there is a U-shaped relationship between the digital economy and logistics carbon emissions, and the digital economy can well suppress and evolve the carbon emissions of the logistics industry ; wang [8] studied the impact of carbon emission reduction on the supply chain of fresh agricultural products in the context of digital villages ; in addition, Liu [9] used the two-way fixed effect model and the two-stage least squares method to empirically evaluate the emission reduction effect mechanism of digital economy under the development of local logistics in 31 provinces in China from 2015 to 2019. The empirical results show that the growth of digital economy has an inhibitory effect on pollution emissions.

In summary, at present, scholars mostly focus on the mechanism of action between digitization and agricultural products or logistics, and rarely study the relationship between digitization and low-carbon cold chain of agricultural products and lack empirical research. Secondly, the existing scholars seldom explore the influencing factors of digitization and low-carbon cold chain of agricultural products, and only study whether digitization can reduce the carbon emissions of agricultural products cold chain, and the research combined with the local situation of Guangxi is relatively lacking. This will lead to the low-carbon transformation of Guangxi agricultural products cold chain enterprises only stay in theory, lack of actual data support. In order to solve this problem and better help Guangxi agricultural products cold chain enterprises to take the ' digital express ' to achieve low-carbon transformation, this paper takes Guangxi agricultural products cold chain as the research object, and finds the relationship between the digital factors of 14 cities in Guangxi and the carbon emissions of agricultural products cold chain through the comprehensive grey correlation method, and then explores the digital influencing factors of low-carbon cold chain of agricultural products in Guangxi, so as to help enterprises explore the digital direction of low-carbon transformation of agricultural products cold chain enterprises in the future from an empirical point of view.

2. Construction of digital evaluation index system of cold chain of agricultural products in Guangxi

2.1 Data source

The data of Guangxi agricultural products cold chain enterprises in 2013-2022 in this paper are derived from ' Guangxi Bureau of Statistics ', Wind database, KPMG, ' China Agricultural Products Processing Industry Yearbook ', and statistical yearbooks of various cities. Some of the data may be missing. This paper uses reptile technology and AHP method to process and supplement.

2.2 Determination of evaluation index

In this paper, through literature research and investigation of agricultural products cold chain enterprises in various provinces of Guangxi, the links and effects of digital development of agricultural products cold chain enterprises are preliminarily explored, and the data are sorted out and summarized. As well as the “Evaluation Index of Digital Level of Small and Medium-sized Enterprises (2022 Edition)” issued by the General Office of the Ministry of Industry and Information Technology, the first-level index of digital evaluation of agricultural products cold chain enterprises was obtained. The four key factors of digital foundation, business process digitization, personnel technology digitization and digital performance are taken as the first-level indicators and further analyzed.

Table 1 Digital evaluation index of agricultural products cold chain

first grade indexes	second index	type	Indicator explanation
Digital foundation	Digital hardware equipment(A)	+	Digitization of hardware equipment mainly refers to the ratio of digital hardware equipment to the number of overall hardware equipment.
	Digitalization of Software(B) equipment	+	Digitization of software equipment refers to the ratio of digital software equipment to the total number of software equipment.
	safety of Network(C)	+	Whether the use of industrial network security products and services, the establishment of network security system and a series of operations.
Digitization of business processes	Procurement and Supply(D) digitization	+	Digital procurement operations
	Warehouse(E) digitization	+	Digitalization of inbound and outbound operations

	Transport(F) digitization	+	In-transit management digitization
	Circulation(G) processing digitization	+	Digitization of processing operations
	Digital(H) distribution	+	Path optimization digitization
Personnel technology digitization	Degree of Digital(I) investment	+	Funds invested by enterprises in digitalization
	Employee(J) digital awareness	+	Employees ' understanding of digitization
	Digital level of Employees(K)	+	Employees ' familiarity with the operation of digital systems
Digital performance	Annual revenue(L)	+	Revenue from digitalization
	Annual return(M)	+	Profits from digitalization

In order to facilitate the writing of the following tables, the digital evaluation indicators appearing in the subsequent tables are replaced by the letters in ( ).

3. Calculation of cold chain carbon emissions of agricultural products in Guangxi cities

3.1. Calculation of cold chain energy consumption of agricultural products

According to the information and data released by China Energy Statistical Yearbook and agricultural products cold chain enterprises, the main energy consumption of agricultural products cold chain enterprises is gasoline, natural gas, heat and other eight kinds of energy. On this basis, the data calculated in this paper are based on the eight kinds of energy consumption of agricultural products cold chain in 11 cities of Guangxi Zhuang Autonomous Region. Due to the different types of energy, in order to more easily count the energy consumption of the cold chain of agricultural products in 11 provinces of Guangxi, this paper is based on the conversion coefficient of 8 kinds of energy standard coal given by the National Bureau of Statistics, as shown in table 2 below.

Table 2 Conversion coefficients of 8 kinds of energy standard coal

energy type	**Conversion coefficient (tons of standard coal)**
Coal (tonnes)	0.71430
Gasoline (tons)	1.47140
Kerosene (tons)	1.47140
Diesel (tons)	1.45710
Fuel oil (tonnes)	1.42860
Natural gas (ten thousand cubic meters)	1.33000
Thermal (millions of kilojoules)	0.03412
Electricity (kilowatt-hour)	0.12290

The calculation formula is shown in (1).

$$E=\sum_i^n C_i \times e_i \quad i=1,2,\cdots,8 \tag{1}$$

Among them, E is the total energy consumption, is the i-th energy, is the i-th energy consumption.

According to the energy consumption of agricultural products cold chain enterprises in Guangxi Zhuang Autonomous Region from 2013 to 2022, the consumption of various energy sources converted into standard coal is calculated by Formula (1), as shown in Table 3 and Table 4.

Table 3 Energy consumption of agricultural products cold chain enterprises in Guangxi Zhuang Autonomous Region from 2013 to 2017 (unit: 10,000 tons of standard coal)

year	2013	2014	2015	2016	2017
Nan ning	2569.12	2832.83	3061.65	3258.84	3615.52
Liu zhou	2265.76	2507.61	2803.02	2991.51	2641.58
Gui lin	710.36	955.83	847.65	868.97	903.60
Wu zhou	355.39	632.24	724.57	1489.37	838.75
Bei hai	344.73	413.09	471.93	639.94	920.45
FangChenggang	135.66	147.35	183.48	294.83	343.88
Qin zhou	298.42	667.81	505.81	1141.28	1332.14
Gui gang	968.93	1148.04	1225.80	1274.53	1096.16
Yu lin	662.59	669.84	764.01	878.20	715.71
Bai se	1307.65	1217.37	1481.75	1547.01	1517.46
He zhou	802.98	934.22	999.07	1457.24	1332.40
He chi	448.96	431.48	498.79	597.01	466.40
Lai bin	692.30	1396.31	2043.90	2064.29	1905.60
Chong zuo	132.27	153.50	191.88	244.93	324.73
Total	11695.12	14107.52	15803.31	18747.95	17954.38

Table 4 Energy consumption of agricultural products cold chain enterprises in Guangxi Zhuang Autonomous Region from 2018 to 2022 (unit: 10,000 tons of standard coal)

year	2018	2019	2020	2021	2022	mean value
Nan ning	3814.59	3958.52	4170.81	5318.05	5516.48	3811.64
Liu zhou	2767.17	2971.56	2974.79	4610.77	5211.75	3174.55
Gui lin	951.55	995.15	1034.06	1483.72	1703.67	1045.46
Wu zhou	1000.34	1107.69	933.16	1063.36	1146.44	929.13
Bei hai	1076.47	1313.19	1369.61	1721.00	1901.88	1017.23
Fang Chenggang	402.30	1507.54	1439.77	1934.01	2099.74	848.86
Qin zhou	1390.47	1440.91	1322.83	2039.39	2189.58	1232.86
Gui gang	1189.96	1470.80	1515.81	1529.05	2129.70	1354.88
Yu lin	766.15	818.07	811.53	895.99	985.62	796.77
Bai se	1798.74	1348.35	1065.60	1140.79	1203.10	1362.78
He zhou	1561.64	1594.14	1717.28	2170.13	2375.21	1494.43
He chi	537.11	86.86	80.61	85.32	91.25	332.38
Lai bin	1458.11	1468.58	1957.13	2002.73	2110.78	1709.97
Chong zuo	335.09	313.40	342.12	152.62	319.58	251.01
Total	19049.69	20394.76	20735.11	26146.93	28984.78	19361.96

It can be seen from Table 3 and Table 4 that in the Guangxi Zhuang Autonomous Region, the energy consumption of agricultural products cold chain enterprises in Nanning and Liuzhou ranks in the forefront. Among them, Nanning 's average energy consumption in the past decade is as high as 38.1164 million tons, far ahead of other cities. The lowest energy consumption is Chongzuo City, with an average annual consumption of about one-fifth of Nanning. There is a big gap in the development of agricultural products cold chain enterprises among cities in Guangxi, and the average annual consumption of most cities is concentrated between 7 million and 15 million tons. There is an imbalance in its development. On the whole, the total energy consumption of Guangxi continues to rise every year except 2017.

It is worth noting that the consumption of Hechi, Wuzhou, Fangchenggang and other cities has a large span between years, mainly due to the large gap in the use of coal. In the overall agricultural products cold chain enterprises in Guangxi, the main energy use is still mainly dependent on coal, and the amount of carbon dioxide produced by coal is very high. Therefore, it is necessary to carry out low-carbon transformation of Guangxi agricultural products cold chain enterprises.

3.2 Calculation of carbon emissions of agricultural products cold chain

At present, the official statistical agencies do not give specific carbon emissions data, but this paper can estimate the corresponding carbon emissions through the methods in References [10-13]. In this paper, the carbon emission coefficient method is used to calculate. The CO_2 generated by 8 kinds of energy is used as the basis for calculating the cold chain carbon emissions of agricultural products. The calculation formula of CO_2 emissions is as follows:

$$CO_2=\sum_i^n W_i \times P_i \times F_i \times (\frac{44}{12}) \times E_i \quad (2)$$

where, represents the carbon content of the unit calorific value of the ith energy, W_i represents the average low calorific value of the ith energy, P_i represents the carbon conversion rate of the ith energy, 44 and 12 represent the molecular weight of carbon dioxide and carbon, respectively, and E_i represents the ith energy.

Table 5 Eight kinds of energy CO_2 emission coefficients

energy type	**coal**	**gasoline**	**kerosene**	**diesel oil**	**fuel oil**	**natural gas**	**Heating power**	**electric power**
Carbon content per unit calorific value	26.37	18.90	19.50	20.20	21.10	15.30	—	—
Average low calorific value	20908	43070	43070	42652	41816	38931	—	—
carbon oxidation rate	0.94	0.98	0.98	0.98	0.99	0.99	—	—

In the table, this paper can see that there is no index value of heat and electricity. CO_2 emission coefficient is calculated by $W_i \times P_i \times F_i \times (44/12)$. Therefore, this paper directly queries the CO_2 emission coefficients of electricity and heat for the calculation of Equation (3.2), which are 9.46 (TC/TJ) and 10069 (TC/Gwh), respectively. In addition, the energy consumption after conversion into standard coal can also be multiplied by the C emission coefficient of standard coal. According to the above method, the calculation results are shown in Table 6 and Table 7.

Table 6 Carbon emissions of agricultural products cold chain enterprises in guangxi zhuang autonomous region from 2013 to 2017 (unit: ten thousand tons)

year	**2013**	**2014**	**2015**	**2016**	**2017**
Nan ning	1747.00	1926.32	2081.92	2216.01	2458.55
Liu zhou	1540.72	1705.17	1906.05	2034.23	1796.27
Gui lin	483.04	649.96	576.40	590.90	614.45
Wu zhou	241.67	429.92	492.71	1012.77	570.35
Bei hai	234.42	280.90	320.91	435.16	625.91
Fang Cheng gang	92.25	100.20	124.77	200.48	233.84
Qin zhou	202.93	454.11	343.95	776.07	905.86
Gui gang	658.87	780.67	833.54	866.68	745.39
Yu lin	450.56	455.49	519.53	597.18	486.68
Bai se	889.20	827.81	1007.59	1051.97	1031.87
He zhou	546.03	635.27	679.37	990.92	906.03
He chi	305.29	293.41	339.18	405.97	317.15
Lai bin	470.76	949.49	1389.85	1403.72	1295.81
Chong zuo	89.94	104.38	130.48	166.55	220.82
Total	7952.68	9593.11	10746.25	12748.61	12208.98

Table 7 Carbon emissions of agricultural products cold chain enterprises in guangxi zhuang autonomous region from 2018 to 2022 (unit: ten thousand tons)

year	**2018**	**2019**	**2020**	**2021**	**2022**	**mean value**
Nan ning	2593.92	2691.79	2836.15	3616.27	3751.21	1762.50
Liu zhou	1881.68	2020.66	2022.86	3135.32	3543.99	1467.91

Gui lin	647.05	676.70	703.16	1008.93	1158.50	483.42
Wu zhou	680.23	753.23	634.55	723.08	779.58	429.63
Bei hai	732.00	892.97	931.33	1170.28	1293.28	470.37
Fang Cheng gang	273.56	1025.13	979.04	1315.13	1427.82	392.51
Qin zhou	945.52	979.82	899.52	1386.79	1488.91	570.08
Gui gang	809.17	1000.14	1030.75	1039.75	1448.20	626.50
Yu lin	520.98	556.29	551.84	609.27	670.22	368.43
Bai se	1223.14	916.88	724.61	775.74	818.11	630.15
He zhou	1061.92	1084.02	1167.75	1475.69	1615.14	691.02
He chi	365.23	59.06	54.81	58.02	62.05	153.69
Lai bin	991.51	998.63	1330.85	1361.86	1435.33	790.69
Chong zuo	227.86	213.11	232.64	103.78	217.31	116.07
Total	12953.79	13868.44	14099.87	17779.91	19709.65	8952.97

From Table 6 and Table 7, it can be concluded that in Guangxi Zhuang Autonomous Region, the growth rate of carbon emissions in Fangcheng Port is the highest, with an increase of 1518 % from 2013 to 2022, followed by Beihai and Qinzhou, which are 552 % and 734 % respectively. This is closely related to the development of port trade in Guangxi. In recent years, Fangcheng Port has made use of the Beibu Gulf port to vigorously develop port trade and has established a good partnership with ASEAN and other places. The carbon emissions of other cities except Baise and Hechi are on the rise. The total carbon emissions of Guangxi increased by 248 % from 2013 to 2022, up to 197.0965 million tons. In order to actively respond to the ' double carbon ' policy and help China realize low-carbon life as soon as possible, Guangxi agricultural products cold chain enterprises should realize low-carbon transformation as soon as possible.

4. Grey relational model construction

4.1 Basic definition

The panel data structure is relatively rich, from the vertical observation is the time series, from the horizontal observation is the cross-section data, that is, the description of the dynamic trend of multiple object indicators. In addition, the panel data also includes the time dimension and the index dimension, which can more comprehensively express all aspects of the data. Let the index set $A=\{a_0,a_1,\cdots,a_I\}$(where a_0 is the reference index, the other is the comparison index), the object set $B=\{b_1,b_2,\cdots,b_M\}$, the time level $C=\{c_1,c_2,\cdots,c_N\}$, and write u^i_{mn} as the value of the mth object of the ith index at the nth time, then the panel data can be represented by three tables, as shown in Table 8.

Table 8 Three-dimensional table of panel data

idex	**0**					⋯	**i**					⋯	**I**				
object	Time					⋯	Time					⋯	Time				
	1	⋯	n	⋯	N	⋯	1	⋯	n	⋯	N	⋯	1	⋯	n	⋯	N
1	u^0_{11}	⋯	u^0_{1n}	⋯	u^0_{1N}	⋯	u^i_{11}	⋯	u^i_{1n}	⋯	u^i_{1N}	⋯	u^I_{11}	⋯	u^I_{1n}	⋯	u^I_{1N}
⋮	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮
m	u^0_{m1}	⋯	u^0_{mn}	⋯	u^0_{mN}	⋯	u^i_{m1}	⋯	u^i_{mn}	⋯	u^i_{mN}	⋯	u^I_{m1}	⋯	u^I_{mn}	⋯	u^I_{mN}
⋮	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮	⋱	⋮
M	u^0_{M1}	⋯	u^0_{Mn}	⋯	u^0_{MN}	⋯	u^i_{M1}	⋯	u^i_{Mn}	⋯	u^i_{MN}	⋯	u^I_{M1}	⋯	u^I_{Mn}	⋯	u^I_{MN}

Due to the different units of each index, the data may belong to the benefit index, cost index or moderate index. If the direct calculation of Table 4 is directly used, it will lead to the distortion of the correlation analysis results in the modeling process. Therefore, the data needs to be preprocessed. The digital evaluation indexes of agricultural products cold chain constructed in this paper are all benefit oriented. Therefore, this paper takes benefit oriented as an example.

Definition 1 [14] Let $X=(X_1,X_2,\cdots,X_N)$ be the index behavior sequence of panel data, where X_i is the matrix of panel data under index b_i. If b_m is a benefit index, then the decision grey target under index b_m is $u^i_{mn} \in [u^i_{n_0m_0}, \max_m \max_n u^i_{mn}]$, where $u^i_{n_0m_0}$ is the critical value of u^i_{mn}.It is called

$$x^i_{mn}=\frac{u^i_{mn}-u^i_{n_0m_0}}{\max_m \max_n u^i_{mn}-u^i_{n_0m_0}} \tag{3}$$

It is a benefit index effect measure function.

In order to be able to describe the geometric characteristics of panel data, this paper uses the method of literature [15].

Definition 2 Let $x_i(s,t)$ be the value of index i with respect to the object s in time t.

$$X_i=\begin{bmatrix} x_i(1,1) & x_i(1,2) & \dots & x_i(1,N) \\ x_i(2,1) & x_i(2,2) & \dots & x_i(2,N) \\ \cdots & \cdots & \ddots & \cdots \\ x_i(M,1) & x_i(M,2) & \dots & x_i(M,N) \end{bmatrix} \tag{4}$$

X_i is the behavior matrix of index i, abbreviated as $X_i=(x_i(s,t))_{M\times N}$,$X=(X_1,X_2,\cdots,X_I)$is the sample sequence of panel data.

4.2 Model construction

In order to reasonably evaluate the impact of digital indicators of agricultural products cold chain on carbon emissions of agricultural products cold chain, this paper constructs data models on two-dimensional, three-dimensional and four-dimensional planes from the perspectives of similarity and similarity. In this paper, similarity is to describe the degree of similarity between two entities, and to solve it in the form of derivative. Similarity describes the ' distance ' between two entities, which is more inclined to the size of the entity value. For example, the area of a rectangle and a circle is $1\,m^2$. this paper think that it has high similarity and poor similarity. It can be seen that if this paper only relies on similarity or proximity to solve the correlation degree, it will lead to one-sidedness of the results. The following table shows the composition of similarity and similarity correlation in this paper.

Table 9 The composition of similarity and similarity correlation degree

degree of association	composition	dimensional	feature
the similarity relational degree	Displacement correlation degree	two dimensions	The distance is solved for the time dimension of panel data.
	Speed correlation degree	two dimensions	First-order derivation is performed on the time dimension of panel data.
	Acceleration correlation degree	two dimensions	Second-order derivation is performed on the time dimension of panel data.
Similarity correlation degree	Grey projection area correlation degree	three dimensions	The time dimension and object dimension of panel data are considered.
	Tetrahedral network correlation degree	four dimensions	The time dimension of panel data is considered and compared in pairs.

(1) Similarity correlation degree

Definition 3 (displacement correlation degree) Let the reference matrix be X_0, and the comparison matrices $x_i(s,t)$ and $x_0(s,t)$ are the values of the index i and the reference index with respect to the sample s at time t and the vulnerability index, respectively. Then the displacement correlation degree of X_0 and X_i at time t is:

$$r_{0i}^{(0)}=\frac{1}{M\times N}\sum_{m=1}^{M}\sum_{n=1}^{N}\exp(-|x_i(s,t)-x_0(s,t)|) \tag{5}$$

The displacement correlation degree is the overall proximity between the digital index i of agricultural products cold chain and the carbon emission index of agricultural products cold chain. The greater the $r_{0i}^{(0)}$, the greater the impact of the cold chain digitization index i and the cold chain carbon emissions of agricultural products.

Definition 4 (speed correlation degree) Let the reference matrix X_0, the comparison matrix X_i, x_i'(s,t)and x_0'(s,t) are the first-order difference quotients of the index i and the reference index with respect to the sample s at time t and the first-order difference quotient of the vulnerability index value, respectively. Then the bit speed correlation degree of X_0 and X_i at time t is:

$$r_{0i}^{(1)}=\frac{1}{M\times(N-1)}\sum_{m=1}^{M}\sum_{n=1}^{N-1}\exp(-|x_i'(s,t)-x_0'(s,t)|) \tag{6}$$

Which

$$x_i'(s,t)-x_0'(s,t)=(x_i(s,t+1)-x_i(s,t))-(x_0(s,t+1)-x_0(s,t))$$

$$x_i'(s,t)=\frac{x_i(s,t+1)-x_i(s,t)}{\Delta t}$$

$$x_0'(s,t)=\frac{x_0(s,t+1)-x_0(s,t)}{\Delta t}$$

The speed correlation degree is the proximity between the digital index i of agricultural products cold chain and the carbon emission index of agricultural products cold chain. The greater the $r_{0i}^{(1)}$, the greater the impact of the cold chain digitization index i and the cold chain carbon emissions of agricultural products.

Definition 5 (acceleration correlation degree) Let the reference matrix beX_0,The comparison matrices X_i, x_i''(s,t) and x_0''(s,t) are the second-order difference quotient of the index i and the reference index with respect to the sample s in time t and the second-order difference quotient of the vulnerability index value, respectively. Then the correlation between X_0 and X_i at time t is:

$$r_{0i}^{(2)}=\frac{1}{M\times(N-2)}\sum_{m=1}^{M}\sum_{n=1}^{N-2}\exp(-|x_i''(s,t)-x_0''(s,t)|) \tag{7}$$

Which

$$x_i''(s,t)-x_0''(s,t)=(x_i(s,t+2)-2x_i(s,t+1)+x_i(s,t))-(x_0(s,t+2)-2x_0(s,t+1)+x_0(s,t))$$

$$x_i''(s,t)=\frac{x_i'(s,t+1)-x_i'(s,t)}{\Delta t}$$

$$x_0''(s,t)=\frac{x_0'(s,t+1)-x_0'(s,t)}{\Delta t}$$

The acceleration correlation degree is the degree of proximity between the digital index i of agricultural products cold chain and the carbon emission index of agricultural products cold chain. The greater the $r_{0i}^{(2)}$, the greater the impact of the digital index i of cold chain and the carbon emission of agricultural products cold chain.

Definition 6 (similarity correlation degree) Let the reference matrix be X_0 and compare matrix X_i, then the correlation degree between X_0 and X_i at time t is:

$$r_{oi}=\frac{r_{0i}^{(0)}+(\frac{r_{0i}^{(1)}+r_{0i}^{(2)}}{2})}{2} \tag{8}$$

(2) Similarity correlation degree

Definition 7[16] Let the behavior matrix of the i th index in the panel data be X_i, then the projection area functions of X_i in the time plane and the object plane are:

$$F_i(s,t)=\frac{1}{2}[|x_i(s+1,t)-x_i(s,t)|+|x_i(s+1,t+1)-x_i(s,t+1)|] \quad (9)$$

$$G_i(s,t)=\frac{1}{2}[|x_i(s+1,t+1)-x_i(s+1,t)|+|x_i(s,t+1)-x_i(s,t)|] \quad (10)$$

Definition 8 Suppose the panel data are X_i and X_j, then this paper says:

$$\xi_{ij}^{F}(s,t)=\frac{1}{1+|F_i(s,t)-F_j(s,t)|} \quad (11)$$

is the three-dimensional gray projection area correlation coefficient on the time plane from (s, t) to (s, t + 1), which is called:

$$\xi_{ij}^{G}(s,t)=\frac{1}{1+|G_i(s,t)-G_j(s,t)|} \quad (12)$$

is the three-dimensional gray projection area correlation coefficient on the object plane from (s, t) to (s + 1, t).

Definition 9 Let $\xi_{ij}^{F}(s,t)$ and $\xi_{ij}^{G}(s,t)$ be the three-dimensional grey projection area correlation coefficient of the panel data X_i and X_j on the time and object plane, respectively. Then ξ_{ij}^{F} , ξ_{ij}^{G} , ξ_{ij} are called the three-dimensional grey projection area correlation degree of X_i and X_j on the time and object plane, and the three-dimensional grey projection area correlation degree of X_i to X_j. The calculation process is as follows.

$$\xi_{ij}^{F}=\frac{\sum_{t=1}^{n-1}\sum_{s=1}^{m-1}\xi_{ij}^{F}(s,t)}{(n-1)(m-1)} \quad (13)$$

$$\xi_{ij}^{G}=\frac{\sum_{t=1}^{n-1}\sum_{s=1}^{m-1}\xi_{ij}^{G}(s,t)}{(n-1)(m-1)} \quad (14)$$

$$\xi_{ij}=\frac{1}{2}(\xi_{ij}^{F}+\xi_{ij}^{G}) \quad (15)$$

Definition 10 Let $X_i=(x_i(s,\ t))_{M\times N}$ be the behavior matrix of index i, and the object set is $B=\{b_1,b_2,\cdots,b_M\}$.Any two objects in B are marked as b_{j_1} and b_{j_2}, where j_1 and j_2 are any two different numbers in $\{1,2,\cdots,M\}$, then $\{b_{j_1},b_{j_2}\}$ is called a binary combination of the object set. Then all possible binary object combinations are:

$$M_B^2=\{\{b_{j_1},b_{j_2}\}|j_1\neq j_2\in\{\{1,2,\cdots,M\}\}$$

The data corresponding to objects b_{j_1} and b_{j_2} construct a 2×N matrix, denoted as $X_{i(j_1,j_2)}$, which represents the behavior matrix X_i of binary objects b_{j_1} and b_{j_2} of matrix xa, as shown below.

$$X_{i(j_1,j_2)}=\begin{bmatrix} x_i(j_1,1) & x_i(j_1,2) & \cdots & x_i(j_1,N) \\ x_i(j_2,1) & x_i(j_2,2) & \cdots & x_i(j_2,N) \end{bmatrix} \quad (16)$$

According to the permutation and combination, there are m (m-1) / 2 possibilities for the binary combination of M different objects, that is to say, the binary object behavior matrix of X_i has m (m-1) / 2.

Definition 11 Let $X_{i(j_1,j_2)}$ be the behavior sub-matrix of the binary objects b_{j_1} and b_{j_2} of matrix X_i , and connect the four adjacent points $(1,t,\ x_i(j_1,t))$,$(2,t,\ x_i(j_2,t))$,$(1,t+1,\ x_i(j_1,t+1))$, $(2,t,\ x_i(j_2,t+1))$($(1,t,\ x_i(j_1,t))$ corresponding to $X_{i(j_1,j_2)}$ as the points in the three-dimensional space projected by the values in $X_{i(j_1,j_2)}$, t=1,2,⋯,N-1). The aggregate $T_i(j_1,j_2,t)$ is the tetrahedron when $X_{i(j_1,j_2)}$ is at t, and $T_i(j_1,j_2)$ is the set of all tetrahedrons composed of $X_{i(j_1,j_2)}$, which is called the tetrahedron network of $T_i(j_1,j_2)$ is $X_{i(j_1,j_2)}$.

Definition 12[17] Let the volume of $T_i(j_1,j_2,t)$ tetrahedron be $V_i(j_1,j_2,t)$, then the directed volume of $T_i(j_1,j_2,t)$ is

$$V_i(j_1,j_2,t)=\begin{cases} \overline{V}_i(j_1,j_2,t) & \breve{x}_i(j_1,j_2,t) > \breve{x}_i(j_2,j_1,t) \\ 0 & \breve{x}_i(j_1,j_2,t) = \breve{x}_i(j_2,j_1,t) \\ -\overline{V}_i(j_1,j_2,t) & \breve{x}_i(j_1,j_2,t) < \breve{x}_i(j_2,j_1,t) \end{cases} \tag{17}$$

Which

$$\breve{x}_i(j_1,j_2,t)=x_i(j_1,t)+x_i(j_2,t+1)$$

$$\breve{x}_i(j_2,j_1,t)=x_i(j_2,t)+x_i(j_1,t+1)$$

$$\overline{V}_i(j_1,j_2,t)=\frac{1}{6}|\breve{x}_i(j_1,j_2,t)-\breve{x}_i(j_2,j_1,t)|$$

In general, the tetrahedron formed by panel data is very thin, and its discrimination is not large. Therefore, in this paper, when calculating the volume, the front coefficient 1 / 6 is removed, and the formula becomes: : $\overline{V}_i(j_1,j_2,t)=|\breve{x}_i(j_1,j_2,t)-\breve{x}_i(j_2,j_1,t)|$.

Definition 13 $X_0=(x_i(s,t))_{M\times N}$ be the reference index behavior matrix, $X_i=(x_i(s,t))_{M\times N})$ is the index behavior matrix, $X_{0(j_1,j_2)}$ and $X_{i(j_1,j_2)}$ are the behavior sub-matrices of binary objects X_0 and X_1 of b_{j_1} and b_{j_2}, $V_0(j_1,j_2,t)$ and $V_i(j_1,j_2,t)$ are the directed volumes of tetrahedrons $T_0(j_1,j_2,t)$ and $T_i(j_1,j_2,t)$ at time t, respectively. Then $\varepsilon_{0i}(j_1,j_2,t)$ is called the grey tetrahedral network correlation coefficient of X_0 and X_i with respect to objects b_{j_1} and b_{j_2} at time t, and the formula is as follows.

$$\varepsilon_{0i}(j_1,j_2,t)=\frac{1}{1+|V_0(j_1,j_2,t)-V_i(j_1,j_2,t)|} \tag{18}$$

Definition 14 Let $X_0=(x_i(s,\ t))_{M\times N}$ be the reference index behavior matrix, $X_i=(x_i(s,\ t))_{M\times N}$ be the index behavior matrix, $\varepsilon_{0i}(j_1,j_2,t)$ be the grey tetrahedral network correlation coefficient of X_0 and X_i with respect to objects b_{j_1} and b_{j_2} at time t, then ε_{0i} is called the grey tetrahedral network correlation degree of X_0 and X_i.

$$\varepsilon_{0i}=\frac{2}{m(m-1)(n-1)}\sum_{b_{j_1},b_{j_2}\in M_B^2}\sum_{t=1}^{n-1}\varepsilon_{0i}(j_1,j_2,t) \tag{19}$$

Definition 14 Let ξ_{0j} be the three-dimensional grey projection area correlation degree of X_0 to X_j, ε_{0i} is the grey tetrahedral network correlation degree of X_0 and X_i, then the similarity correlation degree of X_0 to X_j is α_{0i}, and the specific formula is as follows.

$$\alpha_{0i}=\frac{1}{2}(\xi_{0j}+\varepsilon_{0i}) \tag{20}$$

(3) Comprehensive grey correlation degree

The comprehensive grey correlation degree of panel data X_0 and X_j is obtained by weighted average of similarity correlation degree and similar correlation degree. The similarity correlation degree is obtained by weighted average of displacement correlation degree, velocity correlation degree and acceleration correlation degree. A similar correlation degree is obtained by weighted average of three-dimensional grey projection area correlation degree and grey tetrahedron network correlation degree. When the difference of different correlation degree is large, it will lead to the distortion of comprehensive grey correlation degree and make the result unreliable. Therefore, this paper introduces the entropy value of grey correlation degree to describe the difference between correlation degrees and sets the weight of similarity correlation degree and similar correlation degree according to the degree of difference, so as to construct a comprehensive and reasonable comprehensive grey correlation degree.

Definition 15 Let the panel data X_0 and X_j, the displacement correlation degree is $r_{0i}^{(0)}$, the velocity correlation degree is $r_{0i}^{(1)}$ and the acceleration correlation degree is $r_{0i}^{(2)}$, then the grey correlation distribution of panel data X_0 and X_j is mapped as follows :

$$P_{ij}^{r0} = \frac{|r_{0i}^{(0)}|}{P_{ij}} \tag{21}$$

$$P_{ij}^{r12} = \frac{|r_{0i}^{(1)} + r_{0i}^{(2)}|}{P_{ij}} \tag{22}$$

Which

$$P_{ij} = |r_{0i}^{(0)}| + |r_{0i}^{(1)} + r_{0i}^{(2)}|$$

Similarly, $T_{ij}^{r} = -\ln P_{ij}^{r0} - P_{ij}^{r12} \ln P_{ij}^{r12}$ is the test coefficient of the similar grey correlation degree of the panel data X_0 and X_j. $T_{ij}^{\xi\varepsilon} = -\ln P_{ij}^{\xi} - P_{ij}^{\varepsilon} \ln P_{ij}^{\varepsilon}$ is the test coefficient of the similar grey correlation degree of the panel data X_0 and X_j. Based on the above analysis, the larger the test coefficient, the smaller the difference, which means the higher the credibility.

Definition 16 Let the panel data X_0 and X_j, r_{oi} is the similarity correlation degree between X_0 and X_j, α_{0i} is the similarity correlation degree between X_0 and X_j, T_{ij}^{r} and $T_{ij}^{\xi\varepsilon}$ are the similarity between panel data X_0 and X_j, and the test coefficients of similar grey correlation degree. Then the comprehensive grey correlation degree γ_{0j} of X_0 and X_j is as follows.

$$\gamma_{0j} = w_1 r_{oi} + w_2 \alpha_{0i} \tag{23}$$

Which

$$w_1 = \frac{T_{ij}^{r}}{T_{ij}^{r} + T_{ij}^{\xi\varepsilon}},\ w_2 = \frac{T_{ij}^{\xi\varepsilon}}{T_{ij}^{r} + T_{ij}^{\xi\varepsilon}}$$

5. Grey correlation degree calculation and analysis

5.1 Grey correlation degree calculation

According to the relevant data and the above formulas, this section calculates by MATLAB and obtains the gray correlation degree between the digital index and the cold chain carbon emissions of agricultural products. The results are shown in Table 10.

Table 10 Various grey correlation degrees between digital indicators and carbon emissions from cold chain of agricultural products

	$r_{0i}^{(0)}$	$r_{0i}^{(1)}$	$r_{0i}^{(2)}$	r_{oi}	ξ_{ij}	ε_{0i}	α_{0i}
A	0.5380	0.9184	0.8608	0.7138	0.9154	0.5976	0.7565
B	0.5436	0.9013	0.8384	0.7067	0.9091	0.5908	0.7500
C	0.6995	0.7406	0.6131	0.6882	0.8169	0.4738	0.6454
D	0.6910	0.7566	0.6024	0.6853	0.8352	0.4924	0.6638
E	0.5247	0.9536	0.9279	0.7327	0.9081	0.6073	0.7577
F	0.6258	0.8105	0.6891	0.6878	0.8603	0.5255	0.6929
G	0.6415	0.8153	0.7014	0.6999	0.8596	0.5354	0.6975
H	0.6412	0.7954	0.6763	0.6885	0.8566	0.5236	0.6901
I	0.5803	0.9175	0.8700	0.7370	0.9999	0.6428	0.8214
J	0.6693	0.7083	0.5451	0.6480	0.8140	0.4676	0.6408
K	0.6359	0.7785	0.6741	0.6811	0.5723	0.5115	0.5419

L	0.5264	0.9309	0.8932	0.7192	0.5743	0.5953	0.5848
M	0.5614	0.8495	0.7577	0.6825	0.6004	0.5445	0.5725

By using the formula (23) to deal with the above table, the comprehensive grey correlation degree between the digital index and the carbon emission of agricultural products cold chain is obtained, and the ranking is carried out according to the numerical value. The ranking results are shown in Table 11.

Table **11** Comprehensive grey correlation degree between digital indicators and carbon emissions of agricultural products cold chain

index	γ_{0j}	**rank**
A	0.7285	3
B	0.7217	4
C	0.6720	9
D	0.6771	8
E	0.7412	2
F	0.6897	6
G	0.6990	5
H	0.6891	7
I	0.7664	1
J	0.6453	11
K	0.6243	13
L	0.6676	10
M	0.6398	12

It can be seen from the above table that the comprehensive grey correlation degree between the digitization degree of agricultural products cold chain and its carbon emissions in 14 cities of Guangxi is ranked as follows : employee digitization level < annual profit < employee digitization consciousness < annual revenue < network security < procurement and supply digitization < distribution digitization < transportation digitization < circulation processing digitization < software equipment digitization < hardware equipment digitization < warehousing digitization < digital investment degree.

5.2 Results analysis

First of all, from table 9, it can be concluded that among the many digital factors, the degree of digital investment has the highest impact on the carbon emissions of Guangxi agricultural products cold chain. With the increase of digital investment, the ability of enterprises to purchase hardware facilities and software facilities will be greatly improved, so that the overall digitization of agricultural products cold chain will increase, and carbon emissions will decrease. Therefore, the degree of digital investment is the basis of other digital factors and the core of reducing carbon emissions of agricultural products cold chain. Secondly, the order of hardware equipment digitization and software equipment digitization is third and fourth respectively. Hardware equipment digitization and software equipment digitization are the overall evaluation of the digitization of agricultural products cold chain business links, which play an important role in the operation of agricultural products cold chain. It is worth noting that in the business link, the digitization of warehousing links ranks second, which exceeds the digitization of hardware equipment and software equipment. In real life, the cost of agricultural products cold chain warehousing is huge. Agricultural products stay in the warehouse for a long time and need to maintain a certain temperature, so in the whole business link. The carbon emissions and cargo damage rates generated by the storage process are very high.

For the digitization of transportation, distribution, circulation processing, procurement and other links, although there is no large correlation between warehousing links and carbon emissions, it also plays a certain role. Finally, the correlation between digital factors such as network security, employees ' digital awareness, employees ' digital level, digital annual revenue, digital annual profit and carbon emissions of agricultural products cold chain is not high, but they are all greater than 0.6, which confirms that these factors have a high degree of correlation with carbon emissions.

In the future, the cold chain of agricultural products in Guangxi can increase the degree of digital investment. By purchasing digital equipment, establishing digital systems, and increasing the training of employees ' digital awareness and ability, the digital degree of cold chain of agricultural products can be improved. In the context of low-carbon, Guangxi agricultural products cold chain enterprises build a low-carbon transformation plan for agricultural products cold chain according to relevant digital influencing factors, help enterprises achieve low-carbon transformation and help achieve the goal of ' double carbon '.

5.3 Comparative analysis

Table 12 shows the ranking results from two-dimensional angle, three-dimensional angle, four-dimensional angle, similarity, similarity and the methods used in this paper.

Table 12 Sorting results of different perspectives

index	Two – dimensional / similarity	three-dimension	four-dimensional	proximity	This paper
A	4	2	3	3	3
B	5	3	5	4	4
C	8	9	12	9	9
D	10	8	11	8	8
E	2	4	2	2	2
F	9	5	8	6	6
G	6	6	7	5	5
H	7	7	9	7	7
I	1	1	1	1	1
J	13	10	13	10	11
K	12	13	10	13	13
L	3	12	4	11	10
M	11	11	6	12	12

First of all, from the perspective of two-dimensional, three-dimensional and four-dimensional, this paper can find that no matter from which perspective, the degree of digital investment ranks first, and the ranking of most indicators is not much different, but the gap between annual revenue and annual profit is large. For annual revenue, two-dimensional and four-dimensional are compared and analyzed from the perspective of time. From the formula, this paper can see that the calculation process includes the data of the previous time period minus the data process of the current time period (Formula 5 and Formula 17), and the three-dimensional perspective is not only from the perspective of time (Formula 10). The angle of the object is also considered (Formula 9). The annual profit is the same in the two-dimensional and three-dimensional, which is different from the four-dimensional ranking. Although the two-dimensional, three-dimensional and four-dimensional all consider the time dimension, the four-dimensional is compared between multiple objects, and in the calculation process, the comparison results between different objects of the same index are integrated (Formula 19), while the three-dimensional only considers the gap between the previous object and the current object and does not compare any objects. Secondly, starting from the similarity and similarity, this paper can see that in addition to the annual revenue, the ranking of other indicators is basically the same, and the similarity is a combination of three-dimensional and four-dimensional. The gray correlation degree of three-dimensional and four-dimensional annual revenue is 0.5743 and 0.5953, respectively. However, in the three-dimensional, the largest gray correlation index is 0.999, and the largest gray correlation degree of four-dimensional is 0.6428. Therefore, in the process of synthesis, the gray correlation degree of annual revenue similarity is not high. Finally, the scheme proposed in this paper comprehensively considers the characteristics of two-dimensional, three-dimensional and four-dimensional. Compared with other single angles, it is more able to synthesize the advantages of different angles and make a comprehensive judgment to avoid the result being too one-sided.

In the above discussion, this paper finds that the ranking gap is concentrated in the index of annual revenue. It can be seen from Table 3-7 that the two-dimensional angle combines the displacement correlation degree, the velocity correlation degree and the acceleration correlation degree. The displacement correlation degree is the subtraction of the time perspective, while the velocity correlation degree and the acceleration correlation degree are the first derivative and the second derivative on the basis of the displacement correlation degree. It can be seen from the results that the displacement correlation degree of annual revenue ranks 12th, which is basically the same as the ranking order of three-dimensional and this paper, while the annual revenue order of velocity correlation degree and acceleration correlation degree is the first, which makes the final similarity correlation degree rank high. The method proposed in this paper avoids this situation.

6. Conclusion

Firstly, this paper clarifies the purpose and principle of constructing the digital evaluation index system of cold chain of agricultural products in Guangxi. According to the ' Evaluation Index of Digital Level of Small and Medium-sized Enterprises (2022 Edition) ' issued by the General Office of the Ministry of Industry and Information Technology and related literature, the digital evaluation index of cold chain of agricultural products in Guangxi is obtained. Secondly, the energy consumption and carbon emissions of agricultural products cold chain in 14 cities of Guangxi are calculated. On the whole, the carbon emissions of agricultural products cold chain in cities of Guangxi are on the rise. Finally, through the two-dimensional perspective to construct the similarity gray correlation degree and the three-dimensional perspective and the four-dimensional perspective to construct the similarity gray correlation degree, the correlation degree of the digital factors on the carbon emission of the cold chain of agricultural products in Guangxi is quantitatively analyzed. The grey correlation model fully excavates the panel data, integrates the advantages of different dimensional perspectives, and enriches the grey correlation theory. Applying this model to the cold chain of agricultural products in Guangxi provides theoretical and practical data support for exploring the relationship between digitization and carbon emissions in the cold chain of agricultural products in Guangxi, and also points out the development direction of digitization for enterprises to achieve low-carbon transformation in the future.

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Digitalization and Management Innovation III
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Blockchain Empowers the Digital Traceability of Geographically Indicative Agricultural Product Supply Chains – Taking Dezhou Braised Chicken as an Example

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Abstract. Blockchain technology empowers the digital traceability of geographically indicative agricultural product supply chains, representing an innovative path towards the modernization of China's agricultural supply chains. This paper aims to explore the application of blockchain technology in the digital traceability of geographically indicative agricultural product supply chains, with a detailed analysis of Dezhou Braised Chicken as a case study. Originating from Dezhou City, Shandong Province, China, Dezhou Braised Chicken is known for its unique geographical flavor and rich geographical characteristics that endow it with a special taste and quality. As a recognized traditional delicacy, Dezhou Braised Chicken has created a brand effect. However, the complex origins of products in the market make it difficult for consumers to distinguish authentic Dezhou Braised Chicken, exposing it to the risks of counterfeiting and imitation. Any local enterprise in Dezhou City can register its own brand of braised chicken for processing and sales. The existence of this social phenomenon confuses consumers, making it impossible for them to judge the many brands on the market by themselves, and local enterprises in Dezhou cannot highlight the characteristics of their own products. By utilizing blockchain technology, it can be ensured that every product labeled "Dezhou Braised Chicken" is genuinely from Dezhou, maintaining the brand's authenticity and reputation, highlighting the unique features of different enterprise brand products, and further enhancing the brand value of traditional products like Dezhou Braised Chicken.

Keywords. Agricultural Product Traceability; Blockchain; Geographical Features; Dezhou Braised Chicken

1.Introduction

The "No. 1 Document" of 2024 issued by the central government calls for the continuous strengthening of quality and safety control over the origin of agricultural products, as well as product testing, to enhance the food safety supervision capabilities throughout the entire process "from the field to the table." At present, China places great emphasis on the traceability of agricultural product safety, and a traceability system has been

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established through relevant technical means, which can effectively supervise and control the quality of agricultural products.

Blockchain technology, as an emerging digital technology, has characteristics such as decentralization, tamper-proof, and transparency, making it widely used in many fields. In the digital traceability of agricultural product supply chains, blockchain technology has unique advantages. The agricultural product supply chain involves many links, including planting, purchasing, processing, storage, transportation, and sales, and the flow and interaction of information are extremely complex. Blockchain technology can effectively solve these problems.

Especially for geographically indicative agricultural products, their origin, production methods, and quality all have distinct regional characteristics. How to ensure their authenticity and avoid counterfeiting and inferior imitations is an urgent issue to be resolved in the market. The introduction of blockchain technology can achieve the full traceability of geographically indicative agricultural products, ensuring the authenticity and transparency of every link, greatly enhancing the trust and market competitiveness of agricultural products.

In this context, this article will delve into how blockchain technology can empower the digital traceability of geographically indicative agricultural product supply chains, elaborate on the future application measures of blockchain technology in this field, and hope to provide beneficial references and insights for related research.

2.Literature Review

Blockchain technology, due to its unique characteristics of decentralization, tamper-proof, and full transparency, has been widely applied in numerous fields. In recent years, its application in the traceability of agricultural product supply chains, especially for geographically indicative agricultural products, has attracted extensive attention. The research of this paper is closely related to the study of geographically indicative agricultural products and the digital traceability of supply chains empowered by blockchain, and the following is a review of relevant literature.

Blockchain, that is, a truly open, distributed, global platform, has its unique potential as the 'Internet of Value' and will change our life and work[1]; Subsequently, a traceability system for agricultural product supply chains based on RFID and blockchain technology was developed, which fully demonstrated that blockchain technology can play a role in enhancing traceability, increasing transparency, and improving supply chain efficiency within the agricultural product supply chain[2]; On this foundation, some scholars have proposed that blockchain technology has the potential to significantly enhance the efficiency, transparency, and consumer trust in the supply chain of geographically indicated agricultural products, and is capable of determining the time, location, and identity of the operator[3];Subsequently, scholars have proposed the construction of a digital traceability system for agricultural products, which can effectively ensure the quality of agricultural products[4].

In recent years, with the continuous development and improvement of blockchain technology and the continuous adjustment of agricultural product supply chain traceability, research on blockchain and supply chain traceability has continued to increase. However, there is relatively little research on the traceability of geographically indicative agricultural product supply chains empowered by blockchain. This paper discusses the digital traceability of geographically indicative agricultural product supply chains under the background of the increasingly perfected blockchain, which is conducive to enriching theoretical research.

3.Traditional Supply Chain Traceability Business - Dezhou Braised Chicken

3.1. Development Status

Dezhou Braised Chicken Co., Ltd. in Shandong, established in September 2010, is a company mainly engaged in the production and operation of Dezhou Braised Chicken. In 2011, the industry standard for “Braised Chicken” drafted primarily by the company was implemented, which better inherits and protects this national delicacy. It is an educational demonstration base for Dezhou Braised Chicken that integrates processing, scientific research and education, cultural exhibition, and sightseeing tourism.

The industry has been continuously improved and developed in a healthy way for many years and has become a pillar industry and the leader of economic development in Dezhou City, making a positive contribution to the rapid economic development of Dezhou. Now, there are 84 enterprises with production qualifications and hundreds of workshop-style braised chicken processing stores in the industry, with dozens of brands such as Dezhou, Yi Pin, Yong Sheng Zhai, Cui Ji, Li Ji, and Sha Xiao Er.

As an outstanding representative and backbone enterprise in the industry, Dezhou Braised Chicken Co., Ltd. has always played a leading and exemplary role in Shandong. By continuously improving the entire industry chain of “breeding-processing-sales” and strengthening technological innovation, product research and development, and brand value mining, it has driven the effective improvement of the overall processing and management level of the Dezhou Braised Chicken industry. The entire industry also shows an unprecedented, good development momentum.

In May 2018, in the special evaluation of the brand value of Chinese time-honored brands initiated by the General Administration of Quality Supervision, Inspection and Quarantine of China, the industry entered the top 20 of the Chinese time-honored brand lists with a brand value of 903 million yuan. In June of the same year, Dezhou Braised Chicken, as a national banquet dish, was served at the Shanghai Cooperation Organization Qingdao Summit, and the 300-year craftsmanship inheritance has made the industry's national banquet quality.

3.2. Pain Points in Traditional Supply Chain Traceability Operations

Dezhou Braised Chicken, as a registered national trademark, has become a well-known brand at home and abroad and a local specialty agricultural product that helps promote rural revitalization in the country. However, as the enterprise continues to expand and develop, some unscrupulous companies and small workshops have been imitating and forging Dezhou Braised Chicken's products and packaging at will and misusing various food additives in the production process. This has led to a mixed market for the industry, with the emergence of “counterfeit Dezhou Braised Chicken,” severely damaging the brand image of the industry.

At the same time, with the continuous occurrence of food quality and safety issues in various industries in recent years, the existing traceability system of Dezhou Braised Chicken cannot effectively find the root of the problem and cannot timely identify the quality issues, greatly affecting consumers' trust and purchasing power for the product [5].

- Geographical Indication Rights Infringement Issue: The characteristic and value of geographically indicative agricultural products lie in their unique geographical environment and specific production processes [6]. However, in traditional traceability business, due to the lack of transparency and susceptibility to data tampering, consumers often find it difficult to determine whether the products they purchase are truly from the geographical indication protection area, making it difficult to protect the rights of geographical indications.
- Data Silo Issue: In traditional traceability business processes, information from breeding, processing, and sales segments is stored independently, lacking effective information exchange. This leads to discontinuity in the entire supply chain information, preventing the formation of a complete traceability chain [7].
- Data Authenticity Issue: Since data recording mainly relies on manual labor, there is a risk of data errors, omissions, and tampering, which may affect consumers' perception of Dezhou Braised Chicken as a geographically indicative agricultural product [8].
- Legal Responsibility Difficult to Pursue: In the event of product quality issues, due to the opacity and unreliability of the data, it is often difficult to trace the responsible link, making it hard to effectively ensure the quality of geographically indicative agricultural products.

Introducing blockchain technology can effectively solve these problems. Through its decentralized, tamper-proof, and transparent characteristics, it can ensure the authenticity and reliability of traceability information for geographically indicative agricultural products, enhance consumer trust, and help protect the rights of geographical indications [9].

4.Suggestions for Blockchain-Empowered Traceability of Geographically Indicative Agricultural Product Supply Chains

In response to the existing business pain points of Dezhou Braised Chicken, a local agricultural product, we can leverage blockchain technology to innovate the traceability of the supply chain for geographically indicative agricultural products. The following suggestions are proposed:

- Protect Geographical Indication Rights: Through blockchain technology, we can accurately trace the product's origin, production processes, and other information, effectively protecting the rights of geographical indications. At the same time, various brand enterprises of Dezhou Braised Chicken can also highlight the unique features of their own brands.
- Establish a Full-Chain Digital Information System: Blockchain technology enables us to implement a full-chain information system from raw material production, processing, to sales. Data from each link will be recorded on the blockchain, creating an information network that connects the entire supply chain [10]. In this way, data from every link can be viewed by other links, achieving data transparency.

- Ensure Data Immutability: An important feature of blockchain technology is the immutability of its data [11]. Once data is recorded on the blockchain, it cannot be modified or deleted, ensuring that every step from the origin, production, processing, logistics, transportation, to market sales will form a traceable and unalterable data chain [12]. This ensures the authenticity and reliability of the traceability of geographically indicative agricultural products, enhancing consumer trust.

In summary, blockchain technology empowers the digital traceability of geographically indicative agricultural product supply chains, ensuring not only the transparency and authenticity of traceability information but also greatly protecting and enhancing the value of geographically indicative agricultural products. It allows consumers to eliminate counterfeit brands that are indistinguishable and lack distinctive features, enabling them to choose higher-quality products based on their needs, significantly increasing consumer trust in the product.

5.Conclusion

This article takes Dezhou Braised Chicken as an example, building upon its existing traceability system, to analyze the development status and pain points of this agricultural product, and proposes more reasonable optimization suggestions. The application of this technology promotes the digital transformation of agriculture, providing new opportunities for the sustainable development of industry. At the same time, it also proves that blockchain technology has significant advantages in the digital traceability of product supply chains, which can fully ensure the security and reliability of information, effectively enhance brand value, and expand the market.

In general, blockchain-empowered digital traceability of geographically indicative agricultural product supply chains represents an innovative way of thinking and a path of action. Through the decentralized, tamper-proof, and transparent characteristics of blockchain, it can solve traditional agricultural product traceability issues such as the infringement of geographical indication rights, data silos, data inauthenticity, and the difficulty of legal responsibility traceability, greatly improving the efficiency and accuracy of agricultural product supply chain traceability. At the same time, it also helps protect and enhance the value of geographically indicative agricultural products, safeguard consumer rights, and promote the optimization and upgrading of the agricultural supply chain. In the future, with the continuous development and popularization of blockchain technology, its application in agricultural product traceability will be more extensive, bringing higher quality agricultural products to consumers and greater benefits to the agricultural industry chain.

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Digitalization and Management Innovation III
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Analysis of the Metaverse Potential as a Digital Platform for Business Innovation

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Abstract. The Metaverse represents a digital platform that not only changes the way one interacts with the world, but is also a generator of innovation in various business sectors. The Metaverse is emerging as a catalyst for future technological trends, transforming not only digital experiences but also society itself. The paper briefly its key technologies such as virtual and augmented reality, artificial intelligence, blockchain, 5G networks. Based on these technologies, the article seeks to analyze new opportunities for business, economic models, social interactions and insights on how the Metaverse can serve as a platform for continuous innovation, shaping the future of the global economy.

Keywords. VR/AR, AI, 5G, Blockchain, Business, Economic Models, Innovation.

1. Introduction

In recent decades, technological advances have changed understanding of the world and the interaction with it, leading to new technologies and how they create new opportunities and challenges, transforming social, economic and cultural structures. In this context, the Metaverse is emerging as the next big step in this evolution – a virtual universe that promises to radically change humans' understanding of reality, interactions and innovation.

The **Metaverse**, often defined as a collection of interconnected virtual worlds where users can immerse, interact and create, is a large-scale digital platform that combines technologies such as virtual and augmented reality (VR/AR), artificial intelligence (AI), blockchain and 5G networks [1]. It is a space where the physical and digital worlds merge, giving users the opportunity to engage in a variety of activities that include everything from social interactions to economic transactions and creative projects. In this new world,

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the boundaries between the real and the virtual are blurred, and the possibilities for innovation seem endless.

Virtual reality (VR) plays a central role in the Metaverse, providing users with immersive experiences that replace the physical world with a fully virtual environment [2]. Through VR head-mounted devices and controllers, users can immerse themselves in interactive 3D worlds, interact with objects and experience the feeling of being truly present in these environments. VR makes possible experiences such as virtual social events, working and learning in simulated environments, greatly increasing realism and engagement in the Metaverse.

Augmented reality (AR) extends the Metaverse by integrating virtual objects and elements into the real world through devices such as smartphones and AR glasses [3]. AR allows users to see and interact with digital content in their physical environment, which creates hybrid virtual-reality experiences. This technology is key to connecting virtual worlds to people's everyday lives, enabling games, virtual stores and interactive ads that appear in the real world. AR makes the Metaverse more accessible and integrated into reality.

Artificial Intelligence (AI) plays an essential role in the development of the Metaverse by providing intelligent, personalized and automated solutions [4]. Through AI, data on user behavior and preferences is analyzed, which enables the creation of personalized virtual experiences. This personalization includes customized content, virtual environments, and interactions to each user's needs. Intelligent non-game characters (NPCs) and AI-powered virtual assistants can interact with users in a natural and intuitive way, creating more realistic and engaging virtual worlds. AI also plays an important role in the automated generation of content, such as virtual objects and environments, which greatly speeds up the development process. Through the use of AI, the Metaverse can create large-scale and dynamic worlds that adapt to user actions in real time. AI also supports moderation and security by automatically detecting inappropriate behavior, abuse and fraud attempts.

5G as a network technology provides the necessary infrastructure to support the complex and tax-intensive virtual environments of the Metaverse [5]. High-speed and low-latency networks enable seamless immersion and interaction in the Metaverse, providing smooth and realistic experiences even when multiple users are simultaneously connected. This makes it possible to hold virtual events, conferences and even concerts in real time that bring together people from different corners of the world in a shared digital world.

Blockchain technology is responsible for the foundation for a decentralized economy in the Metaverse [6]. Through the use of blockchain, users can own, trade and manage digital assets such as non-fungible tokens (NFTs), which could represent unique works of art, virtual real estate or other digital goods. These assets can be traded on virtual markets, creating new economic models and opportunities for monetizing digital content. Blockchain provides security and transparency of transactions in the Metaverse, ensuring that digital assets and identities are secure and easily traceable.

One of the most notable features of the Metaverse is its ability to stimulate innovation in various fields. The technologies that make the Metaverse possible are themselves subject to continuous development and refinement, and their combined use in the context of the Metaverse opens up new horizons for technological and social change. The Metaverse is not only changing the way people use technology, but it is also challenging traditional models of economics, social interactions, and cultural expression. In this new world, companies are discovering new ways to interact with consumers through virtual stores and events that offer unique and personalized experiences. Businesses can also use the Metaverse as a platform to create new products and services that satisfy the needs of the digital generation. The technological innovations that support the Metaverse create new opportunities for collaboration and co-creation, allowing users and creators to work together on projects in real-time without geographical limitations.

It is obvious that the Metaverse represents a successful expanding combination of different ICT technologies, each one being developed on its own, i.e. pure technology is in the hands of IT professionals.

The aim of the paper is to analyze new opportunities for business, economic models, social interactions and insights on how the Metaverse can serve as a platform for continuous innovation, shaping the future of the global economy.

2. Metaverse Potential as a Digital Platform for Business Innovation

The Metaverse market is expected to grow exponentially over the years. Figure1 shows the forecasts until 2033 [7].

The shift to the Metaverse could generate new economic models that will change the way businesses and consumers interact, trade and create value. These new models will be based on the Metaverse technologies, offering innovative ways to create value in the digital world [8, 9, 10, 11, 12, 13].

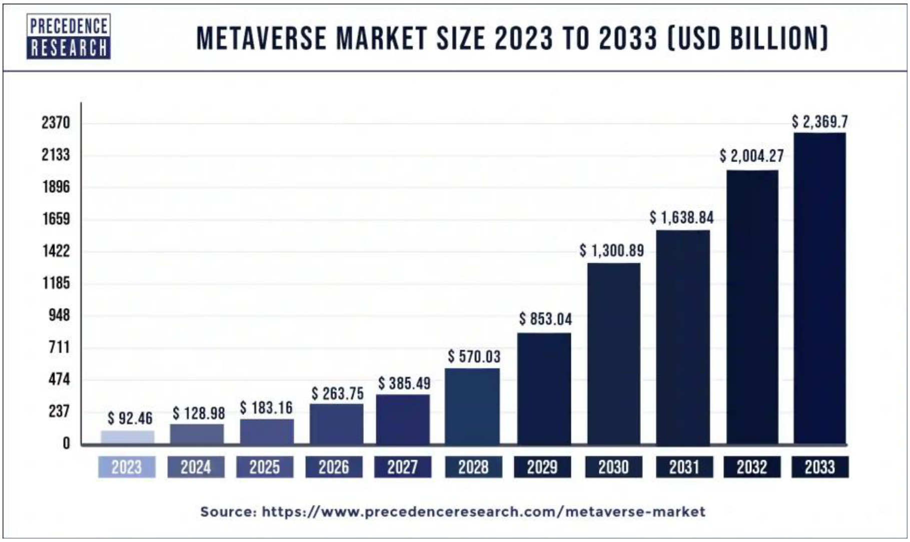

Figure 1. Metaverse Market Size 2023 – 2033.

Digital asset ownership in the Metaverse is accomplished using new forms of ownership through NFTs, which allow consumers and businesses to buy, sell, and exchange unique digital assets such as virtual lands, avatars, artwork, etc. [14, 15]. This form of ownership is made possible by blockchain, which ensures the security and traceability of assets. Through them, businesses can create and trade unique digital assets, such as virtual clothing, artwork, virtual land. NFTs provide new ways to monetize and generate revenue while allowing customers to own truly unique digital assets. This also creates new economic models based on digital ownership and decentralized transactions.

Trade in virtual goods will develop as a major economic activity in the Metaverse [16, 17]. Brands will offer digital products that consumers can buy and use in virtual worlds. This will create new markets and trading opportunities, both between consumers and between businesses. One of the main opportunities that the Metaverse provides to businesses is the creation of virtual stores and showrooms. In these immersive environments, users can view products in 3D, examine them closely and interact with them before making a purchase. This fills the gap between physical and online shopping, providing customers with a unique and personalized experience.

Virtual real estate ownership and rentals can be realized by selling and renting virtual lands [18, 19, 20]. In the Metaverse, virtual spaces are created that can be bought, developed and sold to other users. Businesses and consumers can acquire virtual plots of land on which to build virtual offices, shops, showrooms or entertainment venues. Owners of virtual real estate can rent it out to other businesses or users, creating passive income. companies can rent virtual offices or stores in preferred virtual locations.

Cryptocurrencies for transactions in the Metaverse will serve as the primary medium of exchange in it, allowing transactions to take place without the need for financial intermediaries such as banks [21, 22]. Users can use cryptocurrencies to purchase virtual goods, services and assets. The Metaverse can provide platforms for decentralized financial services (DeFi) such as virtual banking, credit and insurance. Through DeFi, businesses and consumers can participate in financial transactions and investments without the need for centralized control.

Virtual professional services such as consulting, training and coaching can be performed in the Metaverse [23, 24, 25]. Companies can offer services to a global audience through virtual meetings, training and coaching. These services can be complemented with virtual business meetings and events where companies can organize exhibitions, meetings and conferences without physical limitations. These virtual events could help brands reach new audiences that are younger and more technologically oriented. The Metaverse offers also the ability to measure the results of these events in real time – from user engagement to sales of virtual products.

Creating interactive ads and marketing campaigns that engage consumers more deeply are part of the new business opportunities that the Metaverse offers [26, 27]. Brands can create virtual experiences that consumers can explore as part of an advertising strategy. Marketing in the Metaverse can be enhanced by virtual influencers playing an important role in promoting products and services in the Metaverse. Brands can partner with these influencers to promote products in an engaging way to their followers.

Innovation in product development presents an outstanding opportunity in the Metaverse for virtual prototyping and testing of new products [28, 29]. Businesses can create digital prototypes of products and test them in real time with consumers. This capability significantly reduces development costs and accelerates time to market for new products. Virtual testing allows companies to gather feedback and make adjustments even before physical production. The Metaverse offers design collaboration opportunities where teams from different parts of the world can work together in real time. This allows companies to select talent from a global workforce and accelerate the product development process through virtual meetings and 3D modeling. This form of collaboration is particularly useful for industries such as architecture and engineering, where 3D visualization and simulation are essential to project development. The Metaverse also opens up the possibility of co-creating products with customer participation through special platforms where users can propose ideas for new products.

Paid subscriptions and memberships that give users access to exclusive content or special services can be realized in the Metaverse [30]. Companies can offer premium access to virtual events, training, courses or customized products. Businesses can develop virtual membership programs that provide users with privileges such as virtual gifts, discounts or access to unique spaces in the Metaverse. This can drive customer loyalty and create new revenue streams.

Content creation in the Metaverse opens new opportunities for selling digital products and services [31, 32]. Designers, artists and programmers can develop unique digital objects, scenes and virtual experiences to sell as NFTs or directly to other users. One of the most interesting economic models brought by the Metaverse is related to user-generated content, where these users create their own virtual worlds and products and they can profit from selling their content to others users or through advertisements.

Social interactions and cultural expression in the Metaverse, in addition to economic and technological innovations, also provide new opportunities for virtual communities to realize new forms of socialization where people can meet, communicate and work together in an environment that is both fantastical and realistic [33] . These communities are often based on shared interests and values, providing users with a platform to express themselves and participate in cultural events and activities that go beyond traditional forms of art and entertainment.

Education and training opportunities are one of the strengths of the Metaverse [34]. Virtual classrooms and training in the Metaverse can provide immersive and interactive experiences that make learning more effective and fun. Learning simulations based on real-life scenarios can be used to develop skills in fields such as medicine, engineering and business, providing learners with the opportunity to gain hands-on experience in a safe and controlled environment.

The relationship between the Metaverse and **Web3** is interesting because of the potential for the development of the new generation of digital platforms that are based on decentralization and user ownership [35]. While the Metaverse represents virtual spaces for work and interaction, Web3 provides the necessary infrastructure to build these environments on blockchain technologies, providing decentralized ownership and control of data and assets. Web3 allows users to own and control their digital assets, such as NFTs, cryptocurrencies and virtual real estate, which are fundamental to the Metaverse. These assets can be bought, sold and used in different virtual worlds without being dependent on centralized companies. Web3 provides cross-platform interoperability, allowing users to transfer their digital assets and identities between different virtual environments in the Metaverse. This means that users can use the same NFT or avatar in multiple virtual worlds. Web3 provides a framework for decentralized autonomous organizations (DAOs) that can manage communities and projects in the Metaverse by making collective decisions through voting and decentralized control. This connection between the Metaverse and Web3 is transforming the Internet by giving users more control, security, and opportunities to create and participate in economic and social activities in the digital world.

3. Defined challenges for businesses to move to the Metaverse

The move of business into the Metaverse offers many opportunities, but also comes with a number of challenges [36, 37, 38, 39].

Technological complexity is a consequence of infrastructural requirements, where the Metaverse requires serious technical infrastructure, including high computing power, stable and fast networks as well as VR and AR support. Small and medium-sized businesses may find it difficult to invest in the necessary technology and maintain such complex systems. It is important to note that integrating existing business systems into the Metaverse can be complex, especially when it comes to data synchronization and cross-platform management.

Security and privacy are related to data protection due to the fact the Metaverse generates vast amounts of sensitive user data, including personal information and financial data. Protecting this data is an important challenge, especially given the growing threats of cyberattacks. It is also important to note that cyber security, hacking attacks, fraud and theft of digital assets are risks that businesses need to consider. The security of digital assets, such as NFTs and cryptocurrencies, is a key issue that requires reliable solutions and continuous renewal of security mechanisms.

Legal and regulatory uncertainty is due to a lack of clear regulations, as the Metaverse is a new and rapidly developing space that is not yet fully regulated from a legal point of view. This creates uncertainty for businesses, especially regarding issues such as intellectual property protection, taxation and regulation of trading in virtual assets. Businesses must comply with different legal frameworks and regulations in different countries due to the fact that the Metaverse is global, which can be complex and expensive.

Ethics and corporate responsibility as they relate to ethical behavior in digital environments. The virtual nature of the Metaverse could lead to new ethical problems, including issues of discrimination, social justice and mental health. Businesses must develop ethical standards and practices to ensure responsible behavior in these new environments. Companies, both in the real world and in the Metaverse, will be monitored for corporate social responsibility to ensure that their ethical operations in the Metaverse.

User behavior and expectations are related to unclear user expectations due to the fact that the Metaverse is a new concept to many people, meaning that user expectations and behavior can be difficult to predict. Businesses will need to be flexible and ready to adapt their strategies to changing consumer preferences. Maintaining a high level of customer satisfaction in the Metaverse can be challenging, especially if the technology does not function as it should or if the virtual experiences don not live up to expectations.

Costs and investments are due to the high initial costs, as the transition to the Metaverse requires significant investment, especially for small and medium-sized enterprises. These costs include not only the technical infrastructure, but also content development, marketing and support. Unclear ROI are new and unexplored challenges, making investment decisions in new virtual initiatives riskier.

Cultural differences are due to global cultural differences in the Metaverse, where businesses will encounter cultural differences and must be careful how they communicate and adapt their content for different audiences. The Metaverse must be accessible and inclusive to all, including people with disabilities. Businesses must take into account the different needs of users and ensure that their virtual environments are accessible to all.

As technology advances and the Metaverse expands, issues of ethics, privacy, and security also become increasingly relevant. Virtual worlds, like physical ones, must be managed with care and attention to ensure that users are protected from abuse and that their personal data is safe. In this context, blockchain technology and other security innovations can play a key role in ensuring trust and security in the Metaverse.

4. Steps for business transition to operation in the Metaverse

Figure 2 outlines the key steps a business must follow to successfully deploy in the Metaverse. Each step is consistent and plays an important role in the integration of the business in this new virtual world.

Figure 2. Key steps for transition to Metaverse business model.

Step 1. Research and understand the Metaverse - Businesses must research and understand the concept of the Metaverse. This includes learning about the different platforms, technologies such as VR and AR, AI, Blockchain and 5G, and how companies are already using the Metaverse. On this step, it is important to understand the opportunities and challenges it offers.

Step 2. Defining business objectives - The business must define its specific objectives. This can include attracting new customers, creating a virtual store or offering unique products and services through virtual platforms. Businesses can direct their efforts and resources more effectively by setting clear goals.

Step 3. Choosing a platform - The right platform should be chosen to build the virtual presence, depending on the business goals and the target audience.

Step 4. Creating a virtual presence - The business needs to create its virtual presence. This could include creating virtual stores, showrooms, offices or events. The key here is to create engaging and interactive virtual experiences that engage users.

Step 5. Integration of Blockchain and NFTs - Allows businesses to create and trade digital assets such as virtual products, art or other unique objects. Blockchain provides security and ownership of these assets, which creates new opportunities for monetization.

Step 6. Virtual marketing strategies - The business must develop marketing strategies to reach the target audience in the Metaverse. This can include creating interactive advertising campaigns, hosting virtual events and collaborations with influencers from the virtual environment.

Step 7. Engaging with consumers - Businesses should provide opportunities to interact with customers, such as personalized experiences, virtual consultations and real-time support. The goal is to create a long-term relationship with customers that will keep them on the platform.

Step 8. Measuring results - Businesses should analyze engagement, sales and consumer behavior to measure the success of their presence in the Metaverse. Based on this data, the strategy can be refined to improve results.

5. Conclusion

The Metaverse offers significant potential as a platform for business innovation by combining the decentralization of the Web3 with the interactive capabilities of VR and AR. It allows companies to create new user engagement models, innovative products and services, and develop digital assets through NFTs and cryptocurrencies. Metaverse-based virtual economies open for new sources of revenue, while DAOs provide new forms of governance. Despite the challenges, the Metaverse in its role as a digital platform provides significant opportunities for innovation and growth of business in the digital age.

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The Future of Business Innovation Through Generative AI Technologies

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Abstract. Generative AI technologies are revolutionizing various business sectors, providing new ways to automate, personalize and innovate. The aim of the paper is to explore the future of business innovation through generative AI, highlighting its impact on design, manufacturing, logistics, marketing, healthcare and education. Generative AI offers significant benefits such as accelerating new product development, optimizing processes and improving customer experience. However, the use of these technologies also brings challenges, including ethical issues related to intellectual property and employment, as well as the need for regulations. The article predicts that in the coming years, generative AI will play a key role in transforming business models and will continue to drive innovation across industries.

Keywords. Business, innovators, transformations, automation, generative AI

1. Introduction

In recent years, Artificial Intelligence (AI) has become one of the most significant technological breakthroughs, changing the way of work and communications. Generative AI technologies (GenAI), which do not just automate tasks or analyze data, but create something new – texts, images, music and even software code – attract particular attention in this context. These technologies have the potential to transform various aspects of business and be a generator of innovation.

GenAI differs from traditional AI models in that it not only processes and analyzes existing information, but also is capable of creating original content. GenAI-based systems do not simply reproduce what has been learned, but adapt and transform it into something new that can be applied in various business scenarios – from marketing and design to the automation of complex processes.

The technologies behind GenAI are already used in many sectors. Designers can use generative algorithms to create new products and prototypes, which greatly accelerates the innovation process. In manufacturing and logistics, AI systems can optimize

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processes, offering new solutions to improve efficiency and reduce costs. Generative AI plays a key role in healthcare, helping to discover new drugs, diagnostics and personalized therapies. Companies can use GenAI in marketing and advertising to generate personalized content for their customers, creating deeper and more engaging interactions.

Despite the enormous opportunities that GenAI provides, there are also challenges. One of the main issues facing companies is related to intellectual property rights. The issue of ownership and rights to a product created by GenAI system is particularly important when it comes to creative industries such as art, literature and music, where authorship plays a central role. The deployment of GenAI also raises fears of job losses as automation replaces some human activities. All that raises questions of social responsibility and the need for regulations to protect both employees and consumers.

GenAI technologies are not only changing the way businesses operate, but also laying the foundations for a new age of innovation. Their ability to create new products, services and solutions, combined with the ability to optimize processes and reduce costs, makes GenAI a major driver of the future of business innovation.

Figure 1 shows the GenAI market size in the period 2023-2033 in billion dollars [1].

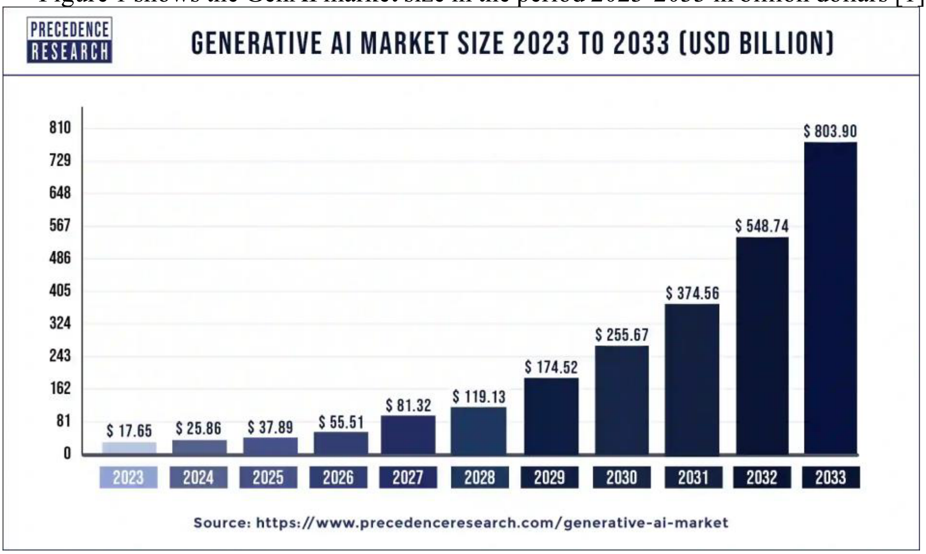

Figure 1. The GenAI market size in the period 2023 – 2033.

2. Theoretical Foundations of GenAI

Generative Artificial Intelligence (GenAI) is a class of algorithms that have the ability to generate new data or content based on a training set of examples. Unlike discriminative models, which focus on classifying input data, generative models attempt to understand and reproduce the structure of the data. The basis of GenAI lies in machine learning and deep learning, which are built on several key concepts [2, 3, 4].

Machine learning (ML) is the foundation of GenAI. Algorithms are trained on large volumes of data to recognize patterns and relationships, which they can then use to make decisions or generate new examples. At the center of machine learning lies the theory of probability and statistics, which allow models to make predictions or make decisions based on uncertain data.

Deep learning (DL) is a subset of machine learning that uses multi-layer neural networks to extract complex dependencies in data. In GenAI models, deep neural networks play a key role, being used to learn and reproduce complex patterns from data. A key feature of these networks is the fact that they can handle many different types of data, including text, images and audio.

GenAI consists of different generative models. The most famous and used models include:

- Generative Adversarial Networks (GANs): There are two models - a "generator" and a "discriminator" that work in competition. The generator creates new examples while the discriminator tries to determine whether an example is real (from the training set) or false (generated by the generator). Over time, the generator gets better at creating realistic data, and the discriminator is trained to recognize these fakes.
- Variational Autoencoders (VAEs): These are neural networks that learn the probability distribution of data and generate new examples by sampling from that distribution. VAEs have two main components - an "encoder" that compresses the input data into a latent space, and a "decoder" that restores that data back to its original form.
- Transformer models (Transformers): Transformers are deep neural networks that have established themselves as powerful generative models, especially in the field of natural language processing (NLP). One of the most famous examples is the GPT (Generative Pre-trained Transformer), which is capable of generating consistent and coherent text based on a given input.

Training generative models is a complex process that requires large amounts of data. The main goal of the training is the model to "learn" the structure of the data and to be able to generate new examples that are close to the real ones. This is done through optimization of the model parameters, which are adjusted to minimize the difference between the generated and real data. Models are often trained in repeated cycles until they achieve optimal performance.

Despite the enormous potential of GenAI, it faces several challenges. One of the main problems is the reliability of the generated data. Models can generate content that is difficult to distinguish from the real thing, but sometimes they can also create false or misleading information. This raises ethical questions about trust and responsibility in the use of GenAI. Other challenges include computational complexity and the need for large volumes of training data, making the development process resource intensive.

3. The Role of GenAI for Innovation in Various Business Sectors

GenAI technologies provide the ability to create new products, services and solutions, combined with the ability to optimize processes and reduce costs.

Figure 2 shows main business sectors for innovation by GenAI.

Figure 2. Main business sectors for innovation by GenAI.

3.1. GenAI for innovation in product design

One of the main benefits of GenAI in product design is the automation of the creative process [5, 6, 7, 8]. GenAI models can generate multiple variants based on set parameters such as form, function, material and aesthetics. This allows designers to explore a variety of concepts that would otherwise require significant time and resources. Generative algorithms use large databases of previous projects to create new solutions that combine aesthetics and functionality. This automation shortens development time and accelerates the innovation process.

GenAI also offers better product optimization. Models can simulate and test different design options, finding the most efficient and appropriate solutions. GenAI can optimize shape and structure to make products lighter and stronger, which not only improves product quality, but also reduces material and manufacturing costs. GenAI technologies analyze a number of factors, such as robustness, material economy and environmental requirements, to generate optimal solutions.

GenAI also helps product personalization. Nowadays consumers are increasingly looking for products that are customized to their needs and preferences. Using generative models, companies can create unique products for each customer, with AI generating custom designs based on specific criteria such as size, shape, style and material.

Visualization is also one aspect where GenAI plays an important role. Models like DALL-E and other generative imaging systems can create high-quality visualizations of products before they are manufactured. This allows designers and manufacturers to evaluate products in 3D form or see how they will look in a real environment. This process not only facilitates decision-making during design, but also facilitates better communication with clients and partners.

GenAI also promotes sustainability. By optimizing materials and manufacturing processes, AI can offer solutions that reduce the waste and energy needed to produce products.

Despite the many advantages, the challenges facing GenAI in product design do exist. One of the main problems is the lack of full human control over the creative process, which can lead to undesirable results or products that do not meet aesthetic or functional requirements. The use of these technologies requires a high level of technical expertise, which limits their spread to smaller companies.

Nevertheless, GenAI is fundamentally changing product design by offering new opportunities for automation, optimization and personalization. These technologies accelerate innovation and help create more efficient and sustainable products that meet the needs of today's consumer and market.

GenAI can generate solutions for material allocation or process optimization to increase efficiency and reduce costs. The General Electric company make uses of it to optimize the design of aircraft engine parts, which result in more efficient and lightweight components.

3.2. GenAI manufacturing innovation

The technology can create multiple variations of the same structure based on certain parameters such as strength, weight and material consumption. Generative algorithms simulate and analyze these options to find the optimal solution that combines efficiency and economy. This allows the creation of products that are lighter, stronger and easier to manufacture [9, 10, 11, 12, 13].

GenAI supports the automation of manufacturing processes. By analyzing large amounts of data from sensors and machines, GenAI can discover patterns that show how to optimize different stages of the production cycle. This includes automating tasks such as machine setup, quality control and production line monitoring. In this way GenAI systems not only increase efficiency, but also reduce the likelihood of errors and unplanned interruptions. This is of primarily importance in industries such as electronics, where accuracy and quality are critical to successful production.

An important aspect of GenAI in manufacturing is the optimization of resources and materials. By generating multiple scenarios for using different materials and production methods, AI can suggest the most effective combinations that minimize waste and reduce costs. This approach supports efforts for sustainable production and reduction of harmful impacts on the environment.

GenAI also promotes manufacturing flexibility. By analyzing dynamic market conditions and demand for different products, AI can help companies adapt their production lines more quickly and efficiently. This is especially important in industries such as consumer electronics and fast moving goods, where demand shifts can occur unexpectedly.

GenAI also plays a role in predictive maintenance of production machinery. By analyzing data from sensors, AI systems can predict when a machine might break down or when maintenance is needed. This allows manufacturers to plan maintenance more efficiently, reducing downtime and costs associated with unscheduled repairs.

One of the challenges in using generative AI in manufacturing is its integration with already existing systems and technologies. Implementing AI requires significant investment as well as having the technical skills to work with these new technologies. There is also a need for reliable data to feed AI models to generate accurate and useful results.

3.3. GenAI for logistics innovation

Supply chain optimization is one of the main applications of generative AI in logistics [14, 15, 16, 17, 18]. The technology can analyze vast volumes of data on demand, inventory, production capacities and transportation options to generate the best supply chain management strategies. This includes forecasting demand, determining the optimal quantities of goods to stock, as well as suggesting the most efficient methods of transportation. GenAI helps avoid shortages and overstocks while improving just-in-time delivery and reducing warehousing costs.

Route optimization is another key aspect of logistics where GenAI is has a significant impact. AI algorithms can analyze real-time data on traffic, weather conditions, fuel prices and other factors to generate optimal delivery routes. This reduces transport time and fuel costs while minimizing environmental impact through more efficient use of resources. GenAI can also foresee potential problems along the route, such as traffic jams or adverse weather conditions, and suggest alternative solutions before those problems affect deliveries.

In the field of warehousing and inventory management, GenAI offers solutions for more efficient organization of warehouse spaces and management of goods. Algorithms can analyze ordering and delivery patterns to optimize the arrangement of products in warehouses so that storage and retrieval processes are faster and more efficient.

AI systems can also predict when inventory needs to be replenished, thereby reducing the risk of stockouts and increasing customer satisfaction. This is especially important for companies with a high volume of orders, where fast processing and shipping of goods is essential.

Personalized supply planning is another application of GenAI in logistics. By analyzing customer behavior and preferences, AI systems can generate personalized delivery solutions that meet each customer's needs. This improves the user experience and increases loyalty to the company.

Maintenance and management of logistics assets also benefits from GenAI. By analyzing data from sensors located on vehicles and logistics facilities, AI can predict when machinery or vehicles need maintenance. This helps prevent breakdowns and reduce downtime due to breakdowns, resulting in more efficient and reliable operations.

Security in logistics can also be improved through the use of GenAI. Technologies can analyze risk data and generate strategies to prevent theft or loss of goods in transit. This is especially important for companies that operate in global supply chains, where the risk of theft and loss is higher.

Challenges to implementing GenAI solutions in logistics include the need for investment in technology and infrastructure, as well as staff training. Certain companies may encounter difficulties in integrating AI solutions with existing supply chain management systems.

GenAI can analyze real-time traffic, weather conditions and other factors to suggest new routes that reduce fuel costs and transport time. Amazon uses AI to optimize its logistics operations, thus significantly reducing delivery times.

3.4. GenAI for innovation in advertising and marketing

One of the main applications of GenAI in advertising is automated content generation [19, 20, 21, 22, 23, 24, 25]. Marketers now use AI models to create ads, copy blog articles, social media posts and personalized emails. This saves time and resources that were previously needed to manually write content. Due to the GenAI ability to analyze and understand user behavior, systems can generate texts that are not only relevant, but also optimized for a specific audience, increasing engagement and the effectiveness of marketing campaigns.

Personalization is a major factor for successful marketing, and GenAI enables companies to create personalized messages and experiences at scale. Thanks to the analysis of user data, AI systems can generate personalized offers, content and advertising campaigns that are tailored to the preferences and needs of individual users. This greatly improves the user experience and increases the likelihood of conversion and brand loyalty.

GenAI also helps create visual content in advertising. Models such as DALL-E allow the generation of images based on textual descriptions, enabling the rapid creation of advertising banners, graphics and visual materials without the need for human intervention. This not only reduces the time to create content, but also opens new opportunities for innovative and non-standard visual solutions that can attract the attention of users and create a strong emotional connection.

Beyond content creation, GenAI has the potential to optimize strategic marketing processes. AI systems can analyze huge volumes of data and offer solutions for the optimization of advertising campaigns in real time. This includes automatically setting ad budgets, choosing the best ad formats and platforms, and targeting the right audience. In this way GenAI helps marketers make informed decisions that lead to higher results and profitability.

Creativity also benefits from these technologies. GenAI enables marketers and advertising agencies to experiment with new ideas and concepts by generating multiple variants of creative materials in a short amount of time. This allows testing different approaches and finding the best working solutions without requiring a significant resource to develop each individual idea.

3.5. GenAI for healthcare innovation

Disease diagnosis and prediction are of the most significant applications of GenAI in healthcare [26, 27, 28, 29, 30, 31]. GenAI models can analyze medical images, genetic data and clinical results to detect abnormalities and symptoms of various diseases at much earlier stages than traditional methods. AI models like those used in radiology can automatically detect tumors or other changes in X-rays or CT scans, leading to faster and more accurate diagnosis of cancer and other serious diseases.

GenAI systems can use historical patient data and create predictive models about the likelihood of developing certain diseases. This allows doctors to implement earlier interventions and offer personalized prevention plans, which significantly improves the prognosis for patients.

The development of new drugs is a process that has traditionally been extremely complex, expensive and time-consuming. GenAI models can analyze thousands of compounds and molecules to suggest new combinations that can be used to create effective drugs. Generative models such as those used in bioinformatics can simulate chemical reactions and predict how certain molecules will interact with target proteins in the body. GenAI is capable of not only discovering new molecular structures, but also predicting how they can be improved to be more effective or less toxic to the body. All this shortens the time to develop new drugs and significantly reduces costs, helping pharmaceutical companies to identify potential drug candidates much faster.

Personalized medicine through GenAI offers individualized treatment approaches based on the genetic profile and unique characteristics of each patient. By analyzing genetic and medical data, AI can generate personalized therapies and recommendations that are most appropriate for the specific patient. This ability to personalize treatment not only improves patient outcomes, but also reduces unwanted side effects, ensuring that each patient receives the optimal therapy for their needs.

Virtual assistants and telemedicine through GenAI solutions support the expansion of telemedicine. With the help of chatbots and virtual assistants, patients can get quick answers to their questions, consult about minor symptoms or schedule appointments with doctors. This facilitates access to healthcare services and improves communication between patients and healthcare facilities.

3.6. GenAI for innovation in education

GenAI is changing the way students learn, and educators teach, providing new opportunities for personalized learning, creating educational content, and supporting the teaching process [32, 33, 34, 35, 36, 37].

Personalized learning with GenAI systems can analyze the needs, interests and progress of each student, to offer individualized learning paths. They can generate personalized tasks, materials and exercises that are tailored to the student's level of knowledge and learning style. This helps each student learn at his or her own pace, getting the support they need at the right time. The approach is particularly useful in distance and online learning, where teachers often do not have the opportunity to interact individually with each student. GenAI can suggest resources to answer the specific questions of the students and adapt lessons to their needs. This significantly improves learning effectiveness and student engagement.

Creating educational content with GenAI can automate the creation of educational content. Models like GPT can generate texts, study materials, and even test questions that are tailored to specific topics and difficulty levels. Such an approach saves educators time and effort in developing learning materials while providing quality learning resources. GenAI technologies can also create visual content –graphs, charts and images that explain complex concepts in an accessible way. In the sciences, AI can generate visual simulations that show processes such as chemical reactions or physical phenomena, greatly aiding the understanding of abstract ideas.

Facilitating distance and hybrid learning through GenAI plays an important role in supporting these new forms of education. Through virtual assistants and chatbots, students can get answers to their questions at any time without having to wait for help from a teacher. These technologies provide ongoing support to students and facilitate their communication with the learning system. AI can also generate video lessons and educational materials that explain lesson content in different ways. This makes learning more accessible to students who have different learning styles or who cannot attend classes in real time.

3.7. GenAI for innovation in the Metaverse

The economic model of the Metaverse is based on virtual ecosystems where users interact through digital avatars and transact in digital currencies, mostly based on blockchain technology [38, 39, 40, 41, 42]. In the Metaverse, the economy includes buying and selling of virtual goods and services such as real estate, accessories and digital assets such as non-fungible tokens (NFTs). Users and businesses can create and monetize content, while the virtual environment is managed by decentralized platforms or companies. One of the main applications of GenAI will be the automated creation of content in the Metaverse. This includes the generation of virtual environments, objects, avatars and interactive scenarios that can be adapted to the needs of users. Businesses could use GenAI to create personalized products and services for the customers, which will increase their engagement and loyalty.

GenAI will facilitate the creation of new business models based on decentralized platforms and digital assets. Companies will be able to offer unique digital products and services, which will provide new forms of value. GenAI will support the automation of business processes in the Metaverse. GenAI-based virtual assistants will assist users with information and personalized recommendations, and companies will automate communication and customer service through real-time interactive chatbots.

GenAI, with its ability to generate dynamic and adaptive solutions, will be a major catalyst for innovation in the Metaverse, creating new opportunities for businesses and consumers in a fully digital world.

GenAI can be used in the Metaverse to create virtual objects, avatars, and environments. Platforms like Decentral and use the technology to create personalized virtual worlds where users can interact, buy virtual goods and even create own virtual stores. Gen AI will play an important role in creating these virtual business ecosystems.

4. GenAI Benefits for Business Innovation

Accelerating innovation and creating new products through GenAI offers new solutions and approaches that people were not be able to think of on their own. By analyzing historical data and identifying hidden patterns, AI offers innovative ideas for product design and features [43, 44, 45, 46]. This is particularly useful in industries such as automotive, electronics and fashion, where creativity and speed are key.

Product customization is also greatly facilitated through the application of GenAI. The technology enables the creation of products adapted to the individual preferences of customers, which increases the satisfaction and competitiveness of the company.

Optimizing and automating routine and complex processes with GenAI includes administrative tasks such as inventory management, document processing, customer request management and data maintenance. Automating these processes allows employees to focus on more strategic tasks, such as creative and analytical activities, resulting in higher productivity. Optimizing resources by analyzing large volumes of data can suggest the best ways to use materials, time and human resources. GenAI technology can analyze business processes and offer real-time optimizations that reduce redundant operations and improve employee efficiency

Predicting future trends and detecting potential problems, allowing companies to be more flexible and adaptive in managing their processes can be supported by GenAI to create action scenarios in case of market changes or risk factors, which provides proactive approach to managing business operations.

Predictive maintenance of machinery and equipment by analyzing data from sensors can predict when maintenance is needed, thus preventing unwanted breakdowns and downtime. This results in better asset management and reduced costs associated with unplanned repairs.

Improving customer experience through personalized solutions leads to greater customer engagement and satisfaction. By analyzing large volumes of data, including user preferences, behaviors and interactions, AI can create personalized experiences that meet the specific needs and desires of each customer. GenAI can create personalized content for each customer. This includes targeted advertising campaigns, emails and marketing messages that are tailored to the interests of the individual user. Personalized content not only makes communication more effective, but also creates a sense of individual attention, which increases customer loyalty to the brand.

5. GenAI Challenges and Ethical Issues in Business Innovation

The challenges and ethical issues surrounding the use of GenAI are many [47, 48, 49, 50]. Intellectual property on products created by GenAI is one of the main challenges associated with its deployment. In traditional creative processes, intellectual property rights belong to the creator of the product, but when AI generates content such as texts, images, music or even product design, it is not clear who should own these rights. The lack of clear legal frameworks around this issue creates uncertainty and can lead to legal disputes and conflicts between different parties. There is also a risk of copyright infringement as GenAI can generate content that is similar to or based on pre-existing works. Transparency and trust in decisions made by GenAI is another essential ethical issue. GenAI solutions often function as “black boxes” – they provide results and solutions, but the process of making those decisions can be difficult for humans to understand. This raises issues of trust and liability, as businesses and consumers may struggle to understand how and why AI made certain decisions. Lack of transparency can be problematic in critical sectors such as healthcare, finance and law, where wrong decisions can have serious consequences. In order to strengthen trust in GenAI systems, it is necessary to develop technologies and approaches that allow greater transparency and traceability of the decisions made. There should be clear accountability mechanisms for errors or incorrect inferences on the part of the GenAI.

The potential displacement of jobs through the automation of tasks that were previously performed by people, such as content creation, design, diagnostics and administrative activities, may lead to a decrease in labor demand in certain sectors. This raises concerns that GenAI technologies will lead to job losses for many people, especially in lower-skilled positions.

The development of GenAI requires the introduction of clear regulations and ethical frameworks to ensure its responsible use. The rapid progress of GenAI technologies often outpaces legal and ethical norms, creating a vacuum in the governance of these technologies. Without regulations, there is a risk of AI being misused, such as creating misinformation, falsifying content, or using AI for illegal activities.

Regulations should cover issues such as personal data protection, ethical norms for AI decision-making, as well as protection of consumer rights. It is also important to define clear responsibilities for companies that develop and use GenAI to prevent unethical behavior. Ethical frameworks should promote transparency, fairness and responsible use of AI while ensuring that these technologies are developed in a way that benefits society as a whole.

6. Conclusion

GenAI is becoming a major driver of business innovation, offering unprecedented opportunities for automation, new product creation and process improvement. Over time, these technologies will develop at an even greater speed, with GenAI becoming an integral part of every industry, from manufacturing and healthcare to marketing and finance. Companies will have the ability to generate customized solutions in real time, optimize their processes and create new, innovative products faster and more efficiently. At the same time, GenAI also raises a number of ethical questions and challenges related to intellectual property, transparency of decision-making and potential job displacement. It will be necessary to put in place clear regulations and ethical frameworks to ensure the responsible use of these technologies. With the right implementations, GenAI has the potential to transform business models, improve efficiency and drive innovation at a global level, providing competitive advantages for companies that use it effectively.

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Evaluating the Manufacturing Enterprises' Digitalization: From the Organization-Environment Nexus Perspective

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Abstract. With the growth of Data Science, digital transformation has become an essential path to sustainable development in the manufacturing industry. In order to help the government make a more effective and accurate assessment of the current state of digital transformation in the manufacturing sector, we construct a measurement system for corporate digital transformation by integrating internal and external perspectives. The internal organization's focus is measured through annual reports, MD&A texts, customer and supplier state, and intangible assets, while the external environment's focus is measured through analyst reports, news reports, and investor Q&A texts. We conduct an empirical analysis of 175 listed manufacturing companies in the Beijing-Tianjin-Hebei region, with results indicating: (1) The digital transformation measurement method that integrates internal and external concerns can compensate for the insufficiency of a single perspective on digital measurement, effectively capturing the interaction between internal organizations and the external environment to achieve a comprehensive assessment of digitalization. (2) The region's overall level of digital transformation is relatively good, suggesting that digital transformation has shifted from an externally environmental-driven model to an internally organizational-driven one.

Keywords. Digitalization, Organization-Environment Nexus Perspective, Natural Language Processing, Manufacturing Enterprises

1. Introduction

The 20th National Congress of the Communist Party of China has emphasized the necessity of anchoring economic development firmly within the tangible economy, advocating for the advancement of a new era of industrialization and the accelerated construction of a leading manufacturing power. Manufacturing is the foundation of the real economy, and digital transformation is a major way to sharpen the competitiveness of manufacturing. The digitalization of manufacturing enterprises refers to the comprehensive optimization and upgrading of the manufacturing production process, product design, supply chain management, and other aspects by means of digital

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technology and information technology [1]. to improve production efficiency, product quality, and market responsiveness. Digital transformation has become a key path to enhancing manufacturing enterprises' competitiveness and achieving sustainable development. The evaluation of digital transformation determines the transformation effect and development potential of the manufacturing industry. How to build an objective and comprehensive index system for measuring the digital transformation of manufacturing enterprises has become the basis of scientific evaluation.

Scholars have begun to pay attention to the methods and practices of enterprise digital measurement. They have built a variety of enterprise digital index systems by collecting a large amount of enterprise data. Pan and his partners have constructed the evaluation index system for the digital level of China's industrial industry from the dimensions of informationization, networking, intelligence, and greening [2]. Zhang and other scholars have built an index system for measuring the digital transformation level of Shaanxi equipment manufacturing enterprises from the management level based on four dimensions: management model reform, organizational restructuring, production process intelligence, and service model innovation [3]. On the other hand, other scholars have constructed a framework for Germany's digital transformation, including operational changes, digital transformation responsibilities, organizational capacity building, and organizational positioning of new activities based on the structural requirements of Germany's digital transformation [4]. In the measurement method of enterprise digital transformation, scholars try to use various quantitative methods to measure the digital level of enterprises, including AHP, entropy weight method, and so on. Zhu and others used the AHP-DEMATEL method to build a model to measure the digital transformation level of construction enterprises [5]. Chen used a fuzzy comprehensive evaluation method to measure the digital transformation level of SMEs [6]. These methods can objectively evaluate the digitalization level of enterprises from different angles and provide scientific decision support for enterprises. With the process of digitalization, in order to make up for the subjective limitations of the above measures, we began to increase the comprehensiveness and accuracy of the measures through data driving. Scholars began to mine the internal and external enterprises' data through big data analysis, machine learning, and other technologies [7] and use the data to describe the digital transformation process and its effects on enterprises.

To sum up, the current research on digital transformation measurement has the following problems: First, the measurement index system of enterprise digital transformation lacks integrity. The existing research only designs the index system from the perspective of enterprise internal management, which ignores the effect of the external evaluation. It limits the comprehensive understanding and effective management of the enterprise's digital transformation process. Secondly, the source of measurement data is too limited. Therefore, in order to help manufacturing enterprises evaluate the progress and effectiveness of their digital transformation more accurately, this study not only considers the internal factors of the organization but also integrates the external environmental factors of the organization to design the digital transformation index system of manufacturing enterprises. It realizes the measurement of digital transformation of manufacturing enterprises by depicting the interaction between organization and environment, making up for the lack of a singular research perspective. It can not only help manufacturing enterprises evaluate the degree of digital transformation of themselves and their partners but also help the government effectively evaluate the status quo of digital transformation in the manufacturing industry, accurately formulate industrial policies, and achieve high-quality development.

2. Construction of digitalization index system of manufacturing enterprises from the perspective of organization-environment interaction

From the motivation analysis, the digital transformation of manufacturing enterprises is a strategic behavior aimed at aligning internal processes with the digitalized technological competitive environment. Therefore, the digital transformation of manufacturing enterprises is not only dependent on the internal organization's digitalization level but also affected by policy and external market environments. On the one hand, manufacturing enterprises are influenced by the promotion policy to greatly improve their own digitalization level. However, the overall digital transformation upgrade of the manufacturing industry also affects the market and investors' decision changes. This dynamic interactive process reflects the matching logic with the organization-environment theory. Therefore, this paper introduces the organizational-environment perspective, paying attention to the internal digitalization process of the organization while considering the external policy and market environment's impact on the enterprise's digital transformation.

2.1 Organizational dimension: full chain internal digitalization of enterprises

1) Strategy and Management Correspondence

For the internal organization of an enterprise, the direction guidance of the strategic layer and the real-time control of the management layer are the core of the entire enterprise's internal digitalization process. By deeply understanding the internal management and strategic direction of the enterprise, especially the detailed description and plan of digital investment and implementation, it can effectively evaluate the internal digitalization level of the enterprise. It can not only reveal the investment strategy results of the enterprise in the digitalization field but also reflect the attitude and degree of attention of the enterprise's management layer toward digital transformation.

2) Customer and supplier linkage

Considering the characteristics of manufacturing enterprises, production is the core business, and the supply of products and the connection with customers are the key points of the entire enterprise operation. The digitalization level of suppliers and customers directly affects the operating efficiency and market competitiveness of the enterprise, and it is of great importance to evaluate the completeness and effectiveness of the enterprise's internal focus on digitalization. Analyzing customers and suppliers can not only reveal how the enterprise optimizes its supply chain management through digitalization technology but also evaluate its digital influence in the entire supply chain.

3) Technological manifestation of intangible assets

Intangible assets serve as a pivotal indicator in assessing a company's innovative capacity and technological acumen, playing an essential role in the digital transformation of manufacturing enterprises. Analyzing a company's intangible assets can evaluate the investment in technology and intellectual property, as well as the efficacy of their application in the digital transformation process. Furthermore, the stewardship and utilization of intangible assets are critical for gauging the level of internal digital focus within a company, directly impacting its position and competitiveness in the digital arena.

2.2 Environmental dimension: multiple factors work together to accelerate digital transformation

1）Market preference

For the external environment, the influence of market preferences and industry trends on enterprises should not be underestimated. A company's business and technology prospects are closely related to market preferences, and understanding the market response to an enterprise's digital transformation can further assess its performance and potential in the digital economy. Understanding whether a company's core business is aligned with industry trends can provide insight into the company's digitalization level.

2) Policy preference

Nowadays, the government has promoted various policies and measures through the Ministry of Industry and Information Technology to guide enterprises to carry out digital transformation. Deconstructing the digital measures contained in the policies can help enterprises understand the government's goals and point direction for them.

3) Investor preference

The level of public and investor interest in a company's digital transformation and how this transformation is interpreted and evaluated by the media and the public can help reveal the external market's response to and expectations of a company's digital strategy. Then, construct a more comprehensive enterprise digital evaluation model.

To sum up, based on the Organization-Environment nexus perspective, we find that from the organizational level, strategic digital investment, management digital level, the digitalization level of supply chains, and the digitalization results of intangible assets determine the digitalization level of internal organizations. At the environmental level, market preferences, industry trends, government policy guidance, and investor preferences together constitute the external environment and drive the digital transformation of manufacturing enterprises. Figure 1 shows the construction of the index system.

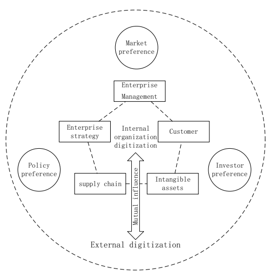

Figure 1. Research framework

3. Index measurement of digital transformation of manufacturing enterprises from the perspective of organization-environment

From the organization-environment perspective, the index of organization dimension can measure the process of digital transformation with the help of the data of the organization's internal management, and the index of environment dimension can mine the environment and effect of enterprise digital transformation with the help of third-party text data. To enhance the objectivity of measurement indicators, this study refers to the dictionary method of the current mainstream research, describing the transformation degree by using the word frequency related to "enterprise digital transformation" in the annual report of listed enterprises [8]. Meanwhile, to improve the problem of a single source of word frequency statistical samples in the mainstream dictionary method, the accuracy of the new data source commission measure is introduced.

3.1 Enterprise digitalization from the internal perspective of organizational dimension

Enterprise digitalization is measured from the internal perspective of the organizational dimension. At the strategic level, this paper obtains the complete text of annual reports and word frequency statistics of A-share manufacturing listed enterprises over the years from Juchao.com, the enterprise information disclosure platform designated by the CSRC. The text of the annual report contains key information about the enterprise's operating results, financial status, future development strategy, and risk management. Through the structured statistics of the digital transformation of the text of the annual report, the strategic digitalization level is obtained. At the management level, we obtained the Management Discussion and Analysis texts of A-share listed manufacturing companies over the years from Juchao.com, which focused more on the management's understanding and interpretation of financial performance and provided investors with more in-depth insights. At the customer and supplier level, this paper compares and selects the data of the CCER economic and financial database and the CNRDS digital transformation database. As one of the earliest economic and financial data service platforms in China, the CCER database provides a wide range of business data, including customer and supplier information. The CNRDS Digital transformation database specifically collates and analyzes the data of supply chain-related parties from a digital perspective. Through the structured statistics of the word frequency of digital transformation of the supplier's annual report and the customer's annual report, the digitalization level of the supplier and the customer is obtained. In terms of intangible assets, this paper selects data from the Wind database, a leading financial data service platform in China. The Wind database provides detailed data related to intangible assets of listed companies, including but not limited to the quantity and quality of intangible assets such as patents, trademarks, and copyrights. Intangible assets, as an essential index to evaluate the innovation ability and technology accumulation of enterprises, play a crucial role in the process of digital transformation. By analyzing the intangible asset data of enterprises, this study can evaluate the investment of enterprises in technology and intellectual property and the effect of their application in digital transformation. In addition, the management and application of intangible assets are also important aspects of measuring the level of digitalization within the enterprise, which is directly related to the status and competitiveness of the enterprise in the digital competition.

The digitalization measurement index system of the internal organization of manufacturing enterprises is constructed, as shown in Table 1 below.

Table 1. Digital measurement index system of internal organization of manufacturing enterprises

Measurement dimension	Index name	Indicator specification
Internal organization digitalization	Strategic digitization	Annual report text digital transformation word frequency structured statistics
	Management digitization	Management discussion text digital transformation word frequency structured statistics
	Supplier digitization	Supplier report digital transformation word frequency structured statistics
	Customer digitization	Customer report digital transformation word frequency structured statistics
	Digitization of intangible assets	Structured statistics of word frequency in digital transformation of intangible assets text

3.2 Measurement indicators of environment dimension

To measure enterprise digitalization from the external perspective of the environmental dimension at the market level, this paper selects the text data of analyst reports of the Radish Investment Research platform. Due to its rich, comprehensive, and highly professional data, this website can provide solid data support for this study. As an important source for evaluating the company's business and technology prospects, the analyst report can be deeply understood from the perspective of market and professional analysts through the structured statistics of text digital transformation word frequency. In addition, the data and opinions in the analyst reports provide a unique perspective for this study, namely market expectations and industry trends, which are of great significance for measuring the external market preferences of companies. Through a comprehensive analysis of these reports, this study is able to grasp the market response of enterprises to digital transformation and further assess their performance and potential in the digital economy.

At the policy level, news report data is obtained from the China Research Data Service Platform, a professional database developed based on the digital transformation of listed companies. Through the analysis of the digital word frequency involved in news reports, the digital process of enterprises is more objectively displayed, reflecting the role of policy preferences in promoting their digital transformation.

From the perspective of investors, the text of investor question and answer is obtained from the CNRDS, and the text analysis is carried out. Doing so can provide a comprehensive understanding of how investors are paying attention to digital transformation and how this transformation is being interpreted and evaluated by the media and the market. This is especially important for building a comprehensive enterprise digital evaluation model that can help reveal the external market's response to and expectations of the enterprise's digital strategy.

According to the digitalization characteristics of manufacturing enterprises and the construction principles of previous research index systems, the digitalization measurement index system of the external environment of manufacturing enterprises is constructed, as shown in Table 2 below.

Table 2. Digital measurement index system of external environment of manufacturing enterprises

Measurement dimension	Index name	Indicator specification
Digitalization of external environment	Market preference	Structured statistics on word frequency for digital transformation of analyst reports text
	Policy preference	Structured statistics on the degree of digital transformation of news reporting
	Investor preference	Statistics on the total frequency of text digitization in response to investor questions and answers

3.3 Measurement Method

Natural language processing methods are used to process large amounts of textual data, including annual reports, management discussion texts, analyst reports, investor Q&A texts, and news report texts. Through natural language processing technology, text data is transformed into structured data for subsequent statistical analysis and model building [9]. Through this method, this study extracts the keywords matching the word spectrum of the characteristic words of the digital transformation level of the existing digital transformation industry from the text data. It makes statistics on them to obtain the core variables in the original data required for measurement, which provides data support and analysis basis for subsequent research.

For different database information, the data screening process is consistent. Taking news reports as an example, using the data in the CNRDS digital transformation database, the limited time is between 2013 and 2022, and only the sum of the word frequency of each keyword is displayed. Finally, 32,999 pieces of news reports digitalization data, namely text word frequency data, are obtained. Data from manufacturing enterprises in provinces other than Beijing-Tianjin-Hebei were excluded to ensure the accuracy and pertinacity of the samples. Finally, the corresponding data are matched with the securities code to obtain the data of 175 selected enterprises. The specific process is shown in Figure 2.

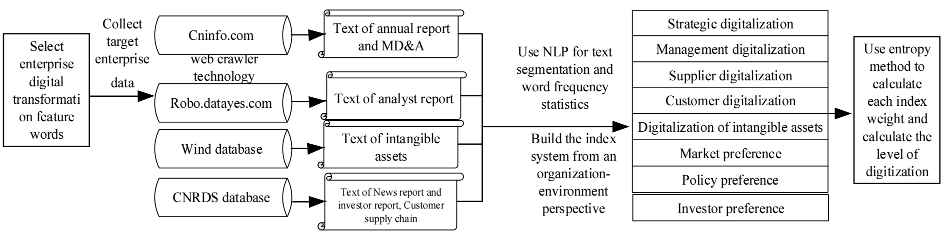

Figure 2. Research procedure diagram

We refer to a series of classic literature on the theme of digital transformation and select the most mainstream enterprise digital transformation characteristic thesaurus including five major fields: artificial intelligence technology, big data technology, cloud computing technology, blockchain technology, and digital technology, as the statistical basis for the word frequency of this study [11].

After constructing the measurement logic and index system of the digital level of manufacturing enterprises, this study uses the entropy weight method to measure the digital transformation level of manufacturing enterprises under each dimension index. The entropy weight method is very objective and based on the data itself, which determines weights by measuring the degree of variation of indicators. It avoids the influence of subjective factors, making the weights more objective and credible. Other reference literature methods were also considered in the study. The detailed method comparison is shown in table 3. However, due to the large amount of data in this study, to ensure the objectivity and credibility of the study, the entropy weight method was ultimately chosen because it does not rely on expert subjective judgments and has better adaptability to the distribution characteristics of the data.

Table 3. Comparison of relevant methods for digital transformation research

Method	Advantage	Scope of Application	Reference
Analytic Hierarchy Process	It can handle decision-making problems that involve both qualitative and quantitative criteria.	Suitable for decision-making problems that need expert views and judgment.	[5]
Entropy Weight Method	It has strong objectivity and does not require subjective judgments, the calculation process is simple.	Suitable for situations with statistically significant and large volumes of data.	[10]
Fuzzy Evaluation	It manages ambiguity and uncertainty well, and is suitable for situations where the indicators are difficult to quantify.	Fit for evaluation problems where indicators are difficult to quantify or involve ambiguity.	[6]

First, the original sample data matrix is standardized to eliminate the influence of units and orders of magnitude between different indicators.

$$\mathrm{r_{ij}} = \frac{x_{ij}}{\sum_{\mathrm{i=1}}^{\mathrm{n}} x_{ij}} \tag{1}$$

r_{ij} is the standardized data, x_{ij} is the element of row i and column j in the original data matrix, and n is the total number of rows of the data.

Secondly, calculate the entropy weight e_j of each index.

$$e_j = -k\sum_{i=1}^{n} r_{ij} \ln r_{ij} \tag{2}$$

Then, calculate the information entropy and index difference coefficient d_j of the standardized data, and finally get the w_j weight of each index.

$$d_j = 1 - e_j \tag{3}$$

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{4}$$

In the following paragraphs, we use the natural language processing method and entropy method to measure and evaluate the degree of digital transformation of manufacturing enterprises based on the digital transformation measurement index system from the perspective of organization-environment.

4. Empirical analysis

4.1 Data source and processing

In this study, the listed manufacturing enterprises in the Beijing-Tianjin-Hebei region during 2013-2022 were selected as empirical samples, and the samples with missing digital index data of more than five years were excluded. 175 enterprises were finally selected, including 108 enterprises in Beijing, 40 in Hebei Province, and 27 in Tianjin. For the missing data, this study combines the mean method and linear interpolation method to supplement and finally get a total of 1750 pieces of aggregated data of 175 enterprises each year.

4.2 Analysis of characteristics of digitalization of Beijing-Tianjin-Hebei manufacturing enterprises

We use the entropy weight method to calculate the weight of the digitalization level of each index of manufacturing enterprises in the Beijing-Tianjin-Hebei region, and the weight value of each index is shown in Table 4.

Table 4. Digitalization index weights of Beijing-Tianjin-Hebei manufacturing enterprises

Year	Annual reports	MD&A	Intangible assets	Supplier	Customer	Investor Q&A	Analyst reports	News reports
2013	0.067	0.038	0.012	0.259	0.259	0.095	0.193	0.078
2014	0.066	0.032	0.042	0.253	0.253	0.081	0.201	0.073
2015	0.064	0.033	0.022	0.247	0.247	0.062	0.247	0.078
2016	0.061	0.030	0.017	0.248	0.248	0.059	0.248	0.088
2017	0.060	0.032	0.013	0.245	0.245	0.070	0.245	0.090
2018	0.061	0.033	0.013	0.274	0.274	0.057	0.179	0.110
2019	0.058	0.030	0.009	0.271	0.271	0.061	0.170	0.131
2020	0.059	0.030	0.010	0.275	0.275	0.062	0.162	0.127
2021	0.051	0.035	0.026	0.263	0.263	0.059	0.172	0.130
2022	0.047	0.026	0.026	0.265	0.265	0.066	0.175	0.129

These weights reflect the relative importance of each indicator in evaluating the digitalization level of an enterprise, and the higher the value, the greater its contribution to the digitalization level.

From the perspective of indicators within the organization, at the strategic level, the weight of digitalization of the annual report text has gradually decreased from 0.067 in 2013 to 0.047 in 2022, and the relative importance of this indicator has a decreasing trend. From a management perspective, the weight of the digitalization of managers' analytical Q&A is relatively stable, decreasing from 0.038 in 2013 to 0.026 in 2022. This shows a slight decline overall. As for a partner, the weight of digitalization of customers and suppliers changed less, from 0.259 in 2013 to 0.265 in 2022. This suggests that the importance of it remained relatively stable throughout the period. For intangible assets, the weight of digitalization in intangible assets has increased from 0.012 in 2013 to 0.026 in 2022. This shows that its importance is increasing year by year.

Firstly, the timeliness of annual report is relatively weak, and as digitalization develops, the importance of annual report for digitalization has been declining due to the exponential growth of instant and diverse data. At the same time, with the continuous development of data analysis tools, production decisions are increasingly inclined to rely on big data, rather than the experience and intuition of managers. The tasks of controlling business processes and market demand, which used to be analyzed by managers, are gradually replaced by big data and intelligent systems, making the internal information of the organization more transparent. Therefore, the weight of management's analysis of digitalization has gradually decreased. On the contrary, intangible assets such as patents, trademarks, and copyrights, which represent intellectual property, are becoming increasingly important in digitalization. Data analysis is the foundation for businesses to gain insights and improve operational efficiency. Therefore, the importance of the digitalization of intangible assets is gradually increasing.

From the perspective of external environment indicators, for investor preference, the weight of the total number of answers to investor Q&A digital questions decreased from 0.095 in 2013 to 0.065 in 2022, indicating that the digitalization of investor Q&A has declined in importance. From a market perspective, analysts report that the weight of digital word frequency has decreased from 0.193 in 2013 to 0.175 in 2022. The importance of the indicators remained relatively stable overall but declined slightly. At the policy level, the weight of digital word frequency in news reports has increased from 0.078 in 2013 to 0.129 in 2022. This shows that the digitalization of news reporting is gradually becoming more important as media and information dissemination methods change.

The importance of investor Q&A digitalization and analyst reports has been declining year by year. Investors' channels for obtaining information are constantly expanding, and they no longer rely solely on time-sensitive reports such as investor digitalization and analyst reports. The public and investors can obtain more transparent and diverse information from news reports and other information channels to help them make decisions. Therefore, their importance in digitalization has been decreasing yearly. At the same time, the importance of news reports has been increasing due to their diversity and quick response.

In general, the weight change trend of each indicator is different. The digital weight of annual report text, management analysis and Q&A within the organization, and investor Q&A in the external environment is declining, while the digital weight of intangible assets and news reports is on the rise. These changes reflect the shifting importance and concerns of the internal and external environment in digital transformation. The digitalization level of manufacturing enterprises in the Beijing-Tianjin-Hebei region also has certain temporal differences in different time periods, as shown in Figure 3.

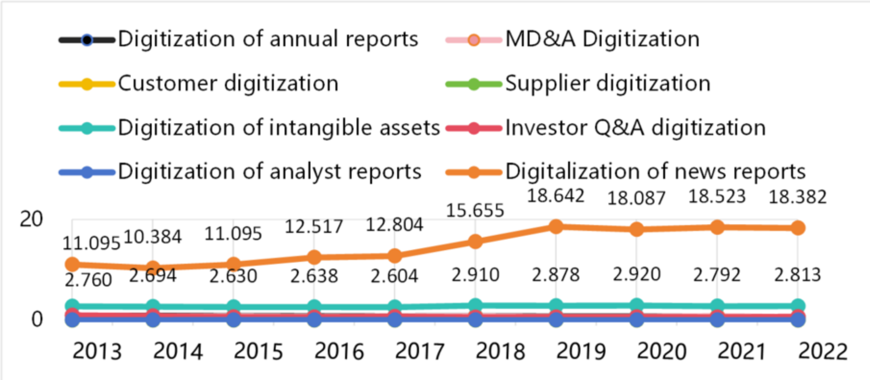

Figure 3. Digitalization sequence change map of Beijing-Tianjin-Hebei manufacturing enterprises

Analyzing the time series, it can be seen that from 2013 to 2022, the digital level of annual reports of manufacturing enterprises in Beijing, Tianjin, and Hebei showed a steady growth trend. Especially in recent years, the digitalization level has increased significantly, indicating that enterprises attach more importance to the digitalization of annual reports year by year. The digitalization of executive analysis and response texts has also increased over the past decade, but the growth trend has been relatively slow. The manufacturing enterprises in the three places have little change in this indicator, and the overall trend is relatively stable. Similar to the digitalization of the annual report text, the digitalization level of intangible assets also shows a steady growth trend. The level of digitalization has increased significantly, indicating that enterprises are paying more and more attention to the digital management of intangible assets. The level of customer digitalization has shown a steady growth trend over the past decade. This may reflect the increasing digital communication between businesses and their customers. The level of supplier digitalization has also grown steadily over the past decade. The importance of supplier digitalization is increasing yearly, and the digital connection between enterprises and suppliers is becoming increasingly close. The change in manufacturing enterprises in the digitalization of investor questions and answers in Beijing, Tianjin, and Hebei is relatively slow, and the overall trend shows steady growth. The emphasis on digitizing analyst reports has also shown a steady increase over the past decade, especially in recent years. The digital level of news reporting has shown a steady growth trend in the past decade, especially in recent years. Enterprises pay more attention to the digitalization of news reports and have more frequent digital communication with the outside world.

In summary, the change trend of various indicators is generally similar, showing a steady growth trend. Although the growth rate of different indicators is different, the overall reflects the trend of enterprises' attention to digital transformation is increasing year by year.

5. Conclusions and Implications

In this research, we conducted a comprehensive assessment of digital transformation from different dimensions. The following implications are obtained by building the index system and analyzing the data.

First of all, by establishing the digital transformation index system of manufacturing enterprises from the perspective of the organization-environment, the digital transformation measurement method integrating internal and external concerns can make up for the deficiency of a single digital measurement perspective and effectively capture the interaction between internal organization and external environment to achieve a comprehensive measurement of digitalization. Secondly, through the research of 175 manufacturing enterprises in the Beijing-Tianjin-Hebei region, it is found that the level of digital transformation in the Beijing-Tianjin-Hebei region is generally good, and the timing difference is large, and the digital transformation has been transformed from an externally driven model to an internally driven model.

The following management implications are proposed: From the organizational dimension, enterprises should further optimize the digitalization degree of annual reports and MD&A, improve the readability and information content of the texts, and thus enhance the trust of investors and stakeholders. When it comes to digitizing customers and suppliers, businesses can enhance customer experience and satisfaction by building more intelligent and data-driven customer relationship management (CRM) systems. In the digitalization of intangible assets, enterprises should attach importance to the protection and management of intellectual property rights, establish a sound intangible assets management system, and promote the transformation of technological innovation and research and development results to improve the core competitiveness.

Enterprises should comprehensively consider the external environment, use big data and artificial intelligence technology to analyze the market and public opinion data, timely adjust corporate strategies, and improve their public image and market-response ability. In terms of news reporting, enterprises should improve the quality of external communication and information disclosure and establish a good corporate image to win public recognition.

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Exploring Digital Transformation in the Grain Supply Chain: A Case Study of the Lu Liang Group

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Abstract. Amid the trend of global economic integration and digitalization, the stability and sustainability of the food supply chain have become a focal point of concern for many. Governments worldwide are promoting the digital transformation of the food supply chain to enhance operational efficiency, strengthen system resilience, and ensure food safety. The use of digital tools has significantly improved the supply chain's response time, providing the flexibility needed to adapt quickly to market fluctuations and potential shocks. However, the digitalization of the food supply chain also faces a series of challenges. This article delves into the patterns of digital transformation, using the Lu Liang Group as a case study to analyze its rationality and feasibility. Through the analysis of the Lu Liang Group, the article aims to provide valuable experience and reference for other companies in the same industry to optimize their supply chain management and play a greater role in the global food security system.

Keywords. Digital transformation; food supply chain; Lu Liang Group

1. Introduction

China, as a traditional agricultural powerhouse, plays a significant role in the country's overall modernization process. Currently, Chinese agriculture is at a critical juncture of transitioning from a smallholder-based system to a modernized agriculture, which is essential for ensuring national food security, enhancing agricultural competitiveness, and achieving sustainable development. Digitalization has become the cornerstone of modernization and innovation, supporting the transformation of industries and economies worldwide[1][2]. As a new engine for economic development, digital transformation provides novel solutions for the modernization of the grain supply chain[3]. However, due to the relatively low value of grain and the significant upfront investment required for digital transformation[4], there are numerous challenges faced during the digital transformation of the grain supply chain [5]. Amid growing concerns over global food security[6], how to enhance efficiency, transparency, sustainability, and ability to tackle various challenges of the grain supply chain through digital means has become a field that urgently needs in-depth research[7]. This study aims to construct a model for the digital transformation of the grain supply chain, taking the practice of Shandong Lu Liang Group as an example to explore its specific applications and

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effectiveness in the digital transformation process, providing a reference for other grain companies and supply chain management.

2. Theoretical Foundation and Literature Review

2.1. Theoretical Foundation

Chen Guoquan (1999) suggests that the concept of the supply chain has evolved from the traditional, expanded production concept. The process, which includes the procurement of raw materials and components, transportation, processing and manufacturing, and distribution, culminating in the final delivery to customers, is regarded as an interlocking chain[8]. This chain is what we define as the supply chain. Supply chain management encompasses the planning, coordination, operation, control, and optimization of the entire supply chain system. The goal is to deliver the right products to the right customers, at the right time and place, in the correct quantity and quality, while minimizing the total cost. Shen Houcai et al. (2000) consider the supply chain to be a business process model. This model encompasses the value chain, starting from the end customer and including raw material and component suppliers, product manufacturers, distributors, and retailers, to fulfill customer demand and provide the necessary products and services[9].

Ma Junkai and others (2023) define the resilience of the grain supply chain as "the capacity of the grain supply chain to withstand and effectively respond to a variety of internal and external shocks and pressures." This includes maintaining stability, preventing disruptions, and adjusting to return to pre-impact operational states[10]. Ideally, the chain should also be capable of leveraging crises as opportunities to innovate and improve its structure in the face of market and environmental challenges, both domestically and internationally. Tao Yaping (2023) further classifies the current grain supply chains in China into four distinct types: processing, wholesale, logistics and distribution, and retail[11].

2.2. Literature Review

Currently, Chinese enterprises generally lack a spirit of cooperation and act independently, which artificially disrupts the connection between supply chain stages, leading to issues such as delayed supply chain response, poor communication, and high supply chain costs.

Li Tianxiang and Zhu Jing (2024), after reviewing the experiences and practices of the United States, Canada, and Japan in developing post-harvest grain services, propose to target the entire chain and actively promote transformation, upgrading, and service extension[12]. The grain supply chain system faces numerous challenges in ensuring an efficient, sustainable, and resilient operation. The digital economy of grain enterprises has experienced two significant leaps: first, from tool-based to intelligent systems, and second, from intelligent to more integrated and systematic approaches. These advancements have bolstered the resilience of the grain supply chain, optimizing the production process, enhancing management capabilities, and upgrading the sales segment. Abduwali Aibai and colleagues (2024) believe that rural digitization directly enhances the resilience of the grain supply chain by bolstering its resistance, recovery, and transformation capabilities[13]. This enhancement is predicated on the endowment and development level of agricultural resources, which are crucial for the digital economy to empower the supply chain's resilience.

Literature review reveals that current research has to some extent focused on exploring how digital transformation enhances the resilience of the grain supply chain by improving its efficiency and transparency, as well as by applying digital technology to make grain production, distribution, and consumption more intelligent and precise. However, there is still a lack of in-depth analysis on the challenges faced by grain enterprises during digital transformation.

3. Internal and External Factors Driving Transformation

Internal factors in corporate digital transformation often include data-driven integration, innovation, operational efficiency, and upgrades in supply chain collaboration. These elements directly affect the feasibility and efficiency of the transformation process. External factors include policy support, shifts in market demand, and technological advancements. Although not directly controlled by organizations, these factors have a profound impact on the direction and strategic decisions of the organization. This article will explore how these factors propel supply chain digital transformation and innovation.

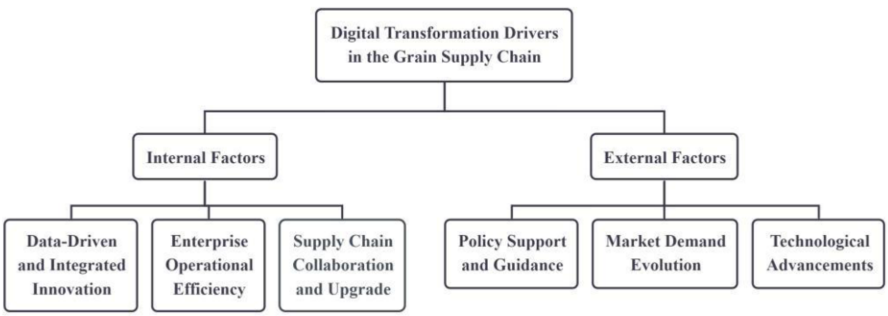

Figure 1. Internal and External Factors Driving Transformation.

3.1. Internal Factors

- Data-Driven and Integrated Innovation

In the digital transformation of the grain supply chain, data-driven and integrated innovation are one of the core internal factors. By leveraging technologies like big data, cloud computing, the Internet of Things, and artificial intelligence, grain companies can achieve real-time monitoring and data analysis of all supply chain stages. This optimizes decision-making, enhances operational efficiency, and improves the ability to respond to market changes. This data-centric culture of innovation is key to propelling the grain supply chain towards intelligence and automation.

- Enterprise Operational Efficiency

Digital transformation significantly impacts business operational efficiency. By adopting advanced information technology, grain companies can automate and optimize production processes, reducing human errors and boosting productivity. With digital supply chain management, businesses can track inventory and logistics in real-time, fine-tune inventory levels, and minimize the risks of overstock or shortage. These efficiency gains not only cut costs but also strengthen a company's competitive edge in the market.

- Supply Chain Collaboration and Upgrade

Supply chain collaboration and upgrading is another crucial internal factor in the digital transformation of the grain supply chain. The application of digital technology facilitates information sharing and process collaboration between upstream and downstream enterprises in the supply chain, enhancing its transparency and coordination. By establishing a unified data platform, all supply chain parties can share inventory, demand, and logistics information in real-time, leading to more accurate supply-demand matching and more effective resource allocation.

3.2. External Factors

- Policy Support and Guidance

The government plays an indispensable role in fostering the digital transformation of the grain supply chain. By enacting and implementing policies, it offers directional guidance and substantial support to businesses, including funding, tax incentives, and research and development grants. The policies and measures collectively constitute a significant external driving force for the digital transformation of the grain supply chain.

- Market Demand Evolution

As consumer demands for food safety and quality increase, market demand evolution becomes another significant external factor driving the digital transformation of the grain supply chain. Consumers increasingly prefer food brands that offer transparent and traceable information, prompting companies within the grain supply chain to meet these needs through digital means. This shift in market demand undoubtedly provides a strong impetus for the digital transformation of the grain supply chain.

- Technological Advancements

Technological advancements provide a solid foundation for the digital transformation of the grain supply chain. New-generation information technologies, such as big data, cloud computing, the Internet of Things, and artificial intelligence, are profoundly changing the way the grain supply chain operates. The application of these technologies not only improves the efficiency and transparency of the grain supply chain but also brings new growth opportunities for businesses.

4. Digital Operation Modes

Han Ji (2024) defines the supply chain as the complex network composed of all individuals, organizations, and companies involved from product production to sales. This article provides a detailed analysis of the digital operation models across various stages of the grain supply chain, including procurement, processing, storage, distribution, and delivery[14].

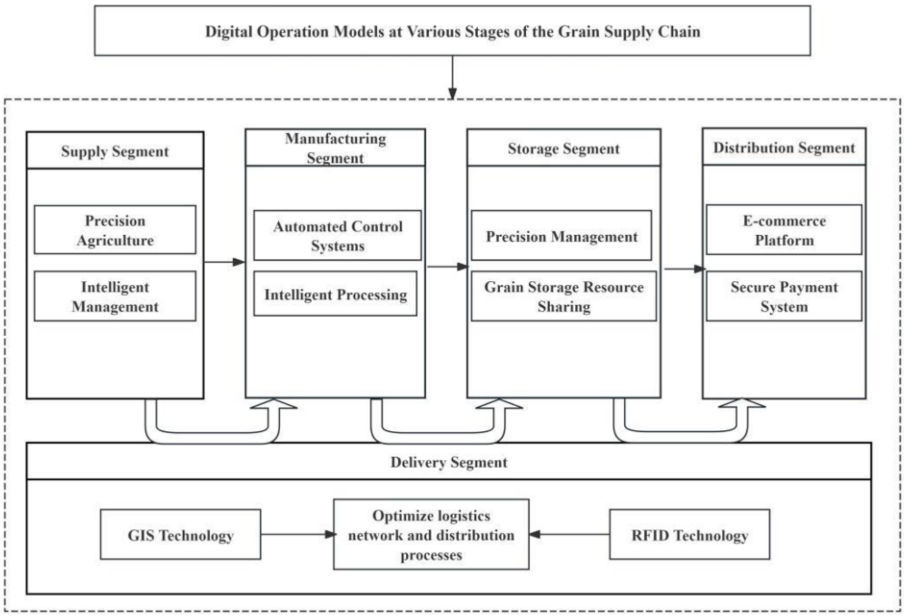

Figure 2. Digital Operation Models at Various Stages of the Grain Supply Chain

4.1. Digital Operation Modes in the Supply Segment

Digital transformation in the supply segment of the grain supply chain is primarily evident in precision agriculture and smart management practices. Using IoT devices and sensors, farmers can monitor crop growth conditions in real time, including soil moisture, temperature, and nutrient levels, leading to more informed planting decisions. Big data analysis predicts crop diseases and market demand, which can optimize planting structures and yields. Blockchain technology ensures traceability of grain sources, enhancing food safety and quality assurance. The application of these technologies not only enhances the efficiency and quality of agricultural production but also solidifies the stability and reliability of the grain supply chain.

4.2. Digital Operation Modes in the Manufacturing Segment

In the grain processing and manufacturing segment, digital technology is primarily applied in the form of automated production lines and intelligent processing equipment[15]. Implementing advanced automation control systems allows grain processing companies to monitor and optimize the production process in real time, thereby enhancing production efficiency and product quality. Furthermore, artificial intelligence and machine learning algorithms enable businesses to analyze production data deeply, predict equipment maintenance requirements, minimize downtime, and maximize operational efficiency. Digitalization also fosters energy conservation and emission reduction in grain processing, supporting the achievement of sustainable development goals.

4.3. Digital Operation Modes in the Storage Segment

Digital technology enhances the intelligence and precision of grain storage management by installing IoT devices, such as sensors for temperature, humidity, and gas, which allow for real-time monitoring of storage conditions. This ensures optimal grain preservation and reduces the risk of loss and spoilage. Big data analysis and forecasting optimize inventory management by predicting storage needs and turnover rates. Digital platforms facilitate the sharing and efficient allocation of grain storage resources, enhancing the utilization and responsiveness of storage facilities. Digital transformation not only ensures the safety and efficiency of grain storage but also solidifies the stability of the grain supply chain[16][17].

4.4. Digital Operation Modes in the Distribution Segment

In the distribution segment of the supply chain, digital transformation primarily involves the construction of e-commerce platforms and the security of payment systems. E-commerce platforms provide online shopping channels, enabling consumers to browse and purchase products anytime, anywhere, which not only enhances the user experience but also expands sales channels for businesses. At the same time, to ensure the security of transactions, payment systems employ encryption technology, security protocols, and fraud detection systems to protect consumers' financial information, ensuring the security and integrity of the data. Through these measures, the distribution segment of the supply chain can operate more efficiently and safely, meeting the needs of modern consumers.

4.5. Digital Operation Modes in the Delivery Segment

Digital transformation in the delivery phase of the grain supply chain enhances efficiency and accuracy by optimizing logistics networks and delivery processes. GIS technology and optimization algorithms plan the most efficient delivery routes, cutting transportation costs and time. RFID technology and real-time tracking systems ensure transparent and traceable grain delivery, guaranteeing timely and quality arrivals. Digital platforms facilitate real-time communication and feedback with customers, thereby improving service quality and satisfaction. Moreover, digital delivery systems can swiftly adapt to market fluctuations and urgent demands, bolstering the supply chain's flexibility and resilience.

5. Case Analysis of the Lu Liang Group

5.1. Basic Overview of the Shandong Grain Group

Lu Liang Group Co., Ltd. is a provincial state-owned key grain enterprise, established in August 2017 by the Shandong Provincial Party Committee and the provincial government to implement the national grain security strategy and enhance Shandong Province's responsibility in grain security. Lu Liang Group focuses on the management of reserved grain as its main responsibility and business, innovatively proposing the work positioning of "reserved grain has to choose me" and the management guidance system of "responsible grain storage, scientific grain storage, and clean grain storage". The group is committed to building a scientific, informatized, and intelligent “Qi Lu Granary”, which is in a leading position nationwide.

5.2. Lu Liang Group's Digital Transformation Initiatives

In response to the national grain security strategy, Lu Liang Group has actively embraced digital transformation and technological innovation to ensure grain safety and promote the innovative development of the grain supply chain. The group has implemented a 'one network' centralized control system and a data mid-end project, focusing on supporting the full industry chain development plan that encompasses “planting, producing, purchasing, storing, processing, and selling”. It utilizes internet technology and information tools to bolster grain security.

Table 1. Lu Liang Group's Digital Transformation Initiatives

Measures	Time	Description
Data Mid-end Construction	2023	Built a unified and controllable data governance system at the group level, relying on Huawei Cloud's data governance center to build a data mid-end.
Green Storage Upgrade and Transformation	July 2023	Invested over 88 million yuan for the quasi-low temperature transformation and functional enhancement of nearly 500,000 tons of provincial grain storage warehouses, reducing the grain storage cycle loss rate.
Automated Production	August 2021 - June 2023	Lu Liang Grain Industry established a modern sightseeing experience type rice processing factory, achieving automated production and increasing daily output to 300 tons.
Intelligent Transformation	2023	Promoted the exploration and practice of information technologies such as big data, artificial intelligence, 5G, and industrial internet in the grain industry, empowering the transformation and upgrading of traditional industries.
Grain Warehouse Phosphine Aluminum Fumigation Robot "Liang Huibao"	May 2024	Independently developed the third-generation product of the grain warehouse phosphine aluminum fumigation robot "Liang Huibao", which has intelligent functions such as unmanned fumigation, unmanned inspection, and real-time monitoring.
Electronic and Intelligent Management System for Grain Warehouses "Hui Guan Liang"	May 2024	Jointly developed with Inspur Digital Grain Storage, it is an intelligent management platform that integrates grain storage, grain purchase and sale, safe grain storage, and safe production.

Lu Liang Group has entered into a strategic cooperation agreement with Inspur Group to jointly advance the construction of smart grain systems, integrating new-generation information technology with the traditional industrial economy to safeguard national grain security. Additionally, the group's self-developed phosphine fumigation robot for grain warehouses, 'Liang Huibao,' and the electronic and intelligent grain warehouse management system 'Hui Guan Liang,' co-developed with Inspur Digital Grain Storage, have garnered attention at the 2024 National Grain and Materials Reserve Science and Technology Activity Week.

Lu Liang Group's digital practices serve as a benchmark for other grain enterprises and supply chain management, particularly in enhancing the digitalization and intelligence of the grain supply chain. As a leader in the industry, Lu Liang Group is at the forefront of these advancements.

6. Conclusions and Recommendations

Through the analysis of the digital transformation of Lu Liang Group's supply chain, it is evident that the digital transformation of the grain supply chain faces numerous challenges, such as uneven technology application, inadequate data sharing, incomplete infrastructure, and governance structures that are not well-suited, all of which hinder its in-depth development. To address these issues, this article proposes the following strategies:

1. Strengthen the integration of technology and business: To mitigate the risk of misalignment between technology and business operations, it is imperative for enterprises to engage in a profound comprehension of their operational requirements. Such an approach facilitates the seamless integration of technology within the business framework, thereby preventing the occurrence of technological and operational misalignment. Furthermore, the implementation of ongoing assessments and modifications is essential to guarantee the efficacious utilization of technological solutions and to foster the enhancement of business procedures.

2. Enhance data governance capabilities: Establish an effective data governance system to ensure the accuracy, completeness, and security of data. Strengthen data security and privacy protection, promote standardized data management, and address challenges related to data security and compliance.

3. Reinforce cybersecurity protection: In the face of increased cybersecurity risks, companies need to establish a robust cybersecurity system to protect critical information infrastructure from attacks and ensure the security of data transmission and processing. Adopt advanced technologies to optimize network management models and improve the efficiency of cybersecurity management.

4. Promote the upgrading of traditional industries: Overcome internal and external resistance by promoting the digital transformation of traditional grain businesses through technological innovation and improvements in management models. Strengthen staff training to increase acceptance of new technologies and ensure that business processes can adapt to the application of new technologies.

5. Increase policy support and financial investment: The government should provide policy support and financial investment, especially in areas and segments where technology is lagging, to promote the balanced application and development of technology. At the same time, strengthen infrastructure construction to improve network coverage and the efficiency of logistics and distribution systems.

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Digitalization and Management Innovation III
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A Review of Research on Digital Regulation of Hazardous Materials Supply Chain Security

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Abstract. With the acceleration of industrialization, the safety of hazardous chemicals (Hazardous Chemicals) in production, storage and transportation is becoming more and more prominent, posing a serious challenge to public safety and environmental protection. The safety management of the hazardous chemicals supply chain is not only related to the sustainable development of enterprises, but also directly affects social stability and the safety of people's lives and properties. Therefore, it is of great practical significance and strategic value to realize the safety digital supervision of hazardous chemical supply chain. This paper provides theoretical support and practical guidance for the digital regulation of hazardous chemical supply chain safety by reviewing the current research status of hazardous chemical supply chain accidents, digital regulation, and digitalization of hazardous chemical supply chain issues.

Keywords. Hazardous chemicals supply chain; security; digital regulation

1. Introduction

As an important pillar of the global economy, China's petroleum and chemical industry, although its contribution is significant, with the output value of chemicals accounting for about 40 per cent of the world's output value, the safety supervision situation in the field of hazardous chemicals is still grim, with frequent accidents and serious consequences, and the supervision is facing great challenges. With the continuous expansion of the petrochemical industry chain and the surge in the number of hazardous chemical species, their flammable, explosive and toxic properties pose high risks in all aspects of production, transport and storage, coupled with the emergence of new industries and modes of operation, which has further exacerbated the difficulty of regulation. In order to address this issue, the government has taken proactive action through the implementation of “Industrial Internet + Hazardous Chemical Safety Production” pilot construction, as well as the formulation of the “14th Five-Year” Hazardous Chemical Safety Production Planning Programme, which aims to build a comprehensive, efficient and intelligent The aim is to build a comprehensive, efficient and intelligent safety supervision system for the supply chain of hazardous chemicals, and to implement fine and dynamic supervision of the entire life cycle of hazardous chemicals through digital and intelligent means. These initiatives not only enhance the level of safety risk management and control, but also promote data interconnection between enterprises, regulatory authorities and emergency rescue departments, and build an all-round, multi-level regulatory system, with a view to realising early research, early warning, discovery

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and disposal of hazardous chemical safety risks. However, the digital supervision of hazardous chemicals in China is currently facing multiple challenges such as late start, mixed platforms, data silos, and lack of standards, resulting in an unsound supply chain monitoring, early warning, control and disposal system for the entire life cycle. Hazardous chemicals big data industry has not yet achieved industrialisation, data openness and ownership are unclear, cross-platform sharing is hindered, big data potential has not been fully released. In this context, it is important to explore the research lineage and history of digital regulation of hazardous chemicals supply chain safety, to study in depth the causes and evolution of hazardous chemicals accidents, to analyse in depth the key role of digital means in enhancing regulatory effectiveness, promoting supply chain transparency, and reinforcing risk early warning and emergency response, so as to lay a foundation for building a safer, more efficient, and more sustainable hazardous chemicals management system.

2. Literature review

2.1 the study related to accidents in the hazardous chemical supply chain.

With the rapid development of the chemical industry, safety issues arising from the production, storage and transport of hazardous chemicals have become a major concern. The supply chain covers the movement and storage of raw materials, in-process products and finished products from the point of origin to the point of consumption. As a result, there has been an increase in research on the hazardous chemical supply chain and the accidents that occur during its operation. To address the accidents in the hazardous chemical supply chain, it is important to firstly clarify the background and causes of the accidents. Li Na and Chen Jianhong (2020) [1] found, based on the information published by China Chemical Safety Network and China Chemical Safety Association, that during 2013-2019, the accidents of hazardous chemicals in China were high in May-August and November-December, which were related to the seasonal climate, and the leakage, explosion, and fire were the main types of accidents, and most of them occurred in Jiangsu, Tianjin, Zhejiang, Taiwan, and Shaanxi. Zhang Shengzhu et al. (2021)[2] analysed the data of chemical and hazardous chemical accidents in China from 2016 to 2020, and concluded that although the overall number of accidents showed a decreasing trend, the number of deaths still fluctuated, and there were some obvious months and regions of high accident occurrence, meanwhile, explosions and poisonings and suffocations were the most serious categories of accidents, and the production link was the most frequently occurring link of accidents. Sirpa Laitinen a, Juha Laitinen et al. (2016) [3] assessed the exposure of employees to biological and chemical substances in hazardous chemical plants using questionnaires and biological sample testing. There was an association between exposure to biological and chemical substances in hazardous chemical plants and the health status of employees. Yang, Zheng (2022) [4] statistically analysed 195 large-scale and above hazardous chemical accidents in China from 2000 - 2020 and explored the developmental pattern of the occurrence of large-scale hazardous chemical emergencies. The occurrence of HCFs has a clear temporal and spatial domain and regional characteristics The highest number of casualties occurs on Wednesdays of weekdays, and 9:00-11:00 and 15:00-16:00 of each day are the two periods of high occurrence of accidents.

It was found that operational errors, lack of safety awareness, packaging and loading/unloading of hazardous chemicals, corporate management and inadequate supervision by government departments are important causal factors in road transport accidents involving hazardous chemicals. Ambisisi Ambituuni et al. (2015) [5] used a customised risk assessment framework to analyse a total of 2318 accidents involving tanker trucks from 2007 to 2012, using the developing country of Nigeria as an example. 2318 accidents involving tanker trucks from 2007 to 2012. The results showed that 79% of the accidents were caused by human factors, mainly dangerous driving. Wang Huanhuan et al. (2022) [6] adopted the methods of rooted theory and grey correlation analysis to conduct an in-depth analysis of 158 typical cases of hazardous chemical road transport accidents, and the results showed that vehicle factors, driver factors and weather conditions are the key factors affecting hazardous chemical road transport accidents during the process of hazardous chemical transport. Translated with DeepL.com (free version). Pan Zheng et al. (2022) [4] based on Bayesian Network (BN) risk analysis model, analysed that the main types of accidents in petrochemical enterprises include leakage, fire and explosion, and human factors are one of the six most important sources of risk affecting enterprise safety. Chen Wenying et al. (2024)[7] predicted the risk of hazardous chemicals road transport based on DBN model by using data from 2017-2021 and found that driving for more than 3 hours significantly increased the risk of fatigue driving and accidents. The study of Luo Cheng and Zhou Chuangui et al. (2022)[8] pointed out that the coastal area is a high incidence area of hazardous chemical transport accidents due to the special geography and complex sea environment, especially in May, September, December and early morning hours. Accidents occur frequently in Guangdong, Jiangsu, Zhejiang, etc., in which the number of accidents of liquid flammable hazardous chemicals tops the list, while the explosion type of accidents is rare but the consequences are extremely serious. Driver violations and environmental factors such as rain and curves were identified as key risk factors, and the coupling of subjective and objective factors is more likely to cause accidents than a single factor, and the superimposed effect of rain and curves with other risk factors is particularly significant. In addition, Liu Jianguo et al. (2018) [9] emphasised that the port and waterborne hazardous chemicals supply chain also faces severe challenges, and the profit drive of illegal transport by port enterprises directly affects their strategy choices. Zheng Yunliang et al. (2023) [10] further pointed out that the aging and large-scale trend of liquid hazardous materials transport ships and the diversification of transport modes, such as miscellaneous cargo consolidation and bulk diversification, have become key factors restricting the safety of waterborne transport, and urgently need to pay great attention to and take measures to deal with them.

In addition, to address the causes of accidents in the hazardous chemical supply chain, scholars at home and abroad have proposed many corresponding models and patterns to try to solve the problem. Deng et al. (2020) [11] proposed a general method for hazardous chemical accident prevention based on K-mean cluster analysis, established a database of hazardous chemical accidents, and classified the types of accidents for research and prevention. Yalcin et al. (2023)[12] similarly adopted a classification approach using data from 251 accident reports collected from various online data and used human factors analysis. A more specific and intuitive explanation of the interrelationships between accident causes and revealing the pathways through which accidents occur is presented. Magdalena Bogaleck and Ewa (2023) [13] presented an innovative simulation technique, Monte Carlo simulation, for modelling shipping accidents and the consequences of chemical releases in the world's marine waters. The results obtained are used practically by maritime practitioners for rapid response. By analysing a series of hazardous chemical accidents, Shiying Zhang and Yang Li (2023) [14] proposed a path of emergency intelligence support that integrates matter-of-fact knowledge mapping and network public opinion analysis by analysing a series of hazardous chemical accidents, aiming at the deficiencies of static knowledge, matter-of-fact ambiguity, and spatial singularity in the current intelligence support of emergencies and proposing a path of emergency intelligence support that integrates matter-of-fact knowledge mapping and network public opinion analysis, aiming at improving the overall situational awareness ability of emergencies and the ability of predicting and responding to emergencies in complex situations, supporting The aim is to improve the overall situational awareness and prediction and response capabilities of emergencies in complex situations, and to support the innovation of emergency intelligence paradigm in the era of digital intelligence.

2.2 the study related to digital regulation.

Under the current new research model combining emerging information technology and traditional evaluation and analysis technology, focusing on highlighting the proportion of intelligent technology such as Internet of Things, Big Data, Artificial Intelligence, Blockchain and so on is an important way for the future development of information technology supervision of hazardous chemicals. In this era of the Internet of Everything, the control technology of hazardous chemicals should also be innovated to solve the problems of modern hazardous chemicals safety supervision, the key lies in the use of new digital technology to strengthen the control of hazardous chemicals related information, to build a digital management system that can cover the whole life cycle of hazardous chemicals, in order to achieve the closed loop of "monitoring and sensing - prediction and warning - emergency disposal". The key is to use digital technology to strengthen the control of hazardous chemicals related information and build a digital management system that can cover the whole life cycle of hazardous chemicals, to achieve the closed loop of "monitoring and sensing - prediction and early warning - emergency response" (Liu Zhifeng et al., 2022) [15]. To achieve the safety supervision of the whole process of hazardous chemicals and prevent safety accidents, Liu Qibin (2022) [16] used blockchain technology to study the safe and trustworthy sharing of data in all aspects of hazardous chemicals and the collaborative management technology between multiple subjects. Dong Changqi, Liu Jida and Mi Ganin (2023)[17] argued that in the current context of risk society and digital era superposition, to improve the emergency warning, response and disposal capabilities through digitalisation and informatisation technology, to inhibit the adverse impacts of risks, crises and disasters on the society, so as to improve the performance of public safety has gradually become the main direction in the field of safety governance. In addition, accelerating the digital intelligent construction of hazardous chemical safety risk control is a general trend and a strategic move, for the characteristics of hazardous chemical storage, high risk, and difficult to prevent, Zhu Youxiang (2022) [18], taking Qingdao City as an example, put forward the digital construction of the double prevention mechanism, and focused on solving the problem that the risk control measures of the double prevention mechanism are not implemented in the offline, the hidden danger investigation is not accurate, the full participation is not sufficient, and the rectification is difficult to trace the situation and other pain points and difficulties. situation is difficult to trace and other pain points and difficult problems. Zhang Liujun (2020)[19] proposed that in view of the frequent occurrence of safety accidents in the transportation of hazardous chemicals, the development of safety standards for the transportation of hazardous chemicals, the use of the latest ICT technology to build a supply chain and logistics cloud platform with unified standards and data sharing, standardise the selection, assessment and evaluation of carriers and carriers, and strengthen the access management; and achieve full monitoring and early warning of the transportation process of hazardous chemicals, and strengthen the access management. transport process of the whole process of monitoring and early warning, to improve safety and reliability; the development of accident plans, the transport process of emergencies to achieve emergency guidance and regional linkage, and comprehensively improve the level of emergency disposal and safety management of hazardous chemicals transport. Finally, Chen Fei (2023) [20] believes that when hazardous chemical enterprises carry out safety management, it is necessary to introduce digital means to collaboratively monitor the safety status of the enterprise, and in each production link, store all kinds of information about the product, so that the intelligent terminal can view the real-time status of each product and each link of production at any time and set up alarms and tips to remind the safety of hidden dangers to be investigated.

2.3 research related to digitalisation issues in the hazardous materials supply chain.

In recent years, research and practice on the digitisation of the hazardous chemicals supply chain has achieved certain results. In terms of technology, the wave of digital technologies such as the "industrial Internet", digital twin, artificial intelligence and the Internet of Things (IoT) has swept across the globe, bringing profound changes to the chemical industry. In terms of practice, some enterprises have begun digital transformation, achieving real-time monitoring and management of the hazardous chemical supply chain through the establishment of digital platforms. However, there are still some problems in the digital application of the hazardous chemical supply chain, on the one hand, the research and development and use of digital intelligent construction of hazardous chemical safety risk warning and control are still insufficient, on the other hand, with the deepening of the digital transformation and the continuous emergence of emerging industries and technologies, the hidden technical loopholes, safety hazards and potential risks behind them have become more complex and difficult to detect, which further aggravate the This further aggravates the difficulty of security control and risk prevention in the supply chain of hazardous chemicals. Some scholars have also put forward the digital challenges in different parts of the hazardous chemical supply chain, Li et al. (2022) [21] argued that China's hazardous chemical intelligent supervision system is still imperfect, facing the three major obstacles of insufficient cognition, lack of soft and hard engineering and insufficient application scenarios, which affects the realisation of the whole chain safety control. Sun Bai, Tao Weixiang et al. (2022) [22] Proposed that in the digital closed management of the park there is a low degree of park infrastructure informatisation, which restricts the level of intelligent supervision of hazardous chemical transport vehicles. Lu Yangming (2023) [23] Proposed in the digital service platform operation, the current hazardous chemicals logistics industry in China is still in a more traditional, more monotonous mode of operation, the service platform is relatively small, did not form a new type of business model, there is an urgent need to use information technology, to build out a modern hazardous chemicals logistics service platform, in the government, the industry, the enterprise to achieve the exchange of information and the interconnection of information. Guan Xiaoqian (2023)[24] pointed out that the customs information technology supervision of hazardous chemicals is faced with problems such as insufficient scientific and technological support, low on-site law enforcement effectiveness, shortage of talents, unsound collaboration mechanism and inspection and testing effectiveness not being brought into full play. Zhang Heng, Chen Hao and Zeng Yanhong (2023) [25] further reveal that there are digital shortcomings in the production, warehousing and transportation of hazardous chemicals enterprises, including low quality of logistics services, insufficient digital investment, slow transformation and upgrading, and the lack of an integrated logistics service platform to optimise capacity. All of the above scholars' problems in the digitalisation of the hazardous chemical supply chain will become bottlenecks restricting the development of digital regulation of hazardous chemical safety and are worthy of the industry's attention.

3. Concluding remarks

This paper draws the following conclusions by describing the frequency of accidents in the digital regulation of hazardous chemical supply chain safety, the fact that digital regulation can improve the effectiveness of safety regulation, and the problems of digitisation of the hazardous chemical supply chain:

(1) The causes of accidents in the hazardous chemicals supply chain are complex and require a multi-dimensional approach: accidents in the hazardous chemicals supply chain are frequent, and their causes involve human factors, environmental factors, management factors and other aspects. To effectively prevent and reduce accidents, it is necessary to take comprehensive measures from laws and regulations, technology application, personnel training and other dimensions. Measures such as improving the management system, improving equipment and facilities, standardising personnel operation, strengthening environmental monitoring and response, optimising transport links, and strengthening supervision and inspection can effectively reduce the incidence of accidents in the hazardous chemical supply chain, and safeguard the safety of people, property and the environment. At the same time, enterprises and all sectors of society should strengthen their attention and investment in the safe production of hazardous chemicals, and jointly promote the safe development of the hazardous chemicals industry.

(2) Digital supervision is an important way to enhance the safety of the hazardous chemical supply chain: in terms of enhancing the ability of intelligent safety control of the whole life cycle of hazardous chemicals that integrates knowledge and data, it is necessary to accelerate the digital transformation of chemical enterprises, and promote the development of intelligent sensing, early warning, decision-making and analysis, and management and control technology systems relying on the industrial Internet, big data, and artificial intelligence technologies. At the same time, it is also necessary to develop key technologies such as abnormal working condition monitoring, equipment intelligent operation and inspection, video intelligent analysis, risk trend prediction and other key technologies oriented to the industrial internet platform, to build a new model and new method of systematic and intelligent risk control. The introduction of digital regulatory technologies, such as the Internet of Things, big data, artificial intelligence and blockchain, can significantly improve the regulatory effectiveness of the supply chain of hazardous chemicals and realise the fine management of the whole life cycle from production, transportation to storage.

(3) Build a comprehensive and efficient hazardous chemical supply chain safety management system: The complexity and high risk of the hazardous chemical supply chain require all relevant parties to strengthen data sharing and collaboration, and build

an all-round, multi-level regulatory system and supply chain safety management system. Through the introduction of new technologies and techniques, such as digital twins and artificial intelligence, the intelligent level of hazardous chemical supply chain safety supervision can be improved to achieve transparent management and fine control of the hazardous chemical supply chain. It also realises early research, early warning, detection and disposal of hazardous chemical safety risks by improving emergency response capabilities.

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Digitalization and Management Innovation III
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Research on the Impact of Digital Transformation on the Resilience of Cross-Border Agricultural Product Supply Chains – Based on a Grounded Analysis of Durian Import and Export Trade

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Abstract. Digital transformation and development is a national development strategy. Through digital development, enterprises can make full use of resources in a complex and changing external environment, improve the resilience of their supply chains, and effectively cope with exceptional risks. Through rooted analysis, this paper analyzes cross-border durian foreign trade enterprises, and draws three core categories of digital transformation and development, intelligent operation, and supply chain resilience, and makes clear the internal logical correlation between the three: Based on the development of digital transformation, enterprises can realize intelligent operation. Through these two stages, enterprises can use resources more efficiently, prevent risks, and enhance the resilience of enterprise supply chain.

Keywords. digital transformation, supply chain resilience, cross-border trade

1. Research background

As the world's largest agricultural import market, China's agricultural imports account for more than 10% of the global agricultural trade volume. With the diversified development of China's domestic consumption, durian and various derivative products of durian have gradually risen in China, and durian has become a popular single product in China's fruit consumption market. According to the China durian Import and Export Data Analysis Brief of Yunguo Industry Brain in 2024, between 2019 and 2023, China's durian trade volume export trade increased by 819,800 tons, an increase of about 135.57%. At present and even in the future for a long time, China's domestic durian will still be in short supply. China has become the world's largest durian consumer market, and the import of durian will be the main way to meet the demand of China's domestic market for a long time.

The outbreak of the novel coronavirus in 2020, the Russia-Ukraine conflict in 2022, and the continuous escalation of the Palestinian-Israeli conflict in 2023, a series of uncertain events have brought severe challenges to China and even global cross-border

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trade. The cross-border durian supply chain involves multiple links, including planting, picking, grading, packaging, transportation, customs clearance, distribution, etc. Each link may be affected by various factors such as natural environment, policy changes, and market demand fluctuations. In addition, durian, as a perishable product, has extremely high requirements for logistics and transportation conditions, further increasing the complexity of the supply chain. In the face of such huge consumer demand and complex and changing international conditions, how to optimize supply chain management with digital technologies such as the Internet, the Internet of Things, and artificial intelligence, improve the resilience of cross-border agricultural supply chains, and enhance the risk resistance of cross-border product supply chains is an inevitable choice in the current complex international and natural environment.

2. Theoretical basis and research review

2.1 Research on digitalization and digital transformation

Digitalization and digital transformation are not clearly defined in academia. Digital technology refers to a technical means to convert information into digital (i.e., binary) format, which simplifies the process of information storage, access, management and transmission. In today's era, thanks to the rapid progress of computer and Internet technology, digital technology has become a key driving force for social development, penetrating into all walks of life and People's Daily life [1]. From the perspective of transformation and innovation, digital transformation is a systematic change triggered by a new generation of information technology as a universal enabling technology, which gives rise to a series of transformation and innovation processes of enterprises in strategic adjustment, capacity building, technological innovation, management reform and mode transformation [2]. Digitization has significantly reduced the information imbalance between enterprises, promoted enterprises to fully integrate information technology into management, product innovation and marketing, and realized the comprehensive enabling of technology for enterprise operations, so that enterprises can effectively control all aspects of activities from production to sales, and realize the entire digital management. From the perspective of value-added value, enterprise digital transformation can give full play to the advantages of enterprises with massive production data, help enterprises to fully understand the production and operation status, and promote the value appreciation of all links of the industrial chain [3]. To sum up, digital transformation is a process of reducing the information asymmetry in all aspects of enterprise production, management, construction, maintenance and communication through a new generation of technological means, integrating the products of the information age into every link of enterprise survival and development, helping enterprises to fully understand the development trend, and promoting the value added of enterprise industrial chain.

2.2 Relevant research on the resilience of cross-border agricultural supply chain

The ability of the supply chain to recover to its original state or to move to a new, more desirable state after a risk shock [4]. Tukamuhabwa et al defined supply chain resilience as the adaptive ability of supply chain to prepare for or respond to disruptions, timely and cost-effective recovery, so as to recover to a stable state [5]. PONOMAROVSY and other scholars believe that supply chain resilience emphasizes the pre-preparation ability of supply chain to cope with emergencies, the resistance ability to cope with supply chain disruptions and the adaptability to recover from shocks [6]. According to Zhao Ling et al., from the perspective of enterprise operation, the stronger the resilience of the supply chain, the stronger the ability to deal with uncertain risks, that is, the ability to still operate normally after the risk impact [7]. To sum up, academic circles have emphasized the ability of supply chain resilience to return to normal operation when dealing with sudden changes in risk. Academic circles also have different views on how to measure the resilience of supply chain. From the perspective of the function of supply chain itself, CHOWDHURY believes that supply chain resilience can also be measured from these three aspects based on the characteristics of flexibility, visibility and agility of supply chain itself [8]. Ru Lei et al. comprehensively measured and evaluated the security and reliability of cross-border supply chain, the supply potential of the main producing country, and the smoothness of transportation channel through two dimensions (bilateral relationship and logistics performance level) and five indicators. The bilateral relationship between the two countries all comprehensively determined the stability and security of cross-border supply chain [9]. Therefore, this paper believes that the resilience of the supply chain refers to the ability of the supply chain to resist risks when it suffers risks, and the ability of the supply chain to recover from the interrupted state when it is forced to interrupt, which can be measured from the characteristics of the supply chain itself.

2.3 Research on the relationship between digital transformation and supply chain resilience

Digital transformation helps enterprises to obtain massive data, optimize and simplify production and operation modes through technical means, reduce the information asymmetry between departments and enterprises, which can greatly reduce the risks caused by information asymmetry and opacity, and improve the ability of supply chain to resist risks. Zhang Shushan et al. talked about the continuous flow of new massive data to enhance the visibility of the supply chain, improve the insight ability and monitoring ability of the entire supply chain, so as to predict potential risks and improve the resilience of the supply chain [10]. At the same time, digital transformation can provide decision support for production managers through a large amount of data analysis to assist users to make reasonable decisions. Zhou Wenhui et al. believe that with the help of digital technology, relevant entities of the supply chain can quickly perceive external changes and respond to changing market demands [11]. Digital technology can clean and process a large amount of communication and transaction information in the supply chain and finally in the form of visualization, so that production managers can make scientific decisions. The application of the combination of digitalization and supply chain can be represented as the application of digital supply chain management system. The digital supply chain management system can track the whole process of fresh agricultural products from production, storage to distribution (traceability, inventory monitoring). Mainly reflected in logistics and data analysis, intelligent logistics system emphasizes cold chain transportation, distribution optimization, and cost reduction. Data analysis from the consumption of good, market forecast. Start with cross-border financial services and payments. Digital transformation has become a key strategy for enterprises to enhance resilience, effectively cope with external shocks, and achieve sustainable development [12].

All in all, digital technology reduces the asymmetry in information transmission by sorting, cleaning and analyzing the massive information in the supply chain, allowing users to have a clearer and more accurate control over the overall operation of the supply chain process, and make use of these data to make management decisions, thus improving the ability of the supply chain to cope with shocks and enhance the resilience of the supply chain.

2. Research design

Supply chain resilience is a relatively new research direction in recent years, but there is no clear definition of it. Grounded theory is suitable for the exploration and construction of new concepts and theories, and also has a strong explanatory power for the systematic exploration and analysis of phenomena. Through rooted analysis of various interviews and reports and literature, this paper extracts and simplifies materials, and digs out the logical relationship between digital transformation and supply chain resilience through structured coding of data.

3.1 Data sources

Considering the completeness and authenticity of the data, this paper mainly uses the literature research method, and selects representative interviews, tweets on the company's official website, media news reports, and research articles in journals such as CNKI and Wanfang in the past two years as the research data. In recent years, the import and export trade of pomegranate is a cross-border agricultural product trade project with a large scale and distinctive product characteristics from China's "Belt and Road" trade to Southeast Asia. Through the reports of Xinhuanet and related media of import and export trade and the literature analysis in recent years, we can have a real and comprehensive understanding of the specific situation of cross-border supply chain.

4. Rooted analysis

4.1 Open coding

The main purpose of open coding is to compare, organize, summarize and encode the original materials in combination with the existing literature, and finally realize the conceptualization and categorization. First, the collected original data are read in the main sentence, without labeling the original data; Secondly, repeated comparison, induction and refinement of the original materials are preliminarily categorized on the basis of the initial concept. In this study, 65 initial codes and 17 subcategories were identified by coding and summarizing the original data one by one. Some examples of open coding are shown in Table 1.

Table 1. Partially open coding

Original statement	conceptualization	subcategory
Strengthen digital trade cooperation with countries along the Belt and Road. On the one hand, China should actively engage in bilateral digital trade rule negotiations with these countries and establish	Trade Standards are established.	Policy support

relevant dispute resolution mechanisms and digital trade cooperation mechanisms to promote the adoption of digital trade rules in these countries. On the other hand, most of these countries have relatively backward digital infrastructure, creating a digital divide with China. China should adhere to a development-oriented approach, leveraging its rich experience in digital economic development to help these countries improve and perfect big data, cloud computing, and financial payment infrastructure. At the same time, vigorously develop "Silk Road e-commerce" to radiate along the Belt and Road countries and regions from key domestic cities, unleashing the potential for digital trade development in these countries.		
The Regional Comprehensive Economic Partnership (RCEP) showcases the highest level of China's participation in the rule-making of digital trade, achieving breakthroughs in areas such as "free flow of cross-border data" and "non-mandatory local storage of data," as well as specific provisions on dispute resolution and transparency. RCEP is the largest free trade area in the world, with its advantage in digital trade rules being good flexibility and inclusiveness, setting exception clauses in topics such as "electronic transmission of information across borders" and "location of computing facilities" and "protection of online personal information."	Digital Trade Agreements	
Cold transport has launched a special preferential support policy for technical service fees for fruit and vegetable orders issued in Yunnan, with an average preferential range of more than 50%. The preferential policy has been launched at the beginning of 2023, and the cumulative preferential amount for Yunnan fruit and vegetable enterprises has exceeded one million yuan.	Digital policy incentives	
Our company imported more than 700 durians this year, with a value of more than 300 million yuan (RMB, the same below), and achieved the best results in history. Han Tao introduced that in his company, 80% of durians are transported through the digital freight platform. The greatest convenience of a digital freight platform is control. He said	Digital platform building	Digital platform building
China has the world's largest "durian appetite". According to the relevant data of CCTV and the General Administration of Customs, China's durian imports in 2010 were US$149.6 million, which increased to US$2.3 billion in 2020, a fifteen-fold increase in ten years. In terms of import volume, 99.99% of China's fresh durian imports come from Thailand. Thailand's Ministry of Agricultural Cooperation also said that in the first six months of 2022, Thailand's durian exports to China have exceeded 500,000 tons, setting a new export record.	Digitally forecasting the size of the market	
Driven by the new generation of information technology, digitalization and platformization have become important trends in the development of enterprise operations	Platform digitalization	
The infrastructure stage of digital transformation has no significant impact on supply chain resilience, but has a significant impact on supply chain resilience in	The application of digital technology enhances the	

the digital technology innovation stage and intelligent application stage, and plays a more significant role in the intelligent application stage of digital transformation		

4.2 Spindle coding

In the open coding stage, a large number of original data have been abstracted out of 17 initial categories, but the logical relations between these initial categories have not been clarified, so it is necessary to conduct cluster analysis of the initial categories through spindle coding, clarify the underlying logical relations between categories, and extract the sub-categories and main categories. The sub sub-category is to summarize the initial category by comparing it to a higher level. In the same way, the main category is a further integration of sub-categories and can effectively contain the meaning represented by all sub-categories. The results are shown in the following Table 2.

Table 2 Selective coding and its connotations

Main category	**Sub-categories**	**Sub sub-categories**	**Connotative relationship**
Digital transformation development	Digital infrastructure	Policy support	The development of digital transformation follows the development of international data, according to the country Relevant laws and regulations stipulate that relying on policy support and relying on various advanced digital Internet technologies to build a digital environment for markets, industries, and supply chains, and to realize the application of digital technologies in all aspects
		external environment	
		Digital environment building	
	Digital applications	Digital platform building	
		Digital-assisted decision-making	
Smart operations	Digitization of quality inspection	Timeliness control	Relying on the digitalization and intelligence of the transportation-warehousing-sales process of cross-border logistics, that is, the use of digital technology to complete the efficient operation of each link to achieve intelligent operation
		Normalize collection and storage	
		Uniform standards	
		Digital surveillance	
	Digitization of warehouse and distribution management	Digital sorting	
		Digital logistics	
	Digitize transaction interactions	Digitization of market interactions	
		Digitization of trade mechanisms	
Supply chain resilience	Predict resistance	Digitization of information	Through digital transformation, real-time information sharing at all nodes of the cross-border trade

		Information sharing	supply chain can be realized, key information can be transparent, and the risk response ability of the supply chain can be improved, as well as the recovery ability after interruption
	Resilience	The supply chain structure is restored	
		Adaptive to supply chain disruptions	
		Risk prevention and control measures	

4.3 Selective coding

The logical relationship can be explained as following figure 1.

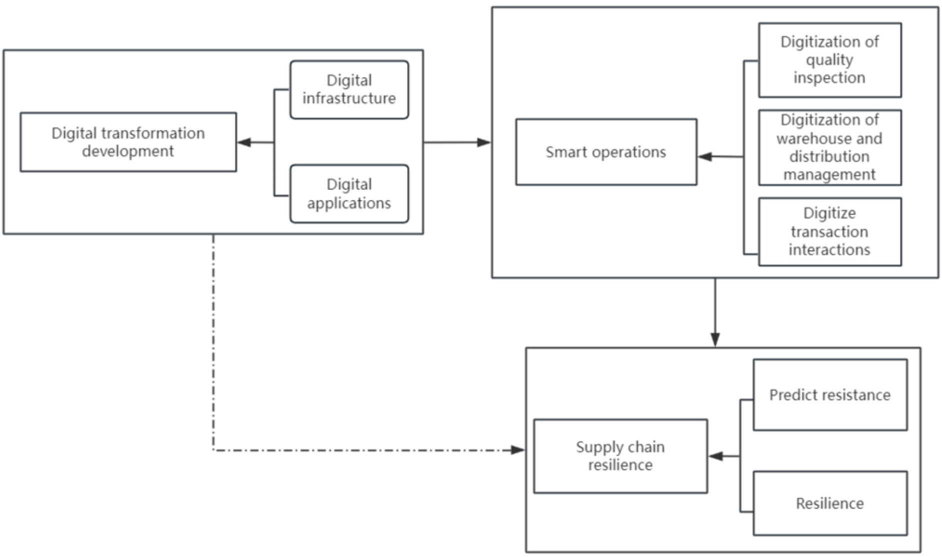

Figure 1. Diagram of logical relationships

4.4 Main category analysis

4.4.1 Digital transformation development

In the strategic landscape of large supply chain enterprises, digital transformation plays a crucial role. It is not only an important driver for enterprises to deepen reform, optimize and upgrade, but also a key driving force for enterprises to stand out in the highly competitive market and achieve sustainable development. Through digital transformation, enterprises can integrate resources more effectively and improve operational efficiency, thereby enhancing their competitiveness and steadily moving toward the goal of high-quality development. The national policy support and international external environment digital transformation trend of The Times, as well as the existing digital technology for the construction of digital infrastructure to create a good digital environment. For the logistics enterprises engaged in durian foreign trade, the cooperation and exchanges with Thailand and other Southeast Asian countries are deeply in line with the national development strategy of the Belt and Road and can get strategic support from the country. At the same time, the domestic and international digital infrastructure construction provides strong support for the application of digital technology at the three levels of data, system and application for the digital transformation and development of enterprises.

4.4.2 Intelligent operation

With the advent of the digital age, enterprise operation management has undergone fundamental changes. Traditional enterprise operation relies on historical data and experience to plan operation and resource allocation, but this method has many shortcomings, such as inaccurate information, strong subjectivity, slow response speed and so on. The impact of the epidemic has made cross-border trade enterprises deeply feel the urgency of digital transformation, but also put forward higher standards for their ability to operate in the digital environment. Through the digital intelligence of the process, after the summary and analysis of multi-party information, the company executes the process with a more unified and professional standard, which not only trains more professional and reliable professional talents for the digital transformation and development, but also the specific landing and development of the digital development of the company.

4.4.3 Supply chain resilience

The resilience of cross-border agricultural supply chain is characterized by predicted resistance ability and recovery ability. For enterprises, having risk awareness, paying attention to information changes, and identifying potential risks can help enterprises predict risks in a timely manner. On the basis of perfect supply chain construction, enterprises can effectively resist the hazards brought by risks to the supply chain. After the supply chain is damaged, the enterprise allocates various resources in time to restore the supply chain to normal operation as soon as possible. Digital transformation development from the development strategy, technical means to help enterprises quickly and comprehensively collect and use available information and resources, timely forecast and resist risks, at the same time, can also help enterprises quickly reorganize, integrate, coordinate resources to deal with risks and challenges.

Based on the logical connection between categories, the research logical framework of this study can be drawn, that is, the development of digital transformation depends on the construction of digital infrastructure and digital application. Digital technology assisting decision making and digital platform building are reflected in digital application, and there is obvious causal, primary and secondary relationships between these categories. Intelligent operation is digital operation, which uses digital technology, digital thinking and digital mode to manage and coordinate the supply chain in quality inspection, warehouse allocation management, transaction interaction between supply chain nodes and various links within the supply chain, so as to achieve visualization and clarity of the supply chain. Through the data and structure of massive information, information transfer and sharing in the supply chain can be realized. The resilience of the supply chain is expressed as the ability of the supply chain to predict the risk resistance and the ability to recover after the risk interruption.

5. Conclusion

In the context of the digital economy and under the macro guidance of the national Belt and Road Development Strategy, all industries and enterprises are pursuing and realizing digital transformation development, which is an inevitable trend to achieve sustainable development in response to the highly uncertain environment and frequent international and domestic risk events. At present, there are some studies on digital transformation and supply chain resilience, but there is no clear research conclusion on the relationship between digital transformation and supply chain resilience in crossborder trade. Therefore, based on the existing relevant research, this paper takes the cross-border trade of durian between China and foreign countries as the research basis, uses the grounded analysis method to code and analyze the original materials and cases, logically summarizes and summarizes, discusses the impact mechanism of digital construction on supply chain resilience, and clarifies how the development of digital transformation has an impact on supply chain resilience.

Firstly, through grounded theory, this paper derives three main categories of logic for the connection between digital transformation development and supply chain resilience: digital transformation development, smart operation, and supply chain resilience. After coding and summarizing these three, it can be concluded that enterprises can realize smart operations through digital transformation and development, thereby improving the resilience of supply chains. Secondly, the three main areas of digital transformation development, smart operation, and supply chain resilience can be influenced by seven sub-categories. Digital infrastructure, the foundation and practical logic of digital application to achieve digital transformation and development; The digitalization of quality inspection, warehouse and distribution management, and transaction interaction are the digital means used by enterprises to achieve smart operation, and these digital means are derived from the realization of digital transformation and development. Supply chain resilience is reflected in the ability of the supply chain to predict and resist and recover from risks. Thirdly, digital transformation is the foundation for enterprises to achieve smart operations, and the digital development of the supply chain ecology can enable the supply chain to enhance its own resource integration and utilization capabilities, as well as reduce the risks caused by information asymmetry, thereby enhancing the resilience of the supply chain.

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Digitalization and Management Innovation III
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Research on the Impact of Digital Transformation on Dual Innovation in Enterprises

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Abstract. As the 20th report urges accelerating "digital China", "manufacturing power" and "network power", enterprises grasp digital transformation's significance for competitive advantage. This paper studies its impact on radical and incremental innovation in China's high-end manufacturing, using 2014-2022 A-share data. Results show positive effects mediated by knowledge absorption capability. The research enriches theory and offers insights for enterprises.

Keywords. Digital transformation, radical innovation, incremental innovation, knowledge absorption ability

1. Introduction

Digital technology integration and application have driven enterprises to fundamentally change their strategies, structures, processes, and culture, leading to innovation and transformation in production service operations [1]. Information technology's rapid growth has garnered attention from governments and businesses aiming to embrace digital transformation [2]. Scholars note that digital transformation significantly enhances corporate innovation capabilities and impacts eco-innovation's sustainable development [3]. In a dynamic and uncertain market, enterprises need high innovation capabilities to adapt. Ettlie et al. suggest that corporate innovation can be categorized into radical innovation, which involves disruptive changes to technology and organization, and incremental innovation, which focuses on continuous improvement of existing technologies [4].

This study investigates how digital transformation impacts the innovation abilities of 292 Chinese high-end manufacturing firms from 2014 to 2022, drawing on resource-based, organizational capability, and technological innovation theories. It concludes that digital transformation notably influences the firms' dual innovation and uncovers the mechanisms behind this effect. The research enhances theoretical insights

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into the role of digital transformation in knowledge absorption and innovation. It provides practical advice for companies aiming to achieve competitive edges and improve performance via digital strategies.

2. Literature Review

The vital theoretical contributions encompass: 1) Distinguishing between radical and incremental innovation, transcending the confines of singular technological innovation studies. 2) Simultaneously examining the influence of enterprise digital transformation on both varieties of innovation. 3) Uncovering the indirect influence of digital transformation on dual innovation mechanisms through the lens of knowledge absorption. Figure 1 presents an illustrative outline of the research framework.

3. Theoretical Advancement & Hypotheses

Enterprise digital transformation signifies business, management, and technology advancement, utilizing diverse IT [5]. It enhances information processing and deepens understanding of sales trends and customer demands, enabling innovation [6]. Current research focuses on economic efficiency, environmental performance, and business model evolution. Scholars emphasize that digital transformation boosts competitiveness, fosters sustained innovation and enables companies to achieve change by introducing innovative business models and new technologies/products [7].

This research argues that enterprise digital transformation positively correlates with dual innovation. Digital transformation deepens integration between traditional and digital technologies, promoting technological advancements and innovation capabilities [8]. This radicalizes organizational and technological prowess, catalyzing radical innovation. Drawing on organizational capacity, digitization fosters innovation via seamless integration [9]. Enterprises use tech prowess to refine processes and nurture capabilities, augmenting innovation potential [10]. Thus, we hypothesize enterprise digital transformation also drives incremental innovation. Based on the insights above, we formulate the following hypotheses:

Hypothesis 1a: Digital transformation positively correlates with radical innovation.

Hypothesis 1b: Digital transformation positively impacts incremental innovation.

Research shows that an organization's knowledge absorption ability positively impacts radical innovation. It roots competitive advantage in valuable, scarce, unimitable resources [11]. This ability aids in acquiring resources, accelerating problem-solving, improving innovation efficiency, capturing consumer needs, and accelerating new product development [12]. Second, compared with incremental innovation, radical innovation can maintain a competitive advantage despite rapid changes in the external environment [13]. Digital transformation has long cycles and uncertainty, causing production issues. Enterprises need radical innovations, breaking R&D practices, discovering new knowledge and resources, and developing new products [14].

Research demonstrates that the capacity for knowledge absorption positively influences incremental innovation. As a pivotal tool for discerning market opportunities, it empowers enterprises to enhance their innovation prowess by integrating external knowledge with internal expertise [15]. Incremental innovation, rooted in technical foundations, expedites enhancing products in response to evolving customer demands [16]. Companies accrue experience and knowledge, assemble data, unify resources, and ignite creativity. Consequently, a heightened capacity for knowledge absorption increases in incremental innovation. In light of this, we formulate hypotheses.

Hypothesis 2a: Knowledge absorption capacity mediates the impact of digital transformation on radical innovation.

Hypothesis 2b: Knowledge absorption capacity mediates the impact of digital transformation on incremental innovation.

4. Methodology

4.1 Data collection and sample

According to China's High-tech Industries Classification (2017), we selected panel data from 292 listed high-end manufacturing enterprises from 2014 to 2022, with a total of 2,438 data entries for the study.

4.2 Model building

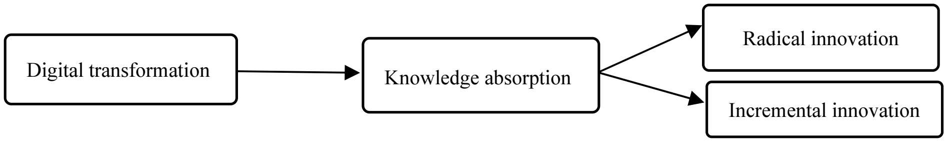

Figure 1. Framework of this research

5. Empirical study and outcome analysis

5.1 Correlation analysis

The study shows significant positive correlations between digital transformation and innovation types, with control variables strongly linked to binary innovation. Knowledge absorption is closely tied to digital transformation and dual innovation, indicating its potential mediating role. Multicollinearity tests reveal a mean VIF of 1.77 and all VIFs below 5, suggesting no multicollinearity issues.

5.2 Benchmark regression test

This paper uses STATA18.0 to test the direct effect of digital transformation and dual innovation, controlling individual fixed effects. Models (1)-(3) in Table 1 show dual innovation and digital transformation on radical and incremental innovation. Coefficients are 0.237 and 0.419, significant at 1%. Digital transformation promotes radical and incremental innovation in high-end manufacturing. Firstly, it broadens info channels, enhances processing ability, aids grasp of sales and customer needs, and adjusts innovation direction. Secondly, organizations learn and adapt to new digital tech, changing strategies and models and improving flexibility and adaptability to assimilate knowledge.

5.3 Mechanism test

The mediation effect of knowledge absorption capacity was tested by regression, and the results are in Table 1. Model (1) shows positive regression coefficients of digital transformation on radical and incremental innovation. Model (2) confirms digital transformation improves knowledge absorption ability. Model (3) indicates both digital transformation and absorption capacity are significant. The absorption capacity mediates digital transformation's impact on enterprise innovation. Thus, H2a and H2b are supported.

Table 1. Test of the mediation effect

	(1)		(2)	(3)	
	INV	NOINV	AC	INV	NOINV
DT	0.237***	0.419***	0.156***	0.155***	0.360***
	(9.117)	(13.606)	(12.339)	(5.985)	(11.459)
AC				0.524***	0.382***
				(12.994)	(7.818)
CS	0.301***	0.124***	0.878***	-0.159***	-0.211***
	(8.842)	(3.069)	(52.871)	(-3.282)	(-3.605)
AGE	-0.053***	-0.068***	-0.021***	-0.042***	-0.060***
	(-10.696)	(-11.542)	(-8.580)	(-8.664)	(-10.168)
EAA	0.101***	0.086***	0.019***	0.091***	0.078***
	(12.129)	(8.675)	(4.690)	(11.253)	(8.000)
LEV	0.778***	1.749***	0.034	0.760***	1.736***
	(3.841)	(7.276)	(0.342)	(3.881)	(7.311)
ROA	1.721***	1.993***	2.132***	0.604	1.178**
	(3.576)	(3.488)	(9.091)	(1.276)	(2.052)
CAP	0.108	-0.659**	-0.090	0.155	-0.625**
	(0.445)	(-2.299)	(-0.765)	(0.662)	(-2.205)
_cons	-7.286***	-3.153***	-1.480***	-6.510***	-2.587***
	(-10.295)	(-3.752)	(-4.290)	(-9.477)	(-3.105)
N	2438	2438	2438	2438	2438
R^2	0.216	0.219	0.669	0.267	0.238
F	95.183	97.001	699.791	110.163	94.623

***p<0.01, **p<0.05, *p<0.10

6. Conclusions and Limitations

This paper explores promotional mechanisms for enterprise digital transformation and dual innovation. It classifies dual innovation into radical and incremental, analyzing how digital transformation and knowledge absorption capacity affect these paradigms. Results show that digital transformation can enhance both types of innovation directly and improve knowledge assimilation capacity.

The study outlines strategies for digital transformation to enhance management and innovation by improving knowledge assimilation and fostering openness. It recommends enterprises focus on digital initiatives, such as developing roadmaps, hosting forums, promoting open dialogue, and staying updated on digital trends. Strategic approaches involve IT-based training, organizational support, sharing advanced knowledge, and integrating it into production. The study also emphasizes the importance of an organization's ability to absorb external knowledge for innovation. Prioritizing interactive management with external networks, including universities, institutions, governments, customers, and suppliers, is crucial. Regular collaborative meetings to develop innovation strategies using new external knowledge, investing in skills training, and refining knowledge absorption capabilities.

This paper identifies enterprise dual innovation research limitations that should be addressed in future studies. The research is based on data from Chinese high-end manufacturing enterprises, and it's still being determined if the findings apply to other cultures. Future research should test these results in different cultural contexts to assess their universality.

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Digitalization and Management Innovation III
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Research on the Mechanism of Digital Transformation's Impact on Firm Value – Moderating Effects Based on Economic Policy Uncertainty

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Abstract: Selecting a sample of 1,284 listed companies in Shanghai and Shenzhen A-shares from 2007 to 2020, the article explores the impact of digital transformation on firm value and further examines the moderating role of economic policy uncertainty in the development process of digital transformation. Digital transformation promotes enterprise value through the transmission of operating cost mechanism and financing constraint mechanism. Therefore, digital transformation should be vigorously promoted, environmental regulation should be improved, and the construction of digital infrastructure and environmental policies should be facilitated to help achieve the 'dual carbon' goal.

Keywords: Digital transformation; enterprise value; moderating effect

1. Introduction

In the context of rapid development of global economy, digital transformation has become an important strategic choice for enterprises to enhance competitiveness and achieve sustainable development. Research shows that through digital means, enterprises can improve the efficiency of resource utilisation, optimise the decision-making process and enhance customer stickiness, thus gaining an advantage in the fierce market competition.

Against this backdrop of uncertainty, enterprises often need to be more cautious in assessing the risks and rewards of related investments when driving digital transformation. The complexity and cost of decision-making in this process may undermine the direct impact of digital transformation on enterprise value enhancement.

This study aims to explore the mechanism of the impact of digital transformation on firm value, focusing on how economic policy uncertainty moderates this relationship.

2. Literature review

2.1 Digital transformation and enterprise value

Digital technology can effectively improve the operational efficiency of enterprises, and then increase enterprise value [1]. Relevant studies have shown that there is a positive

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relationship between digital transformation and enterprise value. Liu Weiqi et al. (2024) found that enterprise digital transformation promotes enterprise value enhancement through micro-information effect and macro-concern effect [2]. Wang Ronglu (2024) found that digital transformation can effectively reduce the supply chain costs of listed companies, thus increasing enterprise value [3]. Zhang Yongkun et al. (2021) and Zhao Chenyu et al. (2021) found through their research that enterprise digital transformation can achieve an increase in enterprise value by reducing enterprise costs [4][5]. Yang Hongxiong et al. (2024) found that the R&D innovation capability of digital transformation enterprises positively affects enterprise value creation [6]. Additionally, studies have shown that economic policy uncertainty contributes to digital transformation. The uncertainty of economic policy makes it more difficult to predict the change trend of economic policy, and the willingness of enterprises to invest in fixed assets investment, R&D investment and other entities decreases. At this point, digital transformation of enterprises has become an effective solution. By widely applying digital technologies to the production and operation field, it helps enterprises optimize business processes, reduce operating costs [7]. When the level of economic policy uncertainty is high, the uncertainty of a company's future profitability also increases, while exacerbating the degree of information asymmetry. This increases the demand for a company's risk-taking ability and reduces investment opportunities, leading to a tendency to reduce investment scale. [8]

3.Research Design

3.1 Data sources

In this paper, the data of Shanghai and Shenzhen A-share listed companies from 2007 to 2020 are selected as the research sample, totaling 1,284 companies. And the samples of financial enterprises and ST stocks are excluded, in addition, all variables are shrink-tailed by 2% and 98%.

3.2 Variable Setting

Explained variable: enterprise value. In this paper, Tobin's Q is used to measure and logarithmise the enterprise value.

Core explanatory variable: digital transformation level. This paper adopts word frequency statistics to extract the characteristic words about digital transformation in the annual reports of enterprises for measurement, and finally adds the number of word frequencies of each perspective to get the total word frequency, and then adds 1 to do the logarithmic processing.

Moderating variable: economic policy uncertainty index. This paper selects large newspapers in China, and filter out articles related to economic policy uncertainty by searching keywords such as 'uncertain/uncertainty', 'economy', 'policy', etc. After statistical and standardized processing, the index is obtained.

Other variables are defined as shown in Table 1.

Table 1: Definition of variables

Variable type	Variable symbol	Variable name
Explained Variable	EV	Enterprise Value
Core Explanatory Variable	Digi	Digital Transformation
Moderating variable	EPU	Economic Policy Uncertainty Index
Control Variables	ES	Enterprise Size
	AE	Age ofEnterprise
	FS	Financial Health state

4.Empirical results and analyses

4.1 Benchmark regression results

Table 2: Descriptive statistical characteristics of the main variables

Variables	Numbers	Mean value	Standard deviation	Minimum value	Maximum value
EV	17,976	1.088352	0.4204103	0.5250249	9.603146
Digi	17,976	0.7854169	1.122016	0	4.406719
EPU	14	164.2505	105.3202	50.44338	390.388

Table 3 reports the regression results of the impact of digital transformation on firm value, and limited to space constraints, this paper omits to report the results of the control variables. The results show that the impact coefficient of Digi is significantly positive, indicating that the development of digital transformation is significantly positively related to firm value.

Table 3: Baseline regression results

Variables	EV	EV
Digi	0.019875*** (0.0025676)	0.0138671*** (0.002844)
Constant term	8.122352*** (0.190615)	11.81512*** (0.32121)
R^2	0.6144	0.8139

5. Heterogeneity analysis

5.1 Regional heterogeneity

In this paper, all sample companies are divided into East, Central, West and Northeast according to the geographical location of the place of registration, and are tested separately, and the results are shown in Table 4. The results show that: only the eastern region of the enterprise digital transformation on enterprise value of the impact coefficient are positive, and passed the 1% significance test, while the central region, the western region, the northeastern region of the impact coefficient are not significant. The possible reasons for this are: the central region, western region, and northeastern region have a slower start in digital development, the digital infrastructure is relatively less perfect, and due to the industrial structure, geographic location, and government policy, there is insufficient capital investment in digital transformation and less government subsidies.

5.2 Industry heterogeneity

Table 4: Regional Heterogeneity Test Results

	Eastern Region	Central Region	Western Region	Northeastern Region
	EV	EV	EV	EV
Digi	0.0165709***	0.0054464	-0.0021943	0.0079109
	(0.0035433)	(0.007713)	(0.0071487)	(0.0119725)
Constant term	10.60378***	9.840043***	15.82073***	6.749622***
	0.4279527	0.8162898	0.6498284	1.18048
R^2	0.8200	0.8179	0.8277	0.8328
N	10676	3023	3300	977

Different industries have different degrees of digital transformation, leading to differences between the values of firms in each industry. In this paper, the sample companies are categorised into manufacturing and non-manufacturing industries for group regression.

Table 5 shows the regression results of the industry heterogeneity analysis, and the digital transformation of non-manufacturing industries is more able to bring significant impact on enterprise value. The reason may lie in the fact that firms in non-manufacturing industries may pay more attention to direct interaction and experience with customers, accurately grasping customers' needs through digitalisation and providing personalised services, which directly contributes to the growth of enterprise value.

Table 5: Results of industry heterogeneity test

	manufacturing industry	non-manufacturing industry
	EV	EV
Digi	0.0096394**	0.0158266***
	(0.0039154)	(0.0040864)
Constant term	12.06734***	11.35993***
	0.4380806	0.4867624
R^2	0.8108	0.8561
N	10583	7393

6. Analysis of Moderating Effects

China's economic uncertainty index for the years 2007-2020 is obtained from the FRED database, and since this data index is measured in months, this paper takes the average of the monthly data for each year 2007-2020 as a measure of the annual economic policy uncertainty index. The coefficient of digital transformation on firm value is significantly positive, while the cross-multiplier of digital transformation with economic policy uncertainty and firm value are significantly negatively correlated, suggesting that the rise of economic policy uncertainty weakens the promotion effect of digital transformation on firm value. This may be because, on the one hand, in times of economic policy uncertainty, firms may be more cautious in their resource allocation and investment behaviour choices.

Since digital transformation usually requires a large amount of upfront investment, including capital, manpower, and time, etc., under high economic policy uncertainty, firms may be hesitant to invest their limited resources in digital transformation, which is a risky project with a long payback cycle, which may cut down on expenditures on digital technology research and development and equipment upgrading, and thus reduce the advancement of the digital transformation efforts and effects, resulting in a slowdown in the digitalisation process and an inability to fully realise its positive impact on enterprise value.

Table 6: Moderating effect test results

	EV
Digi	0.048842***
	(0.0180479)
EPU	0.2353114***
	(0.0356806)
Digi*EPU	-0.0067289**
	(0.0034289)
Constant term	10.86343***
	(0.2968928)
R^2	0.8139
N	17976

7. Analysis of the transmission mechanism

7.1 Operating cost mechanism

The explanatory variables in column (1) of Table 7 are the degree of digital transformation undertaken by listed companies and the operating cost ratio (OCR), respectively, and the regression coefficients of the variables are 0.0136255, and -0.00483, respectively, and both of them are significant at the 1% level. The explanatory variable in column (2) is the degree of digital transformation and the regression coefficient of the variable is -0.00483 and significant at 1% level. The regression results indicate that digital transformation reduces the operating cost ratio of firms.

Table 7: Mechanism identification test results

	EV	OCR	EV	BL
Digi	0.0136255*** (0.0028188)	-0.00483*** (0.00116)		
OCR	-0.3463573*** (0.0199865)			
Digi			0.0137721*** (0.0028442)	0.0049507* (0.0030111)
BL			0.018599** (0.0073172)	
R^2	0.8155	0.2733	0.8140	0.4030
N	17952	17952	17975	17975

7.2 Financing constraint mechanism

The explanatory variables in column (3) of Table 7 are the degree of digital transformation carried out by listed companies and the proportion of bank loans (BL) of firms, respectively, and the regression coefficients of the variables are 0.0137721 and 0.018599, respectively, and both are not less than 10 per cent significant at the 10 per cent level. The explanatory variable in column (4) is the degree of digital transformation is 0.0049507 and significant at 10% level.

8. Conclusion

Enterprises should fully leverage the positive role of digital technology in enhancing their resilience and strengthening their competitiveness. Under the influence of economic policy uncertainty, enterprises should be adept at utilizing digital technology to mitigate adverse risks, accelerating the integration of digital technology with industrial entities, and forging resilience against external negative impacts.

Research has revealed that the initial digital transformation offers enterprises more environmental monitoring tools, enabling them to adhere to environmental regulations, reduce costs, and enhance operational efficiency. Secondly, environmental regulations have, to some extent, fostered the innovation capabilities of enterprises. This innovation not only elevates the market value of the enterprise but also reinforces its brand image. Thirdly, digital transformation and environmental regulation can create a virtuous cycle.

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Competency Model Construction for Middle Managers in Chinese University-Affiliated Hospitals in the Digital Economy Era

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Abstract: The digital economy has penetrated various fields of the social economy, including the healthcare industry, and the high-quality development of hospitals requires high-quality middle-level managers. Most middle-level managers in Chinese university affiliated hospitals come from medical technology backbones, and the phenomenon of "double shoulders" is common. They are tired of coping and lack professional knowledge in management. Constructing a scientific competency model for middle-level managers in Chinese university affiliated hospitals is not only a reference for cultivating middle-level managers in Chinese university affiliated hospitals, but also of great significance for improving the quality of middle-level managers in Chinese university affiliated hospitals. The article extracts the competence qualities of middle-level managers in Chinese university affiliated hospitals through literature analysis and grounded theory and uses fuzzy analytic hierarchy process to determine the weights of various elements of competence, constructing a competence model for middle-level managers. The results show that the competency qualities of middle-level managers in Chinese university affiliated hospitals can be summarized into 26 competency qualities, including five dimensions: digital technology ability, hospital decision-making ability, hospital management ability, personal characteristics, and knowledge learning ability. Among them, hospital management ability and decision-making ability are the most important dimensions.

Keywords: Chinese university-affiliated hospitals, middle managers, competency model

1. Introduction

According to the 2022 China Digital Economy Development Report, the scale of China's digital economy reached 45.5 trillion yuan in 2021, which has become a key

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driving force for stable economic growth. In June 2021, the State Council formally issued the Opinions on Promoting the High-Quality Development of Public Hospitals, which suggests that high-quality development of hospitals requires high-quality managers to promote, and the phenomenon of "double shoulder" [1] of managers is common in the current hospitals affiliated with colleges and universities. Managers "double shoulder" phenomenon prevails, both to engage in clinical work, but also to undertake teaching and research, and the quality of management varies greatly, and there is an urgent need to improve their skills to adapt to the development of the digital economy era.

Scholars have come up with different definitions. Spencer [2] and others believe that competency is an individual characteristic that can be measured reliably and can distinguish good employees from ordinary employees. Nordhaug [3] also believes that the competency quality of employees should be constructed in the context of specific industries. Although there are slight differences in the definition of competency among scholars, two points of consensus can be summarised: ① Competency is a concept in a specific work context and is closely related to the requirements of the position; ② Competency is closely related to work performance and can measure the performance of employees. In this paper, the competency quality of middle managers in university-affiliated hospitals in the era of digital economy is based on the existing research on the competency quality of middle managers in university-affiliated hospitals, and further focuses on the skills and abilities that middle managers in university-affiliated hospitals should have in the context of the digital economy.

Therefore, the competency model can effectively measure the skills and abilities that middle-level managers in Chinese university affiliated hospitals should possess, and existing research mostly focuses on the competency of individual positions in public hospitals, lacking a systematic competency model for middle-level managers. Therefore, this article constructs a competency model for middle-level managers of Chinese university affiliated hospitals in the digital economy era, to enhance the quality of middle-level managers in Chinese university affiliated hospitals, promote high-quality development of Chinese university affiliated hospitals in the digital economy era, and lay a solid talent foundation.

2. Research Methods

2.1. Literature Review Method

Collect relevant literature from websites such as CNKI and Web of Science using keywords such as "university affiliated hospitals", "middle-level managers", and "competence". Then, sort out the content related to the competence quality of middle-level managers in university affiliated hospitals from 50 core papers, 12 master's and doctoral theses, and other literature to form a core element dictionary of competence quality for middle-level managers in Chinese university affiliated hospitals, and form initial indicators of competence quality.

2.2. Grounded Theory

2.2.1. Semi Structured in-depth Interviews

A semi-structured in-depth interview was conducted on 25 middle-level managers of Chinese university affiliated hospitals, using the STAR method to collect information. The successful and failed events of middle-level managers in Chinese university affiliated hospitals were collected, and competency elements such as job requirements, job abilities, personal characteristics, and motivations that affect their performance were identified, providing raw data for research and analysis.

2.2.1.1 Sample Source

Using theoretical sampling method for sampling, to improve the comprehensiveness and scientificity of middle-level managers in Chinese university affiliated hospitals as much as possible, the sample age is between 20 and 65 years old, including 22 functional department managers, 25 business department managers, 21 teaching department managers, and 23 scientific research department managers. The distribution of middle-level managers in various types of Chinese university affiliated hospitals is relatively uniform, and samples distributed in different counties and cities are selected as much as possible.

2.2.1.2 Preparation of Interview Outline

The interview content mainly uses the STAR method to collect key events (including successful and failed events) that the interviewee has experienced in their work, including four aspects: background information (Situation), work tasks (Task), specific behaviors (Action), and results (Result). The interviewee is asked to recall the environment in which the successful and failed events occurred, the specific work tasks completed, how they were handled at that time, and the outcome of the situation. Exploring the specific content of the work of middle-level managers in Chinese university affiliated hospitals through the collection of key information, to uncover the competency elements of middle-level managers in Chinese university affiliated hospitals.

2.2.1.3 Data Collection

Before the interview, the interview outline was given to 24 middle-level managers of Chinese university affiliated hospitals in advance to ensure the reliability of the collected interview data information; During the interview, the interview time for each interviewee was controlled within 30-90 minutes, and the interview records were promptly organized after the interview, resulting in a final interview record of 202900 words. According to the principle of theoretical saturation, 16 out of 24 interview records (2/3 of the interview records) were randomly selected for coding, and the remaining 8 interview records (1/3 of the interview records) were used for further theoretical saturation testing.

2.2.2 Encoding Analysis

Open coding, axial coding, and selective coding will be applied to the raw data collected from interviews to obtain the competency themes and main categories of middle-level management personnel in Chinese university affiliated hospitals, extract competency elements, and obtain the concept/category, main category, and core category of competency quality for middle-level management personnel in Chinese university affiliated hospitals, in order to extract competency elements.

2.2.3. Theoretical Saturation Test

When the coding progressed to the 14th interview record, the concept and scope of competence and quality of middle-level management personnel in Chinese university affiliated hospitals were basically saturated, with very few new concepts and categories emerging; And when encoding up to 16 interview records, almost no new concepts or categories emerge; Finally, encoding the remaining 8 interview materials did not reveal any new main categories, and no new competency traits were found in each main category, reaching theoretical saturation.

2.2.4. Organize and Analyze

The grounded theory extracts the competency quality of middle-level managers in Chinese university affiliated hospitals, which is consistent with the five dimensions summarized through literature. However, upon further analysis of the interview records, it was found that resource management capabilities can be classified as part of hospital management capabilities.

2.3. FAHP Analysis Method

A team of 9 experts (including 3 senior management personnel from Chinese university affiliated hospitals, 3 middle-level management personnel from Chinese university affiliated hospitals, and 3 public health management experts from Chinese university affiliated hospitals) used the Fuzzy Analytic Hierarchy Process (FAHP) to determine the weight of competency indicators for middle-level management personnel in Chinese university affiliated hospitals, which compensates for the shortcomings of the common Analytic Hierarchy Process (AHP): firstly, the consistency of the judgment matrix differs from the consistency of human thinking; Secondly, it is relatively difficult to verify the consistency of the judgment matrix; Thirdly, when the judgment matrix does not have consistency, it is difficult to readjust it to consistency; The fourth is to use $CR<0.1$ to test whether the judgment matrix has consistency, which lacks scientific basis [4].

Firstly, a fuzzy consistency matrix is constructed by comparing the membership degrees of two quality indicators in the competence quality of middle-level management personnel in Chinese university affiliated hospitals. Then, based on the properties of the fuzzy consistency matrix, the weight values wi of each layer element can be obtained. Among them, $w_i=1/n-1/2\alpha+1/n\alpha \times \sum_{k=1}^{n} r_{ik}$, $i \in \Omega$, n is the order of R, $\alpha=(n-1)/2$ [5], $0<r_{ij}<1$ and $r_{ij}+r_{ji}=1$.

3. Results and Analysis

3.1. Selection of Competency and Quality Indicators for Middle Level Managers in Chinese University Affiliated Hospitals in the Digital Economy Era

3.1.1. Collection of Initial Indicators of Competency Quality Based on Literature Research

Based on the induction and summary of literature on the competence and quality of middle-level managers in university affiliated hospitals by relevant scholars at home and abroad, the initial indicators of competence and quality of middle-level managers in Chinese university affiliated hospitals in the digital economy era have been formed, which is shown in Table 1:

Table 1: Literature sources of initial indicators of competency quality of middle managers in Chinese university-affiliated hospitals in the era of digital economy

Connotation framework	Sources of indicators	Number of indicators selected
Digital technology capacity		
Big data management thinking	Fei Xie [6]	3 items
Big data analytics capability		
Emergency response capacity		
Capacity to use digital information technology platforms	Xiaoli Meng [7]	1 item
Hospital decision-making capacity		
Forward-looking decision-making capacity	Hongyu Liu, Meijing Shi [8]	2 items
Breakthrough Innovation Capability		
Capacity for evidence-based policymaking	Liang Z et al. [9]	2 items
Resource management capacity		
Teamwork skills	Jian Chen et al. [10]	2 items
Risk control capacity		
Hospital management capacity		
Conflict resolution capacity	Xiaoxia Song et al. [11]	4 items
Ability to manage time		
Capacity to develop work plans		
cultivation of talent		
leadership	Calhoun J G [12]	2 items
Interpersonal communication skills		
Personal characteristic		
professional ethics	Barati O et al. [13]	3 items
personality trait		
Motivation and interest		
sense of responsibility	Tingting Shao, et al. [14]	3 items
devotion		
Service Awareness		
Knowledge learning capacity		
Medical expertise	Swing S R [15]	2 items
practical ability		
Knowledge of health policies	Lu Han et al. [16]	2 items
interdisciplinary knowledge		

3.1.2. Re-organisation of Initial Indicators Based on Rootedness Theory

Based on the rooting theory, open coding, spindle coding, and selective coding of the interview texts were carried out using Nvivo 12.0 software to obtain the concepts/categories, main categories, and core categories of competency qualities of middle managers in university-affiliated hospitals in the context of the digital economy era, so as to extract the elements of competency. The 16 interview texts collected from the interviews were coded independently until the theory was saturated, to ensure that the extracted concepts and categories of competency of middle managers in university-affiliated hospitals were more scientific. In the open coding stage, through the analysis of the text content, the corresponding concepts and categories were summarised and refined to form the initial 36 concepts; in the main axis coding stage, after eliminating the secondary concepts and categories and integrating the similar concepts and categories, the 16 main categories of competence of middle managers in university-affiliated hospitals were formed; in the selective coding stage, combining the Competency Thesaurus and the theory of Competency Iceberg Model, the elements were grouped to form five main categories, respectively. In the selective coding stage, five main categories were formed, namely, digital technology competence, hospital decision-making competence, hospital management competence, personal characteristics, and knowledge learning competence.

And through theoretical saturation tests, it was found that the concepts and categories obtained from open coding and axial coding are basically saturated, with very few new concepts and main categories appearing; No new competency traits were found in each main category, indicating that the categories obtained through open coding, axial coding, and selective coding analysis have reached theoretical saturation, and the results are reliable and effective.

The above results show that the extraction of the elements of competence of middle managers in university-affiliated hospitals through the rooted theory is consistent with the five dimensions previously identified through the literature as well as summarised and generalised. However, in the further collation and analysis of the interview text data, it was found that the resource management competence can be subsumed into the hospital management competence, therefore, the resource management competence of the original hospital decision-making competence was added to the hospital management competence in the original initial indicators of the literature, and the digital technology competence, personal characteristics, and knowledge learning competence remained unchanged.

3.1.3. Connotation and Dimension of Competence Quality of Middle Managers in Chinese University Affiliated Hospitals in the Digital Economy Era

Through literature research and interview text analysis using rootedness theory, it can be found that the competency quality of middle managers in university-affiliated hospitals in the era of digital economy should not only have the characteristics of middle managers in university-affiliated hospitals, but also need to master the digital technology capabilities of the digital economy, based on which, this paper summarises the competency qualities of middle managers in university-affiliated hospitals in the era of digital economy in five dimensions, i.e. digital technology capabilities, hospital decision-making capabilities, hospital management capabilities, personal characteristics and knowledge learning capabilities. ability, hospital decision-making ability, hospital management ability, personal characteristics and knowledge learning ability.

Table 2: Connotation and dimensions of competency qualities of middle managers in Chinese university-affiliated hospitals in the digital economy era

The first dimension	Secondary dimensions	Essential properties implied or reflected by a notion
Digital technology capacity	Big data management thinking	Using big data concepts to reflect on issues in various departments of a university-affiliated hospital.
	Big data analytics capability	Data collected from university hospitals were analysed using methods such as big data mining.
	Emergency response capacity	To be able to deal with emergencies in university-affiliated hospitals in a timely and effective manner.
	Capacity to use digital information technology platforms	Skilled in the use of digital information systems to achieve multi-dimensional tracking and monitoring throughout the management of university-affiliated hospitals.
Hospital decision-making capacity	Forward-looking decision-making capacity	Ability to keep abreast of national policies and accurately judge the development trends of various departments in university-affiliated hospitals.
	Breakthrough Innovation Capability	Adoption of new technologies and methods for the management of departments in university hospitals.
	Capacity for evidence-based policymaking	Decision-making in the management of university-affiliated hospitals based on available, reliable, and feasible evidence.
	Teamwork skills	It is able to bring into play the team spirit, complementarity and mutual assistance of the various departments of the university hospitals.
	Risk control capacity	Ability to identify and control healthcare risks in all departments of a university-affiliated hospital.
Hospital management capacity	Conflict resolution capacity	Ability to effectively resolve conflicts and defuse conflicts across departments in university-affiliated hospitals.
	Ability to manage time	Adept at achieving effective control of time through advance planning.
	Resource management capacity	To be able to plan, organise and allocate the resources of university-affiliated hospitals to enhance management efficiency.
	Capacity to develop work plans	(c) To develop reasonable, feasible, specific and well thought out work plans for the various departments of the university hospitals.
	Cultivation of talent	Actively building talent ladders in all departments of university-affiliated hospitals and developing long-term training programmes.
	Leadership	Demonstrated ability to lead staff in all departments of a university-affiliated hospital.
	Interpersonal communication skills	Ability to use appropriate communication strategies and language arts to communicate with personnel in all departments of a university-affiliated hospital.
Personal characteristic	Professional ethics	Strict adherence to the national code of medical ethics for medical personnel.
	Personality trait	Lead by example, have a practical and scientific approach, and support and respect each other.
	Motivation and interest	Passionate and dedicated to the medical career of university hospitals.
	Sense of responsibility	Adhering to the spirit of high responsibility, providing accurate and scientific data for the management of university affiliated hospitals.

	Devotion	Insisting on suffering before enjoyment, consciously resisting and correcting unethical practices in the medical profession.
	Service Awareness	Firmly establish the idea of wholeheartedly serving the patients and the medical and nursing staff of the majority of university-affiliated hospitals.
Knowledge learning capacity	Medical expertise	Expertise in clinical medicine, nursing and teaching.
	Competence in medical practice	Practical skills in clinical medicine, nursing and supervised teaching practice.
	Health policy	Keeping abreast of new policies and systems for medical and health care in university-affiliated hospitals.
	Interdisciplinary knowledge	Acquire interdisciplinary knowledge and skills in management, medicine, and health policy.

3.2. Competence Quality Index Weights for Middle Managers in Chinese University-affiliated Hospitals in the Digital Economy Era

3.2.1 Constructing a Competency Quality Hierarchy Model for Middle Managers of Hospitals Affiliated to Universities in the Digital Economy Era

Based on the competency quality index of middle managers in Chinese university-affiliated hospitals in the era of digital economy, the middle management competency quality hierarchy model of university-affiliated hospitals is constructed, which is shown in Table 3.

Table 3: Hierarchical model of competency qualities of middle managers in Chinese university-affiliated hospitals in the era of digital economy

The first dimension (A)	**Secondary dimensions(B)**	
Digital technology capacity (A_1)	Big data management thinking	(B_{11})
	Big data analytics capability	(B_{12})
	Emergency response capacity	(B_{13})
	Capacity to use digital information technology platforms	(B_{14})
Hospital decision-making capacity (A_2)	Forward-looking decision-making capacity	(B_{21})
	Breakthrough Innovation Capability	(B_{22})
	Capacity for evidence-based policymaking	(B_{23})
	Teamwork skills	(B_{24})
	Risk control capacity	(B_{25})
Hospital management capacity (A_3)	Conflict resolution capacity	(B_{31})
	Ability to manage time	(B_{32})
	Resource management capacity	(B_{33})
	Capacity to develop work plans	(B_{34})
	Cultivation of talent	(B_{35})
	Leadership	(B_{36})
	Interpersonal communication skills	(B_{37})
Personal characteristic (A_4)	Professional ethics	(B_{41})
	Personality trait	(B_{42})
	Motivation and interest	(B_{43})
	Sense of responsibility	(B_{44})
	Devotion	(B_{45})
	Service Awareness	(B_{46})
Knowledge learning capacity (A_5)	Medical expertise	(B_{51})
	Competence in medical practice	(B_{52})
	Health policy	(B_{53})
	Interdisciplinary knowledge	(B_{54})

3.2.2. Determining the Weights of Competency Qualities of Middle Managers in Chinese University-affiliated Hospitals in the Era of Digital Economy

Using the Fuzzy Analytic Hierarchy Process (FAHP) to determine the weight values of the competency qualities of middle-level managers in Chinese university affiliated hospitals in the digital economy era. See Table 4-Table 9 below.

Table 4: Fuzzy consistency matrix and its weights of level 1 indicators of competency quality of middle managers in Chinese university-affiliated hospitals in the era of digital economy

Arrangement of ideas	A_1	A_2	A_3	A_4	A_5	w
A_1	0.5	0.3	0.1	0.7	0.4	0.15
A_2	0.7	0.5	0.3	0.7	0.6	0.23
A_3	0.9	0.7	0.5	0.4	0.6	0.26
A_4	0.3	0.3	0.6	0.5	0.3	0.15
A_5	0.6	0.4	0.4	0.7	0.5	0.21

According to Table 4, the relative weights of the first level competency indicators for middle-level managers in Chinese university affiliated hospitals in the digital economy era are 0.15, 0.23, 0.26, 0.15, and 0.21, respectively, indicating that the hospital management capability has the highest weight. The relative weights between the sub-level quality indicators are shown in Table 5-Table 8.

Table 5: Fuzzy consistency matrix and its weights of secondary indicators of digital technology competence of middle managers in Chinese university hospitals in the era of digital economy

Arrangement of ideas	B_{11}	B_{12}	B_{13}	B_{14}	w
B_{11}	0.5	0.6	0.2	0.8	0.27
B_{12}	0.4	0.5	0.1	0.7	0.2
B_{13}	0.8	0.9	0.5	0.9	0.43
B_{14}	0.2	0.3	0.1	0.5	0.1

From Table 5 above, the ranking of the weight of digital technology competence indicators of middle managers in Chinese university-affiliated hospitals is, in order, the ability to deal with emergencies, the thinking of big data management, the ability to analyse big data, and the ability to use digital information technology platforms.

Table 6: Fuzzy consistency matrix and its weights of secondary indicators of hospital decision-making capacity of middle managers of Chinese university-affiliated hospitals in the era of digital economy

Arrangement of ideas	B_{21}	B_{22}	B_{23}	B_{24}	B_{25}	w
B_{21}	0.5	0.6	0.7	0.8	0.9	0.3
B_{22}	0.4	0.5	0.6	0.7	0.8	0.25
B_{23}	0.3	0.4	0.5	0.6	0.7	0.2
B_{24}	0.2	0.3	0.4	0.5	0.4	0.13
B_{25}	0.1	0.2	0.3	0.6	0.5	0.12

As can be seen from Table 6, the weight of hospital decision-making ability indexes of middle managers of Chinese university-affiliated hospitals is ranked in the order of forward-looking decision-making ability, breakthrough innovation ability, evidence-based decision-making ability, risk control ability and teamwork ability.

Table 7: Fuzzy consistency matrix and its weights of secondary indicators of hospital management competence of middle managers of Chinese university-affiliated hospitals in the era of digital economy

Arrangement of ideas	B_{31}	B_{32}	B_{33}	B_{34}	B_{35}	B_{36}	B_{37}	w
B_{31}	0.5	0.7	0.4	0.4	0.3	0.1	0.6	0.12
B_{32}	0.3	0.5	0.2	0.3	0.2	0.1	0.4	0.07
B_{33}	0.6	0.8	0.5	0.7	0.6	0.4	0.9	0.19
B_{34}	0.6	0.7	0.3	0.5	0.4	0.3	0.6	0.14
B_{35}	0.7	0.8	0.4	0.6	0.5	0.3	0.8	0.17
B_{36}	0.9	0.9	0.6	0.7	0.7	0.5	0.9	0.22
B_{37}	0.4	0.6	0.1	0.4	0.2	0.1	0.5	0.09

As can be seen from Table 7 above, the ranking of the weights of hospital management competence indicators for middle managers of Chinese university-affiliated hospitals are, in order of priority, leadership, resource management competence, talent development, ability to formulate a work plan, conflict resolution competence, interpersonal communication competence, and time management competence.

Table 8: Fuzzy agreement matrix of secondary indicators of personal characteristics of middle managers and their weights in Chinese university-affiliated hospitals in the era of digital economy

Arrangement of ideas	B_{41}	B_{42}	B_{43}	B_{44}	B_{45}	B_{46}	w
B_{41}	0.5	0.6	0.4	0.7	0.4	0.9	0.2
B_{42}	0.4	0.5	0.2	0.4	0.3	0.6	0.13
B_{43}	0.6	0.8	0.5	0.7	0.6	0.9	0.24
B_{44}	0.3	0.6	0.3	0.5	0.3	0.9	0.16
B_{45}	0.6	0.7	0.4	0.7	0.5	0.2	0.17
B_{46}	0.1	0.4	0.1	0.1	0.8	0.5	0.1

As can be seen from Table 8 above, the ranking of the weight of the indicators of personal characteristics of hospitals for middle managers of Chinese university-affiliated hospitals are, in order, motivation and interest, professional ethics, dedication, responsibility, personality traits and service consciousness.

Table 9: Fuzzy agreement matrix and its weights of secondary indicators of knowledge learning ability of middle managers in Chinese university-affiliated hospitals in the era of digital economy

Arrangement of ideas	B_{51}	B_{52}	B_{53}	B_{54}	w
B_{51}	0.5	0.6	0.9	0.8	0.38
B_{52}	0.4	0.5	0.6	0.6	0.27
B_{53}	0.1	0.4	0.5	0.4	0.15
B_{54}	0.2	0.4	0.6	0.5	0.2

As can be seen from Table 9 above, the ranking of weights of hospital knowledge learning ability indicators for middle managers of Chinese university-affiliated hospitals are, in order, medical professional knowledge, medical practice ability, interdisciplinary knowledge and healthcare policy.

3.3. Competency Quality Model for Middle Managers in Chinese University-affiliated Hospitals in the Era of Digital Economy

Through literature research and the use of rooted theory to screen out the qualities of competence of middle managers in university-affiliated hospitals in the era of digital economy, and through fuzzy hierarchical analysis to determine the weight of each quality indicator, to construct the quality model of competence of middle managers in university-affiliated hospitals in the era of digital economy, as follows Table 10.

Table 10: Competency quality model for middle managers in Chinese university-affiliated hospitals in the era of digital economy

The first indicators	**Weighting**	**Secondary indicators**	**When the layer weight values**	**Total weight**
Digital technology capacity	0.15	Big data management thinking	0.27	0.04
		Big data analytics capability	0.2	0.03
		Emergency response capacity	0.43	0.06
		Capacity to use digital information technology platforms	0.1	0.02

Hospital decision-making capacity	0.23	Forward-looking decision-making capacity	0.3	0.07
		Breakthrough Innovation Capability	0.25	0.06
		Capacity for evidence-based policymaking	0.2	0.05
		Teamwork skills	0.13	0.03
		Risk control capacity	0.12	0.03
Hospital management capacity	0.26	Conflict resolution capacity	0.12	0.03
		Ability to manage time	0.07	0.02
		Resource management capacity	0.19	0.05
		Capacity to develop work plans	0.14	0.04
		Cultivation of talent	0.17	0.04
		Leadership	0.22	0.06
		Interpersonal communication skills	0.09	0.02
Personal characteristic	0.15	Professional ethics	0.2	0.03
		Personality trait	0.13	0.02
		Motivation and interest	0.24	0.04
		Sense of responsibility	0.16	0.02
		Devotion	0.17	0.03
		Service Awareness	0.1	0.02
Knowledge learning capacity	0.21	Medical expertise	0.38	0.07
		Competence in medical practice	0.27	0.05
		Health policy	0.15	0.03
		Interdisciplinary knowledge	0.2	0.04

As can be seen from Table 10, for middle managers of university-affiliated hospitals in the era of digital economy, hospital management ability is the most important, which is mainly reflected in leadership, resource management ability, talent cultivation and other aspects. At present, most of the middle managers of university-affiliated hospitals are promoted from clinical departments, and due to the differences in the business knowledge of various departments, coupled with the fact that middle managers of university-affiliated hospitals are the backbone of their disciplines, they also need to shoulder the responsibility of cultivating disciplinary talents. Therefore, in the future training, there is an urgent need to train the leadership and talent cultivation ability of middle managers in university-affiliated hospitals.

4. Conclusion and Prospect

4.1. Conclusion

This article will not only determine the five-dimensional elements of digital technology ability, hospital decision-making ability, hospital management ability, personal characteristics, and knowledge learning ability of middle-level managers in Chinese university affiliated hospitals from the perspective of the digital economy, but also establish the weights of various quality indicators. Expanding the competency connotation of middle-level managers in public hospitals, including Zhirong Li, Yachao Gao [17], Xiuqin Peng and Qing Ma [18], to Chinese university affiliated hospitals, and enriching the competency model of young and middle-aged cadres in Chinese university affiliated hospitals, as well as hospital office directors such as Hongyu Liu, Meijing Shi[8], and Xiaoxia Song etal. [11].

4.2 Outlook

Although this article constructs a competency model for middle-level managers in Chinese university affiliated hospitals in the digital economy era, there are still shortcomings. Due to time and manpower limitations, the model could not be tested in practice. Future research can further test the competency model of middle-level managers in university affiliated hospitals in practice.

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Transformation of University and College Education on Tourism Digitalization – Based on the Case of Shenzhen City

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Abstract. The rapid development of Internet technology, the multi-field integration of application scenarios and new technologies, such as AI, big data and cloud computing, have boosted the rapid development of the tourism industry's digitalization. The change and development of the tourism industry have led to an increased demand for tourism digitalization digital technology professionals. This study focuses on the university and college level education to meet the development of new tourism scenarios in the big data era. The research explores "Three-in-One" educational framework and "Three-dimensional Scenarios" educational model. This study also examines the present development trend of the tourism market and the skill characteristics of demand. Additionally, the study explores the training framework of tourism digitalization education. The research analyzes the development of the local tourism industry in Shenzhen City. It suggests that localized training programs can benefit the development of tourism digitalization education at universities and colleges.

Keywords. Tourism Digitalization, Tourism Education, Education Innovation, AI and Big data

1. Introduction

The digital economy and the integration of Internet technology are driving new formats in the cultural tourism industry, leading to a growing demand for high-end tourism professionals. Therefore, training tourism digitalization talents in higher education institutions must be improved to ensure the validity of the teaching system in this field. On the one hand, the recognition of talents in tourism digitalization is rising annually. Enterprises and the market are particularly concerned and recognize high-level talents who possess a mastery of digital technology and Internet business models[1]. On the other hand, the complex and innovative high-end talents in the field of tourism digitalization meet the market demand of the new development of the tourism industry. The digital development of high-end tourism service industry with distinctive characteristics urgently needs to integrate the new digitalization positioning of tourism majors in colleges and universities. Therefore, market demand for tourism digitalization talents has shifted in the educational approach, with traditional tourism as the foundation.

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The rapid development of Shenzhen's digital cultural tourism market requires a platform that can produce high-quality professionals specializing in tourism digitalization. It is imperative to carry out customized and differentiated exploration of tourism digital talent training in colleges and universities.

2. Literature Review

With the rapid development of AI and big data technology, various industries are experiencing significant transformation. The digital transformation journey necessitates appropriate talent - termed "digital talent" - to guide this process. Such individuals possess expertise across multiple domains rather than confined to traditional singular fields[2]. Research by Mohammed Al Haziazi (2023) substantiates those factors including digital skills, employee benefits, and a people-centric culture positively correlate with effective talent management, enhancing the mechanisms for managing human resources in Oman's Sultanate companies[3]. Tourism has also experienced significant changes in digital transformation and is one of the leading sectors in digital transformation[4]. Zhao Lei (2022) pointed out that the continuous penetration and integration of the digital economy into the tourism industry requires the support of substantial human capital accumulation, which forces the continuous improvement of the quality of human capital in the tourism industry[5].

The training of digital talents is strong support for the successful digital transformation of the cultural tourism industry, whose professional quality and professional ability directly affect the service quality and economic benefits of cultural tourism enterprises and directly relate to the completion of the transformation and upgrading of the cultural tourism industry[6]. Dai (2019) points out that in line with the trend of digital transformation of the tourism industry, the training of tourism talents should focus on the cultivation of digital talents with digital office skills, digital tourism operation, tourism product research and development, digital marketing and other capabilities[7]. This requires universities to fully connect with the development of new technologies and new models of the tourism industry and serve new driving forces.

In terms of the cultivation of digital talents, Daniel (2017) combined the characteristics of the tourism industry and formed a tourism industry-oriented talent training model of "two combinations, three progressive and four spiral" with professional quality and ability as the core[8]. Li Junyi and He Zhe (2022) said that the tourism industry needs high-end technical talents with Internet thinking, mastering new technologies and meeting the needs of tourists in the new era, and proposed to build a "three-combination" multi-disciplinary personnel training mechanism[9]. Huang Ke (2021) focuses on analyzing the problems existing in the innovation and entrepreneurship training of tourism talents in the era of the digital economy and proposes to build a training model of "three layers", "six steps" and "four integration" to deepen the reform of "second classroom"[10].

3. Education Environment on Tourism Digitalization and the Case of Shenzhen City

3.1. Development of Global Digital Tourism Market

The tourism industry is experiencing a new surge in development due to the ongoing innovation and application of science and technology. Specifically, emerging Internet technology is serving as a new driving force[11]. Digital technology also brings additional opportunities for the digital culture and tourism market in the deep integration of the cultural and tourism fields. In response to the demand for economic transformation, major tourism cities worldwide are employing digital technologies to promote the digital, networked and intelligent transformation of the conventional tourism sector; and to support the sustainable development of tourism through technological innovation, service upgrading, marketing and promotion. For instance, Izmir, the initial city in Turkey to finalize the development of its digital tourist infrastructure, has created a mobile tourism application called Visit Izmir. This program provides travelers with convenient access to information about more than 2,300 locations in 30 districts of Izmir, at any time and from any location.

3.2. Development of China' s Digital Tourism Market and Changes in Talent Demand

3.2.1. Development of Tourism Digitalization in China

In the context of the vigorous development of the global digital tourism market, China, as a major tourism country in the world, its digital tourism market is also showing a strong growth momentum. Sixteen industry subcategories with additional evident features of digital cultural tourism attained an operating income of 3,962.3 billion yuan in 2021, according to the annual inventory report of China's cultural and tourism industries. This represents an 18.9% increase from the previous year. Compared to the average level of cultural enterprises, the two-year average growth rate was 11.6 percentage points higher at 20.5%. The vigorous development of China's digital cultural tourism industry has been directly influenced by the profound integration of new technologies and tourism as a result of the digital economy's horizontal expansion to multiple fields and levels.

Online travel industry is also experiencing growth due to the emergence of a few new travel websites, such as Ctrip, Qunar and Fliggy which are representative OTA APPs or platforms in China. Additionally, the growing number of tourism consumers is increasingly favoring online travel due to the emergence of new tourism services, including integrated OTA, mobile APP-customized travel, and destination services[12]. According to the 52nd Statistical Report on the Development of China's Internet, the number of online travels booking users in China has reached 454 million as of June 2023, an increase of 30.91 million compared with December 2022, accounting for 42.1% of the total Internet users (Figure 1). Digital cultural tourism products expand the time and space dimensions of the original tourism model. New logic and experiences for cultural tourism consumer products are built through mobile terminals, virtual platforms, and smart media. For example, Online tourism platforms have accelerated the expansion of new marketing channels by incorporating innovative models, such as live streaming, "ticket blind box" and "train blind box" into the layout content ecosystem.

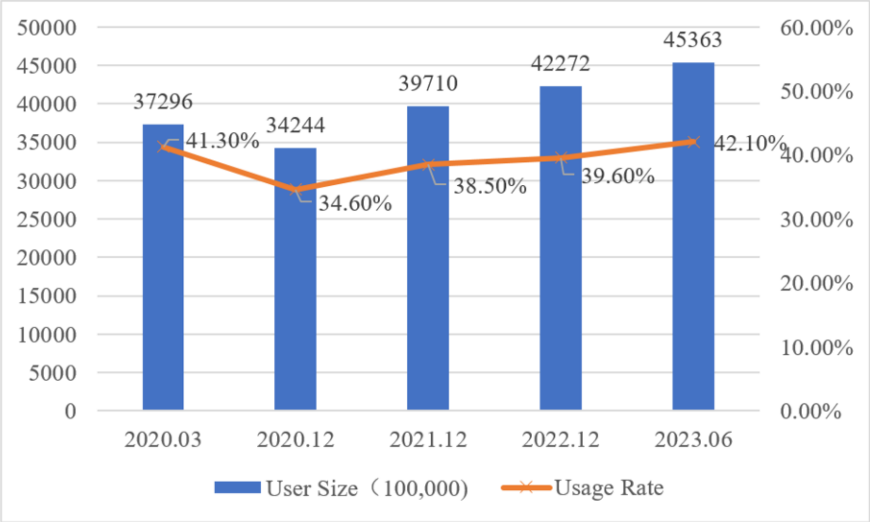

Figure 1. Scale and utilization rate of online travel booking users in China (2020–2023)

Source: 52nd Statistical Report on the Development of Internet in China, sampled valid point data.

3.2.2. Analysis of Demands for Tourism Digitalization Talents in China

The cross-border integration trend of science and technology and the tourism industry has resulted in numerous new scenarios, models, and talent needs, and has also presented new requirements for talent. Tourism companies focus considerably on personal comprehensive abilities. The tourism industry needs to have an entrepreneurial spirit, professionalism, and good skills. Society and industry also need high-end managerial talents with visionary management perspectives and cutting-edge top-tier management capabilities who can gather strength, possess strategic thinking and industry-leading leadership talents. We require skilled talents with a strong understanding of the Internet, proficiency in emerging technologies, and the capacity to explore untapped areas and cater to the changing demands of tourists in the modern Internet era[9].

The significant changes in the tourism industry have raised high demands for high-quality tourism education and talent education. These changes are necessary to strengthen theoretical and practical education and also to emphasize cultural education and interdisciplinary diversified knowledge dissemination[13]. Big data, cloud computing technology, and digital applications are significantly favored in tourism digitalization.

3.3. Tourism Digitalization Development and Tourism Talents Cultivation in Shenzhen

Shenzhen City possesses a wide range of tourism resources. As of 2023, there are 20 scenic spots categorized as A-class, with two designated as 5A-class and eight as 4A-class (Table 1). Additionally, the city is home to National Nature Reserves, National Geopark, and National Wetland Parks, which further enhance its tourism attractions. Shenzhen City also offers numerous recreational and leisure facilities in various types. Additionally, there is a growing number of popular Internet celebrity spots, which are increasingly attracting an increasing number of tourists.

Table 1. Shenzhen City 4A and Above Scenic Spots (as of September 2023)

Number	Scenic Spots	Quality Ratings	Assessment Time (Year)
1	OCT Travel and Resort Area	5A	2007
2	Mission Hills Tourism and Leisure Resort	5A	2011
3	OCT East	4A	2014
4	Evergreen Resort	4A	2011
5	Safari Park Shenzhen	4A	2011
6	Fairy Lake Botanical Garden	4A	2007
7	Waterland Resort	4A	2009
8	Guangming Tour Farm	4A	2017
9	Mission Pastoral Tourism and Culture Park	4A	2009
10	Spring-Mountain Hot Spring Manor	4A	2018

Source: Official website of Shenzhen Municipal Culture, Radio, Television, Tourism and Sports Bureau.

Regarding tourism infrastructure and employees, data extracted from the Shenzhen Statistical Yearbook 2022 indicate that the hotel and catering business in Shenzhen City exhibited 2,066 corporate legal entities by the end of 2021. Specifically, 619 are in the accommodation industry, and 1,447 are in the catering industry, constituting 29.96% and 70.04%, respectively. Currently, the total number of star-rated hotels in Shenzhen City has reached 62, of which 21 five-star, 16 four-star and 22 three-star hotels have been opened. Meanwhile, there are 114,373 employees in the accommodation and catering industries and 30,655 employees in the tourism industry, including 10,363 in the hotel industry, 1,066 in travel agencies and 9,627 in scenic spots.

The statistics mentioned above indicate that cultural tourism consumption in Shenzhen City is demonstrating a sustained surge in popularity, accompanied by ongoing enhancements in infrastructure. Therefore, Shenzhen City' s local higher education institutions need to adjust their educational policies based on the strong market demand and popularity of the tourism digital technology profession, closely follow the demand of the supply side of the real economy and consider the unique characteristics of Shenzhen's local development.

4. Education Innovation on Tourism Digitalization and Education Practices

4.1. New Orientation and Challenge of Talent Training in Tourism industry

The cohesive advancement of the tourism industry has resulted in a notable increase in the demand for proficient professionals. Colleges and institutions offering programs should prioritize developing digital tourism skills among their students. These skills include a profound appreciation for one's country and culture, a strong sense of cultural self-assurance, and the ability to adapt to new business models and utilize emerging technologies effectively; it is essential to develop interdisciplinary knowledge and practical skills in order to excel in the field of digital talent training[14]. Additionally, cross-functional talents with global vision, innovative thinking, and entrepreneurial awareness should be cultivated[15], providing talent guarantee for the tourism industry's digitalization and further fostering integration and innovation.

4.2. Diversified Practices on Tourism Digitalization Talents Training

4.2.1. Explorations of the New Education Mode of "Teaching and Learning"

A new "Teaching and Learning" model has been devised to transform traditional teaching patterns and learning environments, which incorporates a "Three-in-One" approach and "Three-dimensional Scenarios", aimed at integrating cultural tourism and digital development (Figure 2). From the "Teaching" perspective, this model is distinguished by interactive coordination and collaborative roles among students, corporations, and instructors. From the "Learning" perspective, "Three-dimensional Scenario" teaching mode is introduced, which combines advanced technologies, innovative scenarios, and cultural immersion.

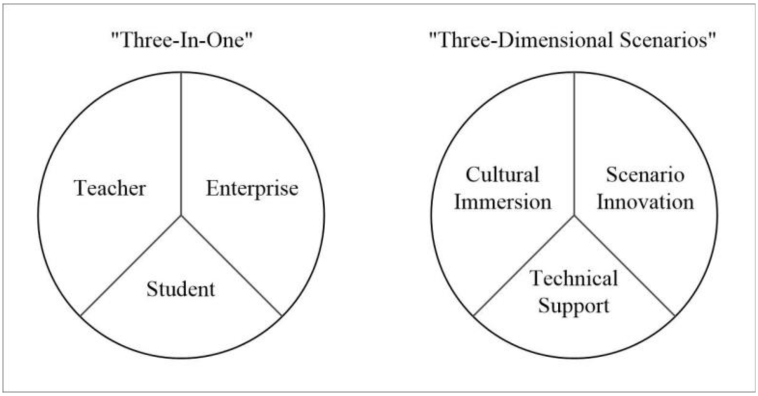

Figure 2. New Model of "Teaching and Learning"

The "Three-in-One" framework focuses on the core of educational ecology, reshaping the relationships among educators, businesses, and students. Focusing on the demand for tourism digitalization, the curriculum teaching resource base is developed, and technology-intensive curriculum groups are designed to cultivate students' adeptness in perceiving and applying technology. Collaborations with partners in Shenzhen and the Guangdong-Hong Kong-Macao Greater Bay Area are encouraged to establish several off-campus innovative practice bases, encompassing Internet ecological platforms such as OTA platforms, cross-border tourism e-commerce, and new media. Students and teachers will participate in practical, cultural tourism projects, allowing students to be both passive recipients and active contributors in course design and project execution. This engagement will deepen their understanding and application of technology in solving real-world problems and create a virtuous teaching and learning cycle.

The "Three-dimensional Scenarios" component focuses on the learning experience by integrating culture, scenarios, and cutting-edge technology. Cultural embedding ensures that technological innovation always serves cultural inheritance and enhances tourism experiences. It expands students' learning and practice by introducing new knowledge, concepts, methods, and scenarios driven by innovation, changing demands, and business transformations in various industries. Students can immerse themselves in authentic cultural contexts through practical teaching methods that combine new technology and resources, gaining a deeper cultural understanding. This experience enhances their learning autonomy, the practicality of knowledge, and innovative thinking while developing their ability to renew and regenerate their technical knowledge continually.

4.2.2. Constructions of a New Experiential Teaching System

The construction of comprehensive on-campus laboratories and smart tourism experience centers should be emphasized. To strengthen university-industry cooperation and establish off-campus industry-university-research bases should be emphasized. This will enable teachers and students to engage in practical cultural and tourism projects, thereby enhancing students' capacity to integrate theory with practice[16]. To build multiple Teaching system and Environmental Creation. The teaching format can be enriched with digital technologies to fully expand the boundaries of the classroom, incorporating different dimensions, such as online teaching, blended learning combining online and offline methods, and virtual simulation experiments. Specifically, course resource packages are produced in the form of online MOOC, and AI service terminals are introduced to provide course learning tools, forming a digital-intelligent teaching model.

4.2.3. Constructions of Dual-Teacher Model of Teaching Staff

Integration of digital technology in the tourism discipline involves the convergence of diverse knowledge domains. The teaching staff in higher education institutions specializing in tourism should consist of professionals with different disciplinary backgrounds, particularly those who possess multidisciplinary knowledge and skills. An essential requirement for nurturing versatile talents in tourism digitalization is establishing a "dual-teacher model" teaching staff with solid professional foundations, high teaching capabilities, strong research skills, proficiency in modern teaching methods, and outstanding practical experience. This teaching staff is crucial for cultivating multifaceted tourism digitalization professionals[17]. Additionally, incorporating professionals and highly skilled sales personnel as adjunct instructors in the institution can enhance the diversity of the part-time teaching team.

5. Summaries and Future Research

In the digitalization era, tourism digital technology talent education must be in accordance with industry requirements and developments. This undertaking requires a focus on integrating new knowledge and skills, as well as the coexistence of professionalism and innovative capacity. Reforms and innovations in talent education models suitable for tourism digital technology application scenarios are imperative. This study analyzes tourism digitalization environments in the digital era. Based on development assessment of China's digital tourism technology and changes in talent demand, we explored a new talent education model from the perspectives of target orientation, optimization of knowledge system and capability development. Furthermore, by taking into account the specific talent demand patterns in Shenzhen City and the unique characteristics of the tourism digital technology market in the city, this study enhances the practical teaching system and methods for cultivating tourism digital technology talents. The present research comprehensively proposes a diversified talent education pathway for higher education institutions, encompassing innovative teaching models, the construction of practical systems, instructional design, environment creation, and faculty team development.

From an interdisciplinary perspective, a new teaching model with “Three-in-One” and “Three-dimensional Scenarios” as the core is constructed, and the practical teaching system for the training of digital cultural tourism talents is improved to meet the requirements for composite digital cultural tourism talents in the development of new tourism. The new model of “teaching and learning” in this study emphasizes the students' rapid cognitive ability to use new technologies, scenarios, and formats, as well as the new tourism talents who can apply new technologies and the development of tourism digitalization in real time. The teaching innovation model aims to establish a joint practice-based partnership with benchmark companies in the tourism and cultural industry and high-tech enterprises in Shenzhen City, such as OCT Group and Invengo Company. Joint practice bases are established to integrate teaching and research, combining full-time and part-time teachers. Innovative practical teaching methods are devised by incorporating new technologies and resources, forming an integrated tourism digital technology practical teaching system that includes “points, lines and areas”. The aim is to establish a specialized education system focused on digital tourism technology, specifically designed to support the growth of the local industry in cities. In conclusion, this research intends to inject new sources of energy and explore new development paths for cultivating tourism digital technology talents, and ultimately support the training needs of Shenzhen and even the Guangdong-Hong Kong-Macao Greater Bay Area composite digital cultural tourism talents.

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A Review of Research on the Impact of Ageing on the Digital Economy and Its Countermeasures

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Abstract. With global demographic changes, population ageing has become one of the most important social phenomena of the 21st century, with far-reaching implications for China and the global economic system. This article comprehensively analyses the impact of population ageing on macroeconomics, regional economy and microeconomics, and discusses effective policy response strategies. The article first analyses the current situation and trend of population ageing, then discusses its impact on digital macroeconomics, digital regional economy and digital microeconomics, and finally makes macroeconomic and social security policy recommendations to cope with ageing. The findings of this study underscore the necessity for collective action by governments, businesses, social organisations and individuals alike in order to effectively address the challenges associated with an ageing population. Further research is required to enhance comprehension of the impacts of ageing, particularly in the context of the accelerated development of the digital economy. Additionally, investigation into the effective utilisation of technology to optimise the quality of life and social participation of older individuals is a subject that merits comprehensive examination. This paper advocates for collective action by all societal sectors to construct a comprehensive strategic framework for adapting to an ageing society, with the objective of ensuring sustained and robust economic growth and comprehensive and harmonious social advancement.

Keywords. Population ageing; digital economy impact; economic growth; social security; technological innovation; policy recommendations

1. Introduction

In the context of the significant global demographic shifts that have occurred in the twenty-first century, the phenomenon of ageing has emerged as a particularly salient social issue. The issue of ageing has become a significant concern for governments and sociologists due to the ongoing decline in fertility rates, the increasing longevity of life expectancy, and the entry of large-scale populations into old age. As projected by the United Nations, the global population of individuals aged 60 and above will reach 2.2 billion by 2050, representing 22% of the total population. In Europe, this proportion will reach 34%. Developing regions, such as Asia and Latin America, will also be confronted with the unprecedented challenge of an ageing population.

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In China, the world's most populous country, the issue of an ageing population is particularly salient. Since China entered an ageing society in 2000, the proportion of elderly people in the country has continued to rise. It is projected that the number of elderly individuals in China will reach 480 million by 2050, representing approximately a quarter of the global elderly population. This demographic shift presents a number of challenges to the family structure, social security system and distribution of healthcare resources. Furthermore, it has the potential to impact the sustained and healthy development of the digital economy. In this context, an in-depth study of the impact of ageing on the digital economy and its countermeasures is of great theoretical and practical significance for achieving sustainable economic and social development.

The existing literature on the economic impact of ageing focuses on the following aspects: firstly, the impact of ageing on the labor market. As the proportion of the population of working age declines, the issue of an insufficient labor supply becomes increasingly salient. This may give rise to higher labor costs and lower productivity, which in turn may affect economic growth. A second area of focus is the impact of an ageing population on consumption and savings. The process of ageing may result in alterations to the consumption structure, with the consumption requirements of the elderly differing from those of the young. This may consequently influence the advancement of related industries. Furthermore, the process of ageing may also exert an influence on investment and capital accumulation, as a consequence of its impact on the savings rate.

The objective of this paper is to put forth a series of proposed countermeasure suggestions, based on a comprehensive analysis of the impact of aging on the digital economy. In terms of methodology, this paper will adopt a systematic literature review approach to examine the existing research literature on the impact of aging on the digital economy, both domestically and internationally. This analysis will be contextualized within the specific circumstances of China. This paper's research content is comprised of three principal elements. Initially, the current situation and trend of population ageing in China will be analyzed. Subsequently, the impact of ageing on digital macroeconomics, digital regional economy and digital microeconomics will be explored. Finally, macroeconomic policy and social security policy suggestions will be put forward to cope with ageing.

The paper makes two distinct contributions to the existing body of literature. Firstly, it conducts an extensive review of the multifaceted ways in which an aging population influences the digital economy, a perspective that has been underexplored in prior research. The analysis delves into the intricate dynamics between aging and key components of the digital economy, such as labor market shifts, evolving consumer behaviors, and the pace of technological innovation. This comprehensive examination reveals the profound economic implications of demographic aging, paving the way for more strategic and effective policy interventions. Secondly, this research presents a set of policy recommendations specifically calibrated to China's aging scenario. These recommendations are designed to harness the digital economy as a lever for addressing the challenges posed by an aging demographic, with a focus on enhancing digital literacy among the elderly, fostering a culture of digital entrepreneurship, and catalyzing the digital transformation of traditional sectors to generate inclusive employment opportunities. By offering these targeted suggestions, this study seeks to inform policy discourse and strategic planning in China's pursuit of digital economic growth amidst an aging population.

The theoretical foundation of this paper is primarily based on the principles of population economics, development economics and social security theory. Population economics provides a theoretical framework for analyzing the impact of demographic changes on the economy. Development economics, on the other hand, focuses on structural changes and policy choices in the process of economic development. Finally, social security theory provides theoretical support for analyzing the impact of ageing on the social security system and proposing reforms. The study is of great practical significance about China's response to population ageing. As the process of ageing accelerates, the question of how to balance the social security needs of the elderly population with the sustainability of economic development through policy adjustments represents a significant challenge for China. The research presented in this paper can serve not only to provide a theoretical basis for the formulation of relevant policies by the government, but also to offer a new perspective for academics engaged in the study of the ageing issue.

2. Related works

The burgeoning digital economy and the concurrent rise of an aging population have set the stage for a complex interplay of demographic and economic factors. This section reviews the literature that addresses the impact of aging on the digital economy and explores potential strategies to mitigate any adverse effects[1].

2.1 The Aging Population and Digital Economy Dynamic

The study by Guo and Xiao (2024) [2]delves into the impact of an aging labor force on the employment transformation of migrant workers amidst the burgeoning digital economy in China. Utilizing data from the China Family Panel Studies (CFPS) from 2012 to 2020, they employ multiple Logit regression models to assess the influence of an aging workforce on the transition of migrant workers from traditional to new economy sectors. Their research indicates that while an aging labor force significantly inhibits this employment transformation, the digital economy acts as a catalyst, promoting the shift and alleviating the negative impacts of an aging workforce. This finding underscores the potential of the digital economy as a strategic tool in addressing the challenges brought about by demographic aging.

2.2 Corporate Strategies in Response to Aging

Wang and Zhao (2024)[3] contribute to the discourse by examining the effects of population aging on corporate digital transformation strategies. Through an empirical investigation based on population census data from various provinces in China, they reveal that aging directly hinders financial support and decision-making for digital initiatives. Furthermore, they explore the indirect effects of aging through financial strategies and management perspectives. The study suggests that non-state-owned and small to medium-sized enterprises are more significantly impacted by aging, highlighting the need for tailored strategies to support these vulnerable sectors in the face of demographic changes.

2.3 Policy Implications and Strategic Insights

The synthesis of these studies offers valuable insights for policymakers and corporate strategists. The work of Guo and Xiao (2024)[2] suggests that leveraging the digital economy can be a proactive approach to counteract the employment challenges posed by an aging population. Similarly, Wang and Zhao (2024)[3] emphasize the necessity for enterprises to adapt their digital transformation strategies to accommodate the realities of an aging demographic, particularly for non-state-owned and SMEs that may lack the resources to navigate these changes independently

In conclusion, the existing literature highlights the necessity for a multifaceted approach to address the impact of an aging population on the digital economy. Strategies must consider both the broader economic implications and the specific challenges faced by different sectors and enterprise sizes. By doing so, it is possible to harness the potential of the digital economy to foster inclusive growth and mitigate the adverse effects of an aging workforce.

3. Methods

This literature review aims to assess the impact of an aging population on the digital economy and to explore strategic countermeasures within the Chinese context. The methodology is divided into two focused approaches corresponding to the two parts of the study.

This study employs the bibliometric methodology with the assistance of the Chinese database China Knowledge Network (CNKI). The following keywords were utilized: "silver-hair economy," "aging + medical expenses," "aging + regional development," "aging + finance," "aging + microeconomics," "aging + digital economy," and "aging + macroeconomics." The keywords were then taken as follows, with the time range from 1 January 2018 to 31 December 2023, and with the exclusion of news, conferences and other invalid literature. The CSSCI core journals were selected as the search target, resulting in the screening out of 387 pieces of related core literature. The main focus of the study was then a literature review and summary of this literature.

3.1 Impact Analysis

A systematic literature search was conducted using PubMed, IEEE Xplore, ScienceDirect, and Google Scholar with keywords such as "aging population," "digital economy," and "economic impact." The search was restricted to English-language articles published between 2010 and 2024. Articles were included if they provided empirical or theoretical analysis on the economic effects of an aging population on digital sectors. Non-empirical and off-topic studies were excluded. Data extraction focused on the key findings and methodologies, with a qualitative synthesis to identify the predominant themes and impacts.

3.2 Countermeasures Analysis

The second phase of the review centered on literature discussing strategies and policies to mitigate the impacts identified in Part 1. The search strategy was consistent with Part

1, with additional keywords like "strategies," "policies," and "countermeasures." Inclusion criteria favored articles offering actionable solutions or policy insights. Data were extracted to thematic categories such as policy interventions and technological adaptations, aiming to compile a set of strategic responses to the challenges of an aging population in the digital economy.

4. Results & Discussion

4.1 The impact of the ageing population on the digital economy and the challenges this presents.

As a global challenge of the twenty-first century, the impact of population ageing on the economic system is complex and multidimensional. The phenomenon exerts an influence on economic growth at the macro level, affecting labor markets, consumption patterns, savings and investment behavior. Furthermore, it influences regional economic structures, industrial upgrading and urbanization processes at the mesa level. Furthermore, at the micro level, changes in the age structure of the population are also influencing household decision-making, corporate behavior and individual consumption patterns. From a macroeconomic standpoint, population ageing presents a challenge to economic growth potential, as it leads to a reduction in both labor force participation and productivity. Concurrently, it may also result in alterations to consumption patterns, influencing savings rates and investment behavior, which in turn have far-reaching implications for macroeconomic stability and growth. At the mesa level, the impact of population ageing on regional economies is manifested in several ways. Firstly, there are constraints on economic density, employment density and energy supply levels. Secondly, there are effects on population contraction and economic dynamism. At the micro level, economic decisions made by households and businesses, including asset allocation, entrepreneurial behavior and savings rates, are also significantly influenced by ageing trends[4].

The objective of this paper is to provide a comprehensive analysis of the impact of population ageing on the macro, mesa and micro levels of the economic system, and to explore effective policy response strategies. By undertaking an exhaustive examination of the influence of an ageing population on economic growth, industrial structure, urbanization and social welfare, the paper will put forward a comprehensive strategy to advance high-quality economic development. This strategy will seek to offset the adverse effects of an ageing population while capitalizing on its potential positive effects[5].

4.1.1 This paper examines the impact of population ageing on the macro digital economy.

The phenomenon of population ageing represents a global trend with significant macroeconomic implications. Firstly, the process of ageing has a direct impact on the potential for economic growth, reducing both the participation rates of the labor force and the overall productivity of that labor[6]. Furthermore, this impact displays heterogeneity across regions, indicating the necessity for policymakers to adopt a more nuanced approach to regional considerations[7]. Furthermore, the process of ageing may also engender some positive changes about the growth of the digital economy. For instance, the ageing of the population may facilitate the development of green technology and the substitution of capital, particularly in the environmental and technological spheres, thereby creating new avenues for economic growth. However, the macro-digital economy is also affected by the side effects of ageing to a greater extent. Firstly, it may result in a reduction in per capita consumption and diminished returns on capital, which in turn affects savings rates, industrial upgrading and productivity[8]. Furthermore, the process of ageing may result in a reduction in consumer demand and an increase in labor costs, which in turn have implications for tax policy. Furthermore, from a monetary policy perspective, the process of ageing presents a challenge to the objectives and effectiveness of monetary policy, with the potential to affect the economy by influencing fertility rates and income levels of the older population. Furthermore, the process of ageing exerts both spillover and crowding-out effects on foreign direct investment (FDI)[9], which generally inhibits FDI inflows.

As illustrated in the China Statistical Yearbook, the urban workers' pension insurance dependency ratio (defined as the ratio of the number of insured workers to the number of insured retirees) serves as a case in point. In 2007, the dependency ratio of China's urban workers' pension insurance was 3.07, indicating that for every 3.07 enterprise workers contributing to urban workers' pension insurance in 2007, there was one retired worker receiving pension. From 2007 to 2011, the dependency ratio exhibited a notable decline, dropping from 3.07 in 2007 to 2.017 in 2011. Similarly, from 2007 to 2009, the dependency ratio demonstrated a considerable reduction, dropping from 3.07 in 2007 to 2.53 in 2019, indicative of a general downward trend.

The ratio of income to expenditure of China's urban pension insurance fund provides an illustrative example of the observed declining trend from 2007 to 2022. Despite a brief period of recovery, the ratio of income to expenditure has continued to decline on an annual basis. From 2007 to 2020, the ratio of income to expenditure exhibited a decline, from 1.31 in 2007 to a low of 0.86 in 2020, representing a total decline of 0.45. In 2020, there was already a situation in which income was insufficient to cover expenditure. Subsequently, between 2020 and 2022, the ratio experienced a brief increase, reaching 1.07. Furthermore, the ratio of income to expenditure of the urban workers' pension insurance fund has remained at approximately 1 over the past four years. Given the prevailing trend of decline, it is anticipated that the ratio will continue to fall below 1 in the future, leading to an increased prevalence of insufficient income to cover expenditures.

Second, in the context of science, technology and innovation, there is a complex relationship between ageing and science, technology and innovation. Ageing can affect technological progress through mechanisms such as weakening the physical and mental capacities of workers, affecting the accumulation of human capital and threatening the innovative activities of enterprises. In particular, changes in the age structure of the population lead to a reduction in the labor force and force companies to recruit older workers. As the age of employees increases, their ability to learn and innovate continues to decline, resulting in a lack of innovation in the implementation of innovation projects (Liang et al. 2014)[10].Meyer (2007)[11] found that firms with a high number of older employees usually have a harder time adopting new technologies than firms with a high number of younger employees. People's motivation to innovate changes with age (Bosek et al., 2005; Kanfer and Ackerman, 2004)[12,13], and as people get older, they realise that even learning will not bring much benefit in the future, and due to the time lag in generating benefits from new innovation-related technologies, older people may not be able to wait to enjoy its benefits (Friedberg, 2003).As people get older, they realize that even learning will not bring much benefit in the future, and due to the time lag in generating benefits from new innovation-related technologies, older people may not be able to wait to enjoy its benefits (Friedberg, 2003)[14].

Ultimately, the key determinant of long-term economic development potential is total human resources, rather than total population. Even under relatively pessimistic population growth expectations, China's total human resources will continue to grow until 2040 and remain stable from 2040 to 2050. This indicates that the potential growth rate of China's economy in the next 30 years could be substantial.

Finally, ageing also has a negative impact on health care; in particular, the gradual deepening of demographic ageing can lead to a rapid increase in health care costs, contributing to an excessive financial burden on the national health sector. And why does population ageing lead to a significant increase in health expenditure? One key reason is that health expenditure rises significantly with age. Not only do older people have a higher incidence of disease than younger age groups, but they also suffer from diseases of longer duration, which directly leads to a significant increase in demand for health care and thus drives up the overall cost of health care.

The Special Report on the Sixth National Health Service Statistical Survey (Second Series), prepared by the Statistical Information Centre of the National Health and Welfare Commission, used data from the two national health service surveys in 2013 and 2018 to analyze the self-reported economic burden of chronic diseases among the elderly aged 60 and above. According to the analysis in this report, the economic burden of chronic diseases among the surveyed elderly population in 2018 was 610 million yuan, or 8,813.3 yuan per capita, which is a significant increase compared with the economic burden of chronic diseases among the surveyed elderly population in 2013, which was 2,481.8 yuan per capita. If the scope of the study is extended to the whole country, based on the 249 million elderly people aged 60 and above at the end of 2018, the national economic burden of chronic diseases among the elderly population will be 2.2 trillion yuan, while in 2013, based on the 212 million elderly people, the national economic burden of chronic diseases among the elderly population will be 0.5 trillion yuan.

In addition, according to data released by the National Committee on Ageing of China, without taking into account changes in the hospitalization rate, it is projected that the outpatient and inpatient medical and health care costs for the elderly in China will reach 130,987,000,000,000,000 yuan in 2050; taking into account changes in the hospitalization rate, it is projected that the outpatient and inpatient medical and health care costs for the elderly will reach 155,283,000,000,000,000 yuan in 2050.

In conclusion, the macroeconomic consequences of an ageing population are complex and interrelated, encompassing a range of domains including economic growth, monetary policy, labor productivity, foreign direct investment, science and technology innovation, and healthcare costs. The studies offer a variety of perspectives and comprehensive analyses of the impact of ageing on the economy, thereby facilitating a more nuanced understanding of the challenges posed by ageing. In evaluating the impact of ageing on the economy, it is essential for policymakers to consider the direct effects of ageing and its indirect effects through other factors, such as the urbanization rate and total human resources. This necessitates the adoption of appropriate policy design to mitigate the negative impacts of ageing while capitalizing on its potential positive effects.

4.1.2 This study examines the impact of population ageing on the regional digital economy.

In China, the process of population aging is gradually becoming an important factor affecting the development of regional digital economies. Relevant studies have demonstrated that 34 prefecture-level cities in Northeast China have entered a period of rapid aging, which has a significant impact on the level of local economic density, employment density, and energy supply. The inhibitory effect of aging on regional digital economic growth is evident, but the specific manifestations of this effect vary across different regions.

Firstly, the impact of population aging on the digital economy in towns and villages varies. One study, for instance, found that the aging risk in 31 provinces in China exhibited disparate spatial distributions and evolutionary trends when the PSR model and the weighted TOPSIS method were employed for analysis [5]. The use of panel data and threshold regression models in studies has revealed that when a certain level of urbanization is reached, the process of ageing can in fact facilitate industrial upgrading. Conversely, the process may be hindered. The specific reason for this may be since regions with a high level of urbanization have a high level of digital transformation, which helps to promote the development of the digital economy in towns and cities, especially in the service sector. This can effectively offset the economic pressure caused by ageing.

At the rural level, the adverse effects of population ageing are especially pronounced about the advancement of the digital economy. The low penetration of information technology in rural areas creates greater barriers for older population groups in the use of digital technology. This not only limits their ability to access information and services, but also impedes the pace of rural digital economy development. For instance, obstacles impede the dissemination of e-commerce, telemedicine, and smart agriculture, among other domains. These impediments could potentially enhance the quality of life for older individuals and augment the efficiency of agricultural production. Furthermore, the aging of the population in rural areas can also result in a deficit of individuals with digital skills, as younger generations tend to migrate from these areas, leaving a dearth of local talent with modern information technology. This further constrains the implementation of digital tools and innovation.

From an industrial standpoint, the impact of an ageing population on digital transformation varies across different sectors. From the perspective of the manufacturing industry, the ageing of the population has been observed to drive capital accumulation and productivity growth. This is due to a reduction in the labor supply, which in turn prompts enterprises to rely more on automation technology and intelligent equipment. Concurrently, to address labor shortages, enterprises have augmented their investment in human capital and facilitated technological innovation, thereby propelling the transformation and modernization of the manufacturing industry. Nevertheless, in the eastern developed regions, the process of ageing has resulted in a discernible negative impact on the digital transformation of the service industry [15]. The service industry is characterized by a high degree of dependency on human capital, particularly in sectors that necessitate direct interpersonal interaction, such as retail, catering and personal care services. As the proportion of the population in the older age bracket increases, the structure of the labor market undergoes a series of shifts, with a reduction in the number of younger workers leading to a decline in the quality-of-service provision and a weakening of the incentives for service innovation.

According to the 45th Statistical Report on China's Internet Development Status released by the China Internet Network Information Centre, as of March 2020, older internet users over 60 in China accounted for 6.7% of the total number of internet users, and the penetration rate of older internet users was 23.7%, less than a third of that of younger internet users (73.0%) (estimated based on China's total population and its composition at the end of 2019). Similarly, one in two people in China use mobile phones to access the Internet, but only one in five older people use mobile Internet.

In terms of use, the proportion of elderly people using search engines, installing APPs and using WeChat is significantly lower than that of young people, due to the existence of digital skills deficits. Among them, the proportion of elderly people using search engines is 4.4%, less than 1/6 of non-elderly internet users (27.4%); the number of mobile phone APPs per capita of elderly people is 37, only 44.0% of that of young internet users aged 20-29 (84 mobile phone APPs per capita); the proportion of elderly people using WeChat is 26.2%, less than 1/6 of that of non-elderly users .It can be inferred that the aging population is hindering the popularity of the IT industry.

In conclusion, the process of population ageing exerts a complex and multidimensional influence on the advancement of China's regional digital economy. The phenomenon of deep ageing is particularly pronounced in the Northeast, which is facing significant challenges in terms of economic density, employment and energy supply. In comparison between urban and rural areas, the negative impact of ageing is to some extent offset in urban areas due to higher levels of urbanization and digital transformation, as well as the promotion of services and other sectors. Nevertheless, rural areas are characterized by low levels of IT penetration and difficulties encountered by the elderly in utilizing digital technologies. This has resulted in a notable impediment to the advancement of the digital economy, particularly in the domains of e-commerce, telemedicine and smart agriculture. From an industrial perspective, the impact of ageing on the manufacturing industry is primarily evidenced by the promotion of automation and intelligent processes, which has prompted enterprises to increase their reliance on technology, thereby enhancing productivity and capital accumulation. However, in the service sector, particularly in the developed eastern regions, the structural shifts in the labor force due to ageing have undermined the quality of service and innovation capacity, which has a detrimental impact on the digital transformation of the service sector.

4.1.3 This paper examines the impact of population ageing on the micro-digital economy

As a significant socio-economic phenomenon of the 21st century, the influence of population ageing on the economy has progressively permeated from the macro to the micro level. The rapid development of information technology and the deepening of digital transformation have resulted in the emergence of the digital economy as a new engine for economic growth. However, population ageing is also bringing a series of unprecedented challenges and opportunities. In this context, an investigation into the impact of population ageing on the micro-digital economy is significant for understanding the current economic development trend and for formulating relevant policies to adapt to and guide this change. The objective of this paper is to analyses the impact of population ageing on the micro-digital economy.

From the perspective of business innovation, the process of ageing has had a significant impact on labor-intensive industries, as well as exerting a profound influence on the development of high-technology firms and certain service industries. As the proportion of the population over the age of 65 increases, the overall number of business entries in cities demonstrates a downward trend. This is primarily attributable to a reduction in the labor supply, a decline in human capital levels and changes in local market demand. The tightening of the labor market is compelling firms to reassess their long-term strategic planning, particularly regarding the recruitment of new personnel and the upgrading of technology. Furthermore, population ageing may also impact the innovative capacity and technological progress of firms by altering their age structure. As individuals age, their cognitive and innovative abilities may decline, which not only affects the internal innovation climate of firms but may also result in slow responses to rapidly changing market environments (7). From the standpoint of household economic behavior, the deepening of population ageing will have a profound impact on household consumption patterns and lifestyles, thereby indirectly contributing to an increase in household carbon emissions. A growing elderly population is frequently accompanied by shifts in consumption patterns, including an increased demand for services such as healthcare, leisure, and recreation. These changes may contribute to an overall rise in household energy consumption and carbon footprint.

First, from the perspective of household economic behavior, population ageing will have an impact on household financial allocation. According to the family life cycle theory, the life cycle of a family can be divided into three periods, namely young, middle-aged and old, and in different periods, the financial needs, wealth accumulation and consumption characteristics of family members are different. Therefore, at the level of financial asset allocation, the vast majority of the elderly will choose savings products with faster liquidity or lower risk savings products and financial assets in order to ensure the adequacy of their own funds for their old age and will be resistant to financial assets with higher risk and lower liquidity. In addition, when the family structure changes or family members become older, there is a significant change in individual and family attitudes to risk in financial management. For households with an older population or a relatively high proportion of older household members, attitudes towards financial assets tend to be more aversive, and such households are willing to choose lower-risk and more liquid financial assets when allocating financial assets. According to the 2017 and 2019 China Household Finance Survey (CHFS), the level of equity allocation accounts for a relatively low level of risky financial asset allocation among the financial assets of China's empty nester households. Financial asset management products, a low-risk financial asset, accounted for as much as 51 percent.

Concurrently, the process of ageing can also exert a detrimental influence on the level of entrepreneurial activity within the household. This is since the ageing process can result in a reduction in the number of social activities that are undertaken by the household, as well as a lowering of the risk tolerance that is exhibited by the individuals within that household. As the population ages, there is a corresponding decline in the degree of risk appetite, which affects not only investment decisions but may also lead to conservative investment behavior and asset allocation. This, in turn, affects the overall rate of return in the capital market. Furthermore, population ageing may prompt households to favor more robust financial asset allocation to protect their basic quality of life and cope with future uncertainty. This, in turn, reduces the overall investment risk appetite of residents and increases the margin of safety of household finances [16]. These changes collectively comprise a complex pattern of economic behavior in an ageing society, with significant implications for macroeconomic and social welfare.

Second, population ageing will have a significant negative impact on the development of small and medium-sized enterprises (SMEs). Compared to large enterprises, SMEs lack advantages in financing, core technology and scale, and will find it more difficult to cope with the structural labor shortages and the increase in labor costs brought about by demographic change, which will squeeze SMEs' profit margins and create difficulties for their survival. More specifically, demographic changes affect the sustainable development of SMEs mainly from the perspective of labor supply, labour costs, labor productivity, innovation capacity and consumption. Firstly, from the perspective of labor supply, ageing will lead to a decline in the growth rate of the total working population and a decrease in the labor force participation rate, which will lead to labor shortages in SMEs. Second, from the perspective of labor costs, with the deepening of aging, China's labor market will experience a shortage of labor supply and structural contradiction in employment, and labor costs will continue to rise, which will add to the burden of SMEs. Third, from the perspective of labor productivity. Third, from the perspective of labor productivity, since labour productivity increases with age, peaks in the 40-50 age group, and begins to decline after 50, with the deepening of the ageing process, older workers will be in a state of decline in terms of physical fitness, learning ability and intellectual level; moreover, it may be difficult for older workers to adapt to new skills in their occupations, which will lead to a decline in labor productivity. Fourth, from the perspective of innovation ability, the deepening of ageing directly leads to a decline in the proportion of people with strong innovation ability in society, making it difficult for small and medium-sized enterprises (SMEs) to recruit innovative talents, thus hindering the improvement of their innovation ability and lowering their innovation performance. Fifth, from the perspective of consumer demand, deepening ageing will lead to negative growth in the total population, which in turn will lead to a reduction in the number of consumers and a shrinking of the consumer market.

In conclusion, the process of population ageing has had a significant effect on the micro-digital economy. On the one hand, the process of ageing has resulted in significant disruptions across a range of industries, including labor-intensive sectors, high-technology fields and service-oriented businesses. These developments have led to a reduction in the available labor force and a decline in the level of human capital, prompting firms to rethink their long-term strategic planning, particularly in relation to talent acquisition and technological advancement. Concurrently, as the proportion of the ageing population increases, the innovation dynamism and rate of technological advancement of firms may decline, as the cognitive and innovation abilities of older employees are relatively limited. This, in turn, affects the competitiveness of firms in the fast-changing market environment. Furthermore, population ageing also affects household economic behavior, leading to changes in consumption patterns. These include an increased demand for healthcare and leisure and recreation services, which may result in an overall increase in household energy consumption and carbon footprint. Furthermore, the ageing of the population has been observed to result in a reduction in the frequency of social activities within households, as well as a lowering of the risk tolerance of household members. This has the effect of discouraging entrepreneurial activities within the household. The rising proportion of older people has been found to result in a greater inclination towards conservative investment strategies, with a more robust allocation of financial assets being chosen to ensure quality of life and to prepare for future uncertainties. This conservative behavior has been found to indirectly affect the overall rate of return in the capital market.

Consequently, population ageing not only imposes novel requirements on business operations and technological innovation at the micro level, but also affects economic decision-making at the household level. Collectively, these changes constitute a complex pattern of economic behavior in an ageing society, with far-reaching and profound implications for the development of the micro-digital economy in terms of economic and social welfare.

4.2 The objective is to propose countermeasures and recommendations to address the challenges posed by an aging society to the digital economy

The advent of an aging population in China has precipitated a pressing need for profound adjustments to the country's legal system, educational model, and economic structure. In the context of the current digital economy, the utilization of digital technology to address the challenges posed by an ageing population has become a pressing concern. From a legal standpoint, a series of laws and regulations must be formulated and improved to safeguard the legitimate rights and interests of the elderly, while balancing intergenerational equity to ensure social stability and harmony. In the field of education, there is a need to adapt to this demographic change and enhance the social participation and lifelong learning opportunities of the elderly through the reform of the education system, with the aim of enhancing their social capital and personal well-being. From an economic standpoint, the aging of the population exerts a considerable influence on the labor market, consumption patterns and economic growth. In addition, it necessitates the implementation of corresponding adjustments in economic policy and industrial structure to advance sustainable economic development and enhance the quality of life for older individuals. This paper will examine how the challenges posed by population ageing can be addressed through the development of a digital economy from the legal, educational and economic levels. It will propose strategies that are both aligned with the current societal needs and adaptable for the future, with the aim of establishing a robust foundation for the long-term stability and development of Chinese society.

4.2.1 It is recommended that countermeasures be implemented at the legal level.

In addressing the challenges posed by China's rapidly ageing population, it is imperative to implement robust legal countermeasures at the macro level. It has been emphasized that there is a need to strengthen infrastructure, institutions and resources to enhance the quality of health services for the elderly in rural areas. Furthermore, the strategy of focusing on the quality of the population and replacing 'quantity' with 'quality' has been proposed as a means of achieving a high quality of life for the population [17]. From the perspective of legal protection for socialized old age, it is crucial to elucidate the interrelationship between the rights and responsibilities of the family, society, enterprises and the state in legislation.

In terms of the implementation of the positive ageing strategy in the context of labor law, some scholars have put forth the proposition that the extant labor law system requires enhancement and optimization to ensure the effective protection of the employment rights of the elderly. Furthermore, they have suggested that the delayed retirement system should be improved for workers before reaching the age of majority, and that labor rights and interests should be strengthened for workers after reaching the age of majority. Furthermore, the necessity of the state's obligations in the rule of law for the elderly has been debated. It is proposed that the state should expedite the construction of the legal system for the elderly, with the objective of safeguarding the rights and interests of the elderly group.

To address the challenges inherent in the legislative framework for elderly education, it is essential to establish a fundamental framework for the legal system governing elderly education. This framework should emphasize the value concept of legislation and facilitate the improvement of the legal system. For instance, the legal response to elderly drivers can be examined from the standpoint of traffic jurisprudence with a view to safeguarding their driving safety.

Take Japan's approach to ageing as an example. As early as 1970, the number of people aged 65 and over in Japan reached 7.39 million, accounting for 7.1% of the total population, marking the country's entry into an ageing society. China, on the other hand, only entered an ageing society in 2000, so Japan has more experience in coping with an ageing population in the East Asian region. Moreover, the process and the main causes of population ageing in Japan have a lot in common with China. Therefore, learning from Japan's experience in dealing with population ageing at the legislative level has some reference value for China's current response to ageing.

Specifically, in the 1970s, the Japanese government proposed the construction of a 'Japanese-style welfare society' and began to pay attention to home-based welfare measures, introducing a variety of laws closely related to people's lives; in 1973, a system of paying medical fees for the elderly was introduced, and medical care for the elderly was made free, also known as the 'Year of Welfare'. In the 1980s, Japan began to reduce social security costs in line with fiscal austerity, emphasizing 'individual vitality and the spirit of self-help', but this was widely criticized by society. During this period, the reform of the medical care system for the elderly abolished the free system and replaced it with a system in which the elderly were required to pay part of their medical expenses. In 1990, with Japan's ageing population and growing concern for the elderly, relevant legislation was expanded and enriched. In 1990, the Welfare for the Elderly Act and other laws were revised, and a law was added to promote home-based welfare services and the construction of home-based welfare services and facilities, with city, town and village governments assuming primary responsibility for the provision of home-based welfare services. In 1990, the Law on the Welfare of the Elderly and other laws were amended to include the promotion of home-based welfare services, the provision of home-based welfare services and the construction of facilities mainly at the city, town and village levels, and the obligation of cities, towns, villages and prefectures to formulate health and welfare programmers for the elderly.

The visiting care system for the elderly was introduced in 1992. This was followed in 1997 by the Nursing Care Insurance Act, which introduced a social insurance approach to the provision of nursing care for the elderly. In the 21st century, due to the slow growth of the Japanese economy, some of the laws had to be revised to reduce the proportion of public payments, and the Nursing Care Insurance Law was revised after 2005 to emphasize the role of prevention and to adjust the fees for home care and care in nursing facilities. At the same time, the Law on Employment Stability for the Elderly was amended to promote the extension of the retirement age for the elderly (from 1 January 2010 to 31 December 2011), in line with the policy of raising the retirement age.

In conclusion, the macro-legal dimension of China's countermeasures against ageing necessitates the establishment of a comprehensive and multifaceted legal framework encompassing a vast array of domains, including health services, old-age security, labor law, education legislation, and numerous others. This necessitates that legislators not only concentrate on present social requirements but also anticipate prospective developments and establish legal policies that are both aligned with the present situation and adaptable to future alterations. By implementing these comprehensive measures, it is possible to construct a more inclusive and sustainable society, effectively addressing the challenges posed by ageing and establishing a robust foundation for China's long-term development and social stabile.

4.2.2 It is recommended that countermeasures be implemented at the educational level

Considering the significant challenge posed by population ageing, the field of education assumes a pivotal role. Education is not only a means of promoting the well-being of older persons; it is also a key factor in the advancement of society. The enhancement of the quality of life and social participation of older people can be achieved through the implementation of educational initiatives, which can also serve to strengthen their employability and social networks, thereby promoting active ageing. In response to the decline in student numbers and the uneven distribution of resources faced by China's higher education system, some scholars have proposed the construction of a collaborative education system and the establishment of a lifelong learning platform for older persons. This would enable the adaptation to demographic changes through educational innovations, while simultaneously stimulating the learning potential and creativity of older people.

From the perspective of human resources, enhancing employment services and legal protection for the elderly can optimize the utilization of the elderly group's potential. Furthermore, education policies should be closely integrated with the job market to facilitate continuous learning and re-employment opportunities for the elderly. The development of gerontological education in China draws on the experience of gerontological education in Japan, offering valuable insights into the challenges of an ageing population. It also provides a new perspective on the construction of the discipline of gerontological education. Furthermore, studies analyzing the vocational skills training system for the elderly and the research hotspots of gerontological education from an international perspective have also been conducted, providing innovative ideas for the construction of a harmonious ageing society.

The integration of geriatric education and neuroscience proposes novel mechanisms, directions and technologies for geriatric education, thereby providing scientific support for the strategy of active ageing. It is emphasized that geriatric education should prospectively establish a foundation for future research, with the objective of tapping into the positive plasticity potential of the aging brain and actively expanding the intrinsic and extrinsic value of geriatric education. From the perspective of population change in counties, factors such as the increase in urbanization and the proportion of higher education graduates have created opportunities for the high-quality development of county populations. This indicates that education plays an important role in promoting the economic and social development of counties, and that education can act as a bridge connecting the elderly and society, particularly in the context of an ageing population.

In conclusion, the educational dimension of the response to ageing requires a multidimensional, interdisciplinary and comprehensive strategy. This encompasses, but is not limited to, the elevation of the educational attainment of older individuals, the augmentation of their social involvement and employability, the establishment of a lifelong learning system, and the promotion of the integration of education with employment, health and social services. Through these measures, the potential of education in addressing the challenges of ageing can be fully actualized, thus providing more expansive and inclusive learning opportunities for older individuals, thereby contributing to the comprehensive and harmonious development of society.

4.2.3 Proposals for economic countermeasures

In the economic sphere, the process of ageing presents a duality of challenges and opportunities. It is therefore imperative that effective economic policies are developed to mitigate the impact of ageing. The effects of ageing have a significant impact on the labor market, including an increase in labor costs and a potential decline in labor productivity. However, technological advances can compensate for labor shortages and can also facilitate a transition towards a more technology-intensive economic growth model.

About industrial restructuring, the emergence of the silver-hair economy, comprising products and services tailored to the needs of the elderly, has emerged as a new source of economic growth. Concurrently, it is imperative to reform the retirement system, enhance the scope and sufficiency of pension insurance, and safeguard the economic stability of the elderly. The establishment of a comprehensive pension service system is an effective means of enhancing the quality of life for the elderly. Investment in education is a crucial strategy for upgrading human capital, thereby improving the employability and quality of life of the elderly and mitigating the adverse effects of ageing on the economy. In particular, the challenges associated with ageing can be effectively addressed by optimizing the development trajectory of the silver hair industry.

In terms of economic development, it is also recommended that the relevant policies be improved to adjust the fertility policy, optimize the industrial structure and improve the social security system. From the perspective of fiscal sustainability, we investigate the impact of population ageing on the high-quality development of the economy. We propose that the population policy should be adjusted and optimized to improve the quality of the workforce and activate the consumption potential of the ageing population. Furthermore, it is notable that our study identified population ageing and population mobility as significant drivers of local government debt growth. This finding has implications for the development of evidence-based debt management strategies at the local level. Given the importance of demographic factors in shaping fiscal expenditures, it is essential to consider these factors in the formulation of debt management policies and to adjust the structure of fiscal expenditures according to demographic characteristics.

In conclusion, the effects of an ageing population on China's economy are complex and varied. However, the challenges posed by an ageing population can be effectively addressed and sustainable economic development can be achieved through economic-level countermeasures. These include technological innovation, industrial restructuring, social security reforms, the construction of health and pension service systems, investment in education, and the application of the digital economy. These studies not only provide theoretical analyses of the economic impacts of ageing, but also offer specific policy recommendations, thereby providing valuable references for policymakers.

5. **Conclusions**

In the context of globalization, population aging has become a universal phenomenon with significant implications for economic and social structures. This paper presents a comprehensive analysis of the effects of aging on several macroeconomic areas, including economic growth, the labor market, consumption patterns, savings, and investment. It reveals the dual impact of aging on sustainable economic and social development. In response to China's distinctive population aging challenges, this paper puts forth a series of countermeasure recommendations, including but not limited to technological innovation, industrial structure optimization, enhancement of the social security system, construction of a health and pension service system, and increase of investment in education. The objective of these recommendations is to mitigate the challenges associated with an aging population through the implementation of innovative policy measures and social programs, while simultaneously capitalizing on the opportunities presented by this demographic shift for economic growth.

The conclusions of this paper underscore the necessity for a unified response from governments, enterprises, social organizations, and individual citizens in addressing the challenges of aging. It is imperative that policymakers implement forward-thinking policies to adapt to demographic shifts. Enterprises must prioritize technological innovation to enhance productivity while addressing the unique needs of older individuals. Social organizations should facilitate enhanced social participation and quality of life for older people. Individual citizens must cultivate lifelong learning skills and adaptability to social change.

Further research is required to enhance comprehension of the impact of aging, particularly in the context of the accelerated development of the digital economy. Additionally, there is a need for in-depth investigation into the effective utilization of technology to enhance the quality of life and social participation of older individuals. Furthermore, the acceleration of the aging process necessitates the implementation of stress testing and reforms to the social security system. In conclusion, this paper advocates for unified action across all societal sectors to construct a comprehensive strategic framework for adapting to an aging society. This framework must ensure sustained and healthy economic development and comprehensive and harmonious social progress. It is hoped that these efforts will result in the transformation of the challenges of aging into a driving force for social progress and innovation.

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Section 2

Management Innovation and Innovation Management

Digitalization and Management Innovation III
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The Effect of Pay Satisfaction on Turnover Propensity of Technical Employees in Internet Enterprises in China

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Abstract. With the rapid expansion and development of the Internet, there are more and more Internet companies, and the competition among enterprises is becoming more and more intense. The Internet industry is intellectually intensive, and the core competitiveness of Internet companies is their skilled employees. This article comprehensively analyzes the current research results of correlation between the salary satisfaction degree and the turnover intention, provides ideas and theoretical basis for the research and puts forward the relevant hypotheses through domestic and foreign related literature summary. Taking technical employees of Internet enterprises as samples, the four dimensions of salary satisfaction are verified by factor analysis. Based on the characteristics of technical employees, combined with demographic variables, the effects of the four dimensions of pay level, pay increase, benefit level, and non-economic compensation on the propensity to leave are analyzed, and it is found that non-economic compensation and pay increase have a significant predictive effect on the propensity to leave. Therefore, Internet companies should improve technical employees' salary satisfaction and reduce the tendency to leave by improving the satisfaction of non-economic compensation, formulating a clear and reasonable salary increase system, strengthening salary communication and other comprehensive measures.

Keywords. Technical employees, Pay satisfaction, Turnover intention

1. Introduction

The IT industry has rapidly developed with the emergence of mobile Internet, e-commerce, artificial intelligence, and other industry hot spots. According to the Ministry

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of Industry and Information Technology website data, in 2023, there were more than 38,000 enterprises above the Scale of China's software and information technology service industry, and a cumulative software business income of 123258 billion yuan was completed. As one of China's emerging strategic industries, the IT industry is a technology-intensive industry, and skilled employees are the most crucial driving force for the development of IT companies. The proportion of male technical employees in IT enterprises is high and tends to be younger, they have a higher sense of self-worth and pay more attention to personal learning and growth. In addition, the technical staff market demand is strong, high mobility. Technical employees have strong professional knowledge, the work is less replaceable. From a team perspective, they work with high intensity and have a higher sense of teamwork. Continuously retaining several high technical standards and the rich practical experience of skilled employees is the key to gaining a competitive advantage for IT companies. With the accelerated iteration of technology updates, the IT industry's demand for professionals continues to increase; the talent competition is becoming increasingly fierce, and the flow of skilled personnel accelerates the speed of the industry, resulting in a higher tendency to leave the industry's technical staff and the departure rate. Retaining skilled employees and reducing turnover has become the focus of talent management in IT companies. In this paper, the author will examine the salary satisfaction of technical employees in IT enterprises and its impact on the tendency to leave from multiple dimensions.

2.Literature Review

2.1 Pay satisfaction and its research dimensions

Adams (1965) first proposed the concept of pay satisfaction, and based on the equity theory, pay satisfaction is regarded as an employee's perception of pay satisfaction [1]. Lawer (1971) regarded pay satisfaction as the employee's evaluation of the difference between actual income and expectation [2]. Heneman and Schwab (1985) regarded pay satisfaction as the degree of satisfaction with the current pay, especially the employee's attitude towards work. Satisfaction is employees' attitude towards their work when they compare the effort they put in with the pay they receive and the pay received by others [3]. In subsequent studies, some scholars have focused on the level dimension, growth dimension and structural dimension of pay satisfaction respectively[4][5]. Therefore, this paper defines pay satisfaction as an emotional state that arises from comparing the economic and non-economic pay received by employees and the expected pay. Based on different understandings of the connotation of pay and considering different research subjects and cultural backgrounds, the dimensions of pay satisfaction research vary. The main viewpoints are as follows:

Table 1 Compensation Satisfaction Dimension Classification

Form	Compensation Satisfaction Dimension Classification	Representatives and dates
Two-dimensional	Level of remuneration and benefits	Lawler et al. (1971), He Wei (2011)
	Amount of remuneration and remuneration system	Miceli (1991)
	Level of remuneration and benefits	Lam (1998)
	Economic and non-economic remuneration	Zang Zhipeng (2005), Zhang

		Junqin (2008)
Three-dimensional	Status of remuneration-related policies, remuneration management structures and remuneration levels in the organization	Dyer, Theriault (1976)
Four-dimensional	Salary Levels, Benefit Levels, Salary Increases, Salary Structures & Salary Administration	Heneman (1985)
	Scientific nature of the remuneration system, increase of external competition in remuneration, rationality of the remuneration structure and satisfaction of the remuneration level	Jin Yan, Qiao Jie (2008)
	Satisfaction with development, organizational climate, expectations and other factors	Bian Tao (2014)
	Satisfaction with salary structure and management, satisfaction with employee benefits, satisfaction with salary level	Li, Chunling (2016)
Five-dimensional	Salary level, benefit level, salary increase, salary structure and salary management, one-time bonus satisfaction	Sturman (2000), Garcla (2009)
	External Competitiveness of Compensation, Rationality of Compensation Structure, Efficiency of Performance Rewards, Fairness of Compensation System, Effectiveness of Benefit System	Wang, S. (2015)
	Salary increases, bonuses, salary structure and administration, salary levels, benefit levels	Wu Xiaoyi et al. (2006)
	Pay levels, pay increases, benefit levels, pay structure and administration, non-economic compensation	Xie Xuanzheng (2009), Zhang Yingkui (2012)
Six-dimensional	Compensation system incentives, compensation personal fairness, compensation management basis, compensation internal fairness, public benefits and compensation information communication	Guo, Haixin (2007)

Although scholars have recognized the multidimensional structure of pay satisfaction, there has yet to be a consensus on the specifics of the structure and its measurement. This paper combines the characteristics of the needs of technical employees, refines the inadequacy of the narrow understanding of compensation, adds non-economic rewards, and analyzes compensation satisfaction in five dimensions.

2.2 Differences in propensity to leave and separation behaviors

March & Simon (1958) paid attention to the problem of employee separation at an early stage and considered that the tendency to leave is the intensity of the tendency of employees to give up their current jobs and look for other job opportunities [6]. Mobley (1977) first explicitly put forward the concept of the tendency to leave, which is considered to be an important influencing factor on the behavior of employees to leave their jobs from the dissatisfaction with their current jobs [7]. Abelson (1987) distinguishes between passive and active separation, in which active separation is the behavior of an employee who actively requests to leave the organization in his or her own interest[8]. Bennett (2000) suggests that the propensity to leave is the desire to leave the company after the employee has developed a variety of dissatisfaction with his or her job [9]. Takase (2010) understands the nature of turnover tendency from three perspectives: psychological, cognitive, and behavioral, and argues that turnover tendency is not the same as the actual act of leaving the job but is just a thought and cognitive activity of the employee[10]. Halcomb E explores the relationship between job satisfaction and turnover intention and examines the factors that influence job satisfaction and turnover intention [11]. In a study of small and medium-sized manufacturing firms in southern Germany, work system-related factors were found to have an impact on skilled workers' intention to leave their jobs[12].

Combining conceptual explanations from different perspectives of scholars at home and abroad[13][14][15][16][17], this paper argues that the propensity to leave is the attitude and idea of employees to leave the existing organization after experiencing dissatisfaction in the organization and before the act of leaving the organization takes place, which reflects the degree of the employee's willingness to leave the organization on his own initiative[18].

2.3 Analysis of the role of pay satisfaction in influencing the propensity to leave a job

Compared with other influencing factors, pay satisfaction has a more direct impact on the tendency to leave. First of all, according to the social exchange theory, the tendency of employees to leave is triggered by a series of negative exchange behaviors between the organization and its members. March & Simon (1958) argued that satisfaction with current job comfort and the desire to change it influences the tendency to leave the job [7]. According to the behavioral motivation theory and incentive theory, individual attitude determines behavior, and enterprise employees' salary satisfaction will undoubtedly affect their work attitude and behavior.

From the perspective of the research objective of this paper, relative to ordinary employees, on the one hand, technical employees create more value, relatively low job replaceability, often in short supply in the talent market, and relatively high mobility. On the other hand, technical employees tend to have higher achievement motivation, and pay more attention to non-financial rewards, including a good working environment, more challenging work, more autonomy and growth. As a result, the influence of salary satisfaction, especially non-economic salary satisfaction on technical employees in IT companies will be more obvious.

3.Methodology and research hypotheses

3.1 Determination of research subjects

IT enterprises mainly refer to software industry enterprises engaged in researching, developing, and applying information technology, while IT enterprise's technical employees belong to the knowledge-based category. Management guru Drueker (2006) pointed out that knowledge workers are those who master, use the symbols and concepts needed to perform certain jobs, and utilize knowledge and information [19]. Drawing on existing research [14][20], this paper argues that skilled employees are those who acquire professional knowledge and skills through learning, have strong creativity, and are engaged in technological research, technological development, and technological application in an enterprise.

3.2 Formulation of research hypotheses

In order to explore the dimensional composition of compensation satisfaction of technical employees in IT enterprises and its impact on the tendency to leave, based on the above theory on job satisfaction in job performance department, combined with the management status quo of start-up Internet enterprises and the characteristics of technical employees, further analyzed as follows:

3.2.1Component dimension analysis of salary satisfaction

On the basis of the four-dimensional structure of salary satisfaction proposed by Heneman (1985)[3], taking into full consideration the characteristics of technical employees in IT enterprises who pay more attention to non-economic rewards such as work environment, personal learning and growth, challenging work, teamwork, promotion opportunities, and so on, and drawing on the views of Xie Xuanzheng (2009)and other scholars[21][22], on the basis of the above four-dimensional model, to adding non-economic rewards, the following hypotheses are proposed:

Hypothesis 1: Compensation satisfaction of technical employees in IT firms consists of five dimensions: pay level, pay increase, benefit level, pay structure and management, and non-economic compensation.

3.2.2 Differential analysis of pay satisfaction and tendency to leave the company by the same target group

In order to have a comprehensive and in-depth understanding of technical employees in IT companies in terms of salary satisfaction and tendency to leave, the following hypotheses are proposed in the analysis process, taking into account eight aspects: gender, age status, education level, marital status, years of working experience, position status, and the nature and size of the company in which they work:

Hypothesis 2: There is a significant difference between demographic and job-related factors on the dimensions of pay satisfaction and propensity to leave the job.

3.2.3 Analysis of the impact of various dimensions of pay satisfaction on the tendency to leave the organization

In the above analysis, based on the social exchange theory and behavioral motivation theory, incentive theory, and combined with the characteristics of technical employees and their positions themselves, this paper argues that there is a correlation between the pay satisfaction of technical employees in IT enterprises and their tendency to leave, and that pay satisfaction has a significant negative predictive effect on their tendency to leave, and the following hypotheses are proposed:

Hypothesis 3: There is a significant negative predictive effect of the dimensions of pay satisfaction on the propensity to leave a job.

H3a: Salary level is a significant negative predictor of the propensity to leave a job.

H3b: Salary increase is a significant negative predictor of the propensity to leave a job

H3c: Benefit level is a significant negative predictor of propensity to leave a job

H3d: Compensation structure and management are significant negative predictors of the propensity to leave a job.

H3e: Non-economic compensation is a significant negative predictor of the propensity to leave a job

3.3 Data Survey and Forecast Analysis

3.3.1 Questionnaire design

The overall questionnaire was divided into three sections: respondents' basic information, salary satisfaction questionnaire, and exit tendency questionnaire. The first part collects the basic information of the respondents, which contains 7 questions. It further limits the respondents to the R&D type of post and technical support type of post in IT companies. The second part was designed to find out the level of satisfaction of the respondents with the existing pay situation and was mainly based on the Pay Satisfaction Maturity Scale developed by Heneman (1985) with the addition of the Non-Economic Compensation Scale. Non-financial compensation is an important entry point for exploring the relationship between compensation satisfaction and turnover tendency of technical employees in Internet companies. Therefore, while drawing on the well-established pay satisfaction scale, the non-economic compensation scale was added. The non-financial compensation scale has four main questions dealing with compliance, timeliness and incentive strength of non-material incentive types. The scale was assessed using a Likert 5-point scale, which contains five dimensions and 22 question items, with a maximum value of 110 points and a minimum value of 22 points. The closer the score is to 110, the higher the level of pay satisfaction of the research participants, and vice versa, the smaller the level of pay satisfaction.

The third part understands the extent of respondents' propensity to leave their jobs. Drawing on Mobley's Propensity to Leave Scale, which consists of three main topics, the Scale has been validated several times with good validity. The questionnaire adopts the Likert 5-point method; the great value is 15 points, the small value is 3 points, the closer to 15 points indicates that the employee's tendency to leave the company is higher, and vice versa indicates that their tendency to leave the company is lower.

3.3.2 Pre-survey of the questionnaire and analysis of validity and reliability

The pre-survey was conducted through online up-filling methods such as questionnaire star, e-mail, and Weibo group. A total of 120 questionnaires were recovered in the pre-survey stage, among which the valid questionnaires were 112, with an effective rate of 93.3%. After testing, the KMO test coefficient of the salary satisfaction scale was 0.972, and the approximate chi-square value of Bartlett's test statistic of sphericity was 4016.822, which reached a significant level, indicating that the scale was suitable for exploratory factor analysis. Then the pay satisfaction scale was subjected to exploratory factor analysis, and five common factors were compulsorily extracted for factor analysis and orthogonal rotation was carried out using the maximum variance method. After seven-factor analyses, the questionnaire questions were censored and downgraded to obtain four common factors with a cumulative variance explained of 80.811%, which were named: non-economic compensation, benefit level, pay increase and pay level. Therefore, hypothesis H1 of the validation study is not valid.

Considering the specificity of the research object of this paper, the validity test was conducted on Mobley's Propensity to Leave Scale. The scale contains three questions, and using the scoring principle, the KMO test coefficient was measured to be 0.750, which is greater than 0.70, and the Bartlett's spherical test Sig was 0.00, which is below the 0.05 level, reaching the level of significance, which indicates that the validity level of the scale is acceptable.

Using Cronbach's alpha coefficient method for reliability analysis, the total pay satisfaction scale and the four subscales of pay water, pay increase, benefit level and non-economic compensation, and the propensity to leave scale were analyzed as follows:

Table 2 Pre-survey Reliability Statistics for Pay Satisfaction Scale

variant	dimension (math.)	sample size	item count	Cronbach's Alpha	Cronbach's alpha for variables
Salary satisfaction	pay level	112	5	.924	.970
	Increase in remuneration	112	3	.868	
	Benefit levels	112	4	.923	
	non-economic remuneration	112	4	.927	
propensity to leave office		112	3	.916	.916

3.3.3 Formal survey and data collection

Based on the above analysis, some questions of the questionnaire were modified and improved, reordered, and formed into a formal questionnaire. The study was conducted through a combination of paper and electronic questionnaires and the sample was drawn using convenient sample. The questionnaire was obtained through MBA students working in IT industry and their circle of friends, various alumni working in IT companies and their circle of friends. On the one hand, in the IT enterprise interviews and MBA students when teaching, issued 67 paper questionnaires. On the other hand, through the electronic questionnaire, the author invited friends and their colleagues who are engaged in R&D and technical posts in IT enterprises to fill in the questionnaires, and by joining QQ groups and We Chat groups, the author issued 550 questionnaires in the form of red packets, and recovered 445 questionnaires, and eliminated the questionnaires that were filled in with the same evaluation value of more than 11 items, and finally, the remaining valid questionnaires were 488, and the validity rate was 95.31%. The regional distribution of the samples is shown in Figure 1.

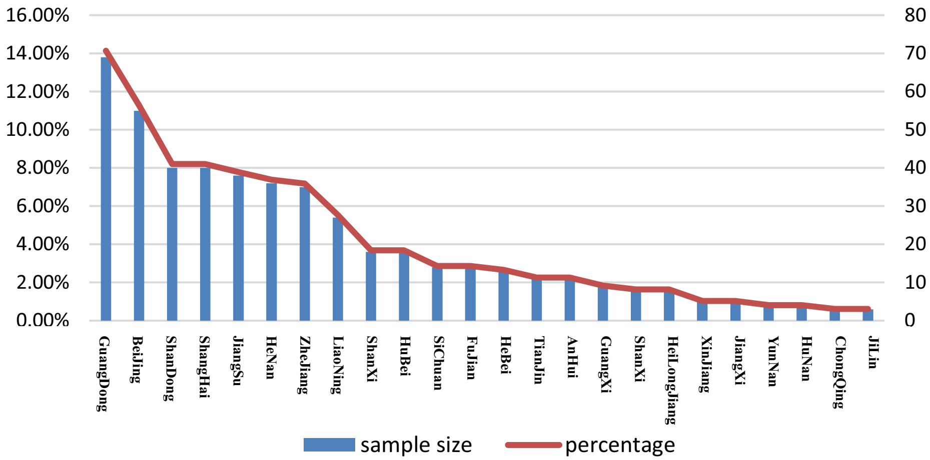

Figure 1 Distribution of provinces in the official survey sample

4. Results of data analysis

4.1 Analysis of the structure of the pay satisfaction scale

The results of the fit index test are shown in Table 3 and all five indexes meet the standard, indicating that the initial model fit is better, the results are more satisfactory, and the four-dimensional structure of salary satisfaction passes the validation factor analysis.

Table 3 Pay Satisfaction Fit Test Indicators

	CNIN	DF	CMIN/DF	GFI	IFI	CFI	RMR	RESEA
initial model	263.159	98	2.69	0.94	0.978	0.977	0.021	0.059

The Cronbach's alpha coefficient method was used to verify that the salary satisfaction scale has good reliability, and the four-dimensional structure of salary satisfaction of technical employees in IT companies was verified by exploratory factor analysis. On this basis, a validation factor analysis was conducted with the help of Amos 21.0 software to verify the representativeness of the four dimensions determined by exploratory factor analysis, and the specific results are shown in Figure 2.

4.2 Analysis of differences in demographic and work-related variables

In terms of gender, there is a significant difference between males and females in the dimension of benefit level, while there is no significant difference in the other three dimensions of salary satisfaction and the tendency to leave the job. In terms of marital status, there are significant differences in the four dimensions of salary satisfaction and the tendency to leave among respondents with different marital status, which may be due to the fact that married employees pay more attention to the stability of their jobs based on family and other reasons, and do not choose to leave their jobs easily. Employees of different age groups show significant differences in the four dimensions of salary satisfaction, but there is no significant difference in the tendency to leave. Employees with different levels of education only show significant differences in two dimensions of salary level and benefit level, but there is no significant difference in non-economic compensation, salary increase, and tendency to leave. Respondents of different enterprise sizes show significant differences in the four dimensions of pay satisfaction, but there is no significant difference in the propensity to leave.

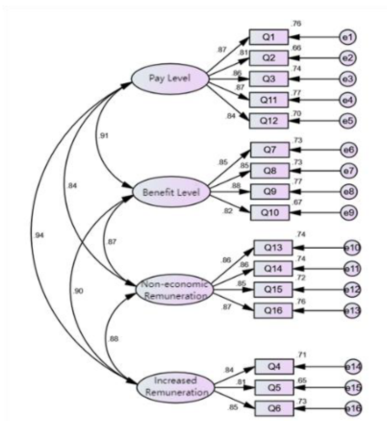

Figure 2 Specific structural analysis of pay satisfaction

Table 4 Differential Analysis of Demographic Variables on Pay Satisfaction and Propensity to Leave Job

	gender difference	marital status	(a person's) age	educational attainment	Nature of the company	Enterprise size
pay level	1.924	2.715**	4.120**	2.926*	--	17.531**
non-economic remuneration	0.846	2.759**	2.938*	1.834	3.155*	8.795**
Benefit levels	2.269*	2.283*	2.462	1.780	--	14.298*
Increase in remuneration	1.665	3.127**	3.407**	2.610	4.952**	7.412**
propensity to leave office	-0.228	-1.964**	1.458*	0.172	1.456*	1.476*

* p<0.05, **p<0.01

Grouped by the nature of the company to carry out variance chi-square test, the probability value of the level of remuneration and the level of benefits are below the level of significance (α = 0.05), does not meet the conditions of one-way analysis of variance, and then carried out two-two grouping using independent samples t-test for analysis. The probability values of the t-statistics corresponding to the different enterprise type subgroups in terms of salary level and benefit level are all below the significance level (α=0.05), so it can be said that the nature of the enterprises where they are located is different, and the satisfaction of the technical employees of IT enterprises in terms of the level of salary and the level of benefits shows significant variability.

Grouped by years of working experience for ANOVA chi-square test, the probability values of the four dimensions of pay satisfaction are below the significance level (α=0.05). The results of the analysis show that respondents with different years of working experience will show significant differences in pay level and benefit level satisfaction, while the differences in non-economic compensation, pay increase and tendency to leave are not significant.

4.3 Correlation analysis between pay satisfaction and tendency to leave the organization

The Pearson correlation coefficients and indicators between the variables in this study are shown in Table 4. The above table shows that the correlations within the dimensions of pay satisfaction and the tendency to leave the job show significance at the level of 0.01. The correlation coefficients of non-economic compensation and pay level satisfaction are -0.285 and -0.265 respectively, which are relatively high, and the correlation coefficients of benefit level and pay increase satisfaction are -0.259 and -0.258 respectively, which are relatively low, which indicates that all four dimensions of pay satisfaction have significant negative correlations on the tendency to leave. The highest negative correlation is found for non-economic compensation satisfaction.

Table 5 Results of correlation analysis between pay satisfaction and tendency to leave the organization

dimension (math.)	norm	pay level	non-economic remuneration	Benefit levels	Increase in remuneration	propensity to leave
pay level	Pearson	1				
	Significance					
non-economic remuneration	Pearson	.778**	1			
	Significance	0				
Benefit levels	Pearson	.842*	.798*	1		
	Significance	0	0			
Increase in remuneration	Pearson	.846**	.791**	.805**	1	
	Significance	0	0	0		
propensity to leave office	Pearson	-.265**	-.285**	-.259*	-.278**	1
	Significance	0	0	0	0	

Note: ** indicates significant correlation at the .01 level (bilateral)

4.4 Regression analysis of pay satisfaction and tendency to leave the company

Regression analysis is used to detect whether there is a predictive effect or a causal relationship between variables. In order to further explore the effect of pay satisfaction on the propensity to leave, this study uses the propensity to leave as the dependent variable and the four dimensions of pay satisfaction as the independent variables, and uses the stepwise regression method to conduct regression analysis. The adjusted R^2 of the regression model reaches 0.279 and Sig is 0.00, indicating that the model passes the significance test of the regression equation and regression coefficients, and the specific results are shown in Table 5.

In the process of regression analysis of the four dimensions of salary satisfaction of technical employees in IT companies and the tendency to leave the company, after the F test, only the two dimensions of non-economic compensation and salary increase in the dimensions of salary satisfaction with a Sig of 0.00 entered into the regression equation, while the two dimensions of salary level and level of benefits were excluded from the regression equation due to the probability value of the F test relative to the value of greater than 0.01. The F value was 42.900, which reached a significant level, and the regression was good.

Table 6 Results of regression analysis of the relationship between pay satisfaction and propensity to leave the organization

Regression variable	R^2	Adjustment R^2	F	B	Standard Beta	t-value	Sig.
propensity to leave office	.281	.279	42.900				.000
constant term (math.)				12.942		25.809	000
non-economic remuneration				-.234	-.285	-6.550	.000
Increase in remuneration				-.178	-.192	-5.726	000
regression equation	Propensity to leave = 12.942 - 0.234 * non-economic compensation - 0.178 * salary increase						

The analysis results show that the constant term in the regression equation is 12.942, and the regression coefficient is negative -0.234, that is, the coefficients of non-financial compensation and salary increase are negative, which indicates that the impact of non-financial compensation and salary increase on the tendency to leave is negative. The Sig value of 0.00 indicates that non-financial compensation satisfaction and pay increase satisfaction are significant predictors of the tendency of skilled employees to leave their jobs in IT companies. Comparatively, the predictive effect of salary level and benefit level is not significant.

5. Conclusion

H1 is not established. Compensation satisfaction consists of four dimensions: pay level, pay increase, benefit level, and non-economic compensation. The four-dimensional structure of compensation satisfaction of technical employees in IT companies and its representativeness were verified by exploratory factor analysis and exploratory factor analysis. The structure and management of employee compensation in Internet companies does not constitute one of the dimensions, which is related to the special management style of Internet companies and needs to be focused on in future research.

H2 is partially established. Salary levels showed significant variability in six dimensions, including marital status, age, education, nature of the company, size of the company, and years of experience. Welfare levels show significant differences in five dimensions: gender, marital status, nature of the company, size of the firm, and years of experience. Non-financial compensation and salary increase showed significant variability in four dimensions: marital status, age, nature of the company, and firm size. The propensity to leave showed significant variability in four dimensions: marital status, age, nature of the company and size of the firm.

H3 is partially established. Through correlation analysis, it is found that there is a significant negative correlation between the four dimensions of pay satisfaction and the tendency to leave according to the degree of correlation are non-economic compensation, pay increase, pay level, and benefit level, that is, with the non-economic compensation, pay level, benefit level and pay increase and other aspects of the satisfaction of the decrease, may lead to the enhancement of the tendency of employees to leave. Through stepwise regression analysis, it was verified that non-financial compensation and salary increases have a significant predictive effect on the tendency to leave.

6. Recommendations and Insights

In order to reduce the tendency of technical employees to leave, IT companies should do a good job surveying the level of pay satisfaction and start from different dimensions of pay satisfaction to do the following work.

6.1 Policy Recommendations

Non-economic compensation has a very important role in influencing the technical employees of IT enterprises. IT companies should attach great importance to the influence of non-economic compensation on the tendency of technical employees to leave their jobs. Combining the questionnaire survey and character interview information, it is recommended that Internet companies create a good working environment, oriented to humanistic culture, respecting every skilled employee and creating a free, loose and comfortable working environment. Technical employees prefer the flexibility of working time and working place, the company can realize telecommuting with the help of the Internet, so that employees have more autonomy to dominate their own time, which can improve the efficiency of the work, thus enhancing their satisfaction. In addition, most of the Internet work is done by teamwork, companies can organize a variety of forms of collective activities to break the traditional grid distance, enhance communication between each other, and enhance the team consciousness and tacit understanding of employees.

IT enterprises should combine with their own reality to formulate a reasonable salary increase system. Careful consideration of the salary level and performance of technical staff, timely communication with employees, and clear salary increase so as to play a positive role in guiding and incentive's salary increases, prompting technical staff to be more motivated to work, forming a virtuous cycle. IT enterprises should use questionnaires, interviews and other forms to understand the salary expectations of technical employees of different age groups, education levels, marital status and years of service in IT enterprises. The company will try its best to show the advantages of the salary level and reduce the tendency of technical employees to leave the company. At the same time, the author should communicate with the employees to understand their needs for welfare programs, increase the welfare programs appropriately, and formulate a flexible welfare system to improve the satisfaction of the skilled employees.

Whether the principles of external competitiveness, internal consistency, and work incentives of compensation design can be implemented depends not only on whether the design of the compensation system itself is scientific and reasonable but also on whether there is timely and effective communication with employees in the process of compensation design and implementation. Treuren (2014) has verified the important and influential role of understanding compensation in improving satisfaction and retaining talent [23]. Therefore, IT companies should first strengthen pay communication so that a sound pay system is not only understood and accepted by the employees of the company but also recognized by society so as to enhance their employer brand image and achieve the purpose of attracting and retaining talents. Secondly, pay satisfaction survey should be strengthened to analyze the reasons for the pay content of the low satisfaction and provide feedback to the employees. Thirdly, in the design of the pay or large adjustments, respect the right to information of the employees. Fourthly, in salary design or large-scale adjustment, respect the employees' right to know, improve the participation of all employees, especially emphasize the opinions of technical employees, and carry out effective and appropriate communication on time.

6.2 Future Insights

Due to the subjective tendency of the research individual, there are some shortcomings in the research of this paper. Relevant variables such as corporate culture and corporate commitment were not taken into account in the research process, which will cause some bias to the research results. The methods of questionnaire survey and statistical analysis used in this paper lack diversity. In the future, the control variables in the research model will be further expanded to reduce the impact of omitted variables on the data, so as to improve the scientificity and accuracy of the study. At the same time, the sample range will be expanded and the research methods will be increased to make the results more explanatory and applicable.

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Enterprise Business Model Innovation in the Platform Economy: A Case Study of Haier Group

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Abstract. In the context of the platform economy, traditional enterprises are confronted with an increasingly intricate and dynamic external landscape, necessitating frequent strategic adjustments to secure sustainable competitive advantages. This paper adopts an exploratory single-case study methodology, focusing on Haier Group, to delve into the evolutionary process of business model innovation in digitally transformed enterprises under the sway of the platform economy, from the standpoint of value co-creation. The study delineates that Haier Group's digital transformation has traversed three distinct phases: exploration, development, and expansion. A comparative analysis of these phases reveals a progression in the business model innovation journey of digitally transformed enterprises from platform mode to community mode and ultimately to ecosystem mode. This examination of the evolution of business model innovation in digital transformation enterprises holds significance for the practical implementation of business model innovation strategies within the digital transformation landscape.

Keywords. Platform Economy, Business Model, Business Model Innovation, Rendanheyi

1. Introduction

In 2021, the National Development and Reform Commission and other departments issued the "Opinions on Promoting the Normative and Healthy Development of the Platform Economy," which explicitly defines the platform economy as an emerging economic system primarily based on internet platforms, driven by core technologies of the new generation, and supported by network information infrastructure. It emphasizes the adherence to market principles, adaptation to the developmental laws of the platform economy, establishment of sound rules and regulations, and optimization of the environment for platform economy development. Traditional enterprises in China, with their large scale, often find their conventional development models inadequate when facing rapidly changing market demands. However, some enterprises that have pioneered business model innovation, such as Haier Group, have already achieved some breakthrough victories. Founded in 1984, Haier Group is the world's leading provider of solutions for better living and digital transformation and is committed to "creating

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infinite possibilities with a borderless ecology", creating infinite possibilities for better living with users, and creating infinite possibilities for industrial development with ecological partners. As a representative of the real economy, Haier continues to focus on industry, always focusing on users, adhering to original technology, and laying out three major segments: smart living, big health and industrial Internet. Through the construction of digital platforms, Haier Group has established a brand-new value ecosystem, enhancing not only the efficiency of value creation but also bringing shared value to users, enterprises, and stakeholders, injecting new vitality into economic growth. Although the advantages brought about by digital transformation are significant, many traditional enterprises encounter significant difficulties in pursuing business model innovation. In fact, fewer than half of enterprises successfully achieve innovation. Therefore, how to facilitate smooth business model innovation for enterprises has become a common focus of academia and practice.

The importance of business models in enterprise development is self-evident. In past business competitions, strategic advantages and uniqueness played a crucial role in sustaining enterprise competitiveness. However, with the rise of the platform economy and the maturity of digital technology, future competition among enterprises may be more influenced by business models and their innovations. Entrepreneurs may be able to discover new business models based on their abilities and experiences, but the process of business model innovation is fraught with unknown challenges and risks. Business model innovation under the platform economy is based on digital technology, implying that the innovation process and new models may to some extent conform to the characteristics of digital economic development. This innovation may impact traditional trading models, operational methods, and interaction modes between enterprises and users, thereby affecting the overall economic structure of enterprises. Especially for mature enterprises with entrenched thinking patterns, business model innovation may face multiple challenges. Challenges may arise from established operating methods, organizational structures, and concerns about the risks and uncertainties that new models may bring. Therefore, even if enterprises recognize the importance of business model innovation, they need to overcome the constraints of entrenched thinking, courageously face change, seek breakthroughs, and adapt to the development needs of the digital economy era.

The transformation process of enterprise business model innovation with platforms as carriers increases the openness of enterprises, facilitating greater stakeholder participation. Based on this, this paper, through a longitudinal exploratory case study method and from the perspective of value co-creation, primarily addresses whether there are significant changes in the innovation process of enterprise business models with the evolution of the platform economy environment, and specifically what forms these changes manifest. This not only enriches the relevant research on traditional enterprise business model innovation from a perspective angle but also holds significant practical implications for promoting the deep integration of the platform economy with traditional enterprises and driving enterprise digital transformation practices.

2. 2. Literature Review

2.1. Platforms and the Platform Economy

The term "platform" has a long history of usage in various fields such as economics, management, business administration, marketing, among others. Initially, the term "platform" was associated with developing technological solutions aimed at facilitating various activities within companies. According to Schweiger et al.(2016)[1], a platform can be defined as a digital infrastructure (hardware and/or software) capable of running various applications; or more broadly, as a limited and clearly defined purpose. This conception implies a technical interpretation of platforms. According to Parker et al.(2016)[2], a platform is defined as a new business model that utilizes technology to connect people, organizations, and resources in an interactive ecosystem, where remarkable value can be created and exchanged.

Kim (2016)[3] proposed three important characteristics to describe platforms: two-sided markets, network effects, and business ecosystems. Two-sided markets refer to the platform's ability to act between different types of consumers and to match value between these different types of consumers. Besides, a platform needs a 'network effect', which tends to radically strengthen the advantages of the platform itself as well as those for participants. Also, a platform typically emerges in the context of modular industries or industry ecosystems in order to generate revenue and continued growth. Chinese scholar He Hongchao (2004)[4], starting from the perspective of the physical economy, analyzed the cooperative competition behavior of large domestic real estate enterprises at that time. Based on this, he first proposed the concept of the "platform economy" and pointed out that the emergence of the platform economy, like any other form of economy, is to meet the objectively existing market needs. He believes that the platform economy is a brand-new cooperative competition system composed of participants, and participants in the platform can equitably enjoy the benefits brought by the new system through cooperation. In recent years, domestic research on the platform economy has mostly started from the perspective of the internet economy, emphasizing the importance of information technology and big data development for the development of platform enterprises. Luo Min and Li Liangyu (2015)[5] proposed the business logic of the Internet era, namely the platform model under the logic of community, where platforms enhance the ability of business models to arrange under information and communication. In summary, platforms bring new opportunities for value creation, acquisition, and transfer, thus enterprises need to innovate their business models through value arrangement or reconstruction, re-intermediation or disintermediation, among other ways[6].

2.2. Business Model and Business Model Innovation

The term "business model" first appeared in computer science journals in the 1970s, describing the associations and structures between data and processes. Magretta (2002)[7] suggests that the term originated from the widespread use of spreadsheet software, which allowed users to conveniently modify parameters based on different assumptions to generate various planning scenarios. Osterwalder and Pigneur (2010)[8] provide a comprehensive explanation of the business model, identifying nine key components: customer segments, value propositions, channels, customer relationships, key resources, key activities, key partnerships, revenue streams, and cost structure. With this framework, companies can more easily describe their business models.

The related concept is business model innovation, which also involves the realization of the business model. Business model innovation can be defined as "changes in the business logic that are new to the firm, but not necessarily new worldwide, and must lead to observable changes in business model practice" (Bouwman et al, 2008)[9]. The introduced changes may be triggered by technological developments (such as social media, the Internet of Things, big data), market conditions (competitive pressures), or even political decisions (regulatory laws). Companies responding to these decisions need to take appropriate actions to change their day-to-day operations, which is reflected in their business models.

With the rapid development of technology and dynamic changes in the market, business model innovation has become a necessity for companies to operate in the market. Business model innovation is driven by a variety of factors, which can be categorized into external factors (e.g., competitive environment, generation of new technologies, shift in company strategy, etc.) and internal factors (e.g., managerial perceptions, change in resource capabilities, etc.), where platforms may be the external factor that drives firms to innovate in the context of their business models. In terms of external factors, Landau et al. (2016)[10], through a study of firms seeking to enter emerging markets, found that when firms enter emerging markets are faced with a mismatch between market demand infrastructure and resources, and deficiencies in the firms' own organizational structure, which leads to change. This suggests that changes in the market are one of the main factors contributing to business model innovation. In terms of internal factors, Feng Xuefei and Dong Dahai (2015)[11] believe that the affirmative cognition of the head managers of the enterprise for business model innovation has a decisive role, and the support of managers for business model innovation is the wind vane to complete the transformation of the enterprise.

3. Analysis of Haier Group's Business Model Innovation Under the Platform Economy

Since its establishment in 1984, Haier's development strategy has undergone continuous changes, but it has always adhered to the development philosophy of "putting user value at the center." Haier's innovation has always been centered around user needs. In 2005, Haier began to envision layout for digital transformation: during this period of development strategy, Zhang Ruimin (founder and honorary chairman of the board of directors, Haier Group) first proposed the new business model of "Rendanheyi" (Integration of Individual and Organization) and began to transition from the traditional enterprise's "production-inventory-sales" mode to the "just-in-time supply under zero inventory" mode.

3.1. Exploration Phase of the New Model: Rendanheyi 1.0

"Rendanheyi" (Integration of Individual and Organization) is a response to the requirements of decentralization and disintermediation in the era of the Internet of Things and the platform economy. It entails disruptive and systematic continuous dynamic changes in strategic positioning, organizational structure, operational processes, and resource allocation across three dimensions: enterprise, employees, and users.

In 2013, Haier introduced the concept of "Micro-enterprises," decomposing the organization into independent micro-enterprise networks, with the aim of establishing a maker platform to transform employees into true entrepreneurs. Through Haier's platform, employees can become makers and utilize various resources to establish micro-enterprises, allowing everyone to become an entrepreneur. Concurrently, Haier proposed the concept of building a shared platform, aimed at achieving enterprise platformization, employee entrepreneurship, and user personalization. Enterprise platformization, also known as borderless enterprise, embodies the openness and interaction of the enterprise. This change in the concept of open interaction is reflected in the shift from a closed system to an open system, and from adversarial relationships with various internal and external aspects of the enterprise to interactive relationships. By leveraging internet platforms, enterprises are transformed into open, sharing, co-creating, and win-win platforms, thereby achieving accurate matching of resources and demands quickly and efficiently. Employee entrepreneurship embodies leaderless management, where everyone can become an entrepreneur through the internet. By empowering employees with certain rights, they transition from passive command executors to proactive entrepreneurs seeking development, not only mobilizing employees' sense of participation and initiative but also encouraging them to actively create value for users. User personalization embodies the concept of a scale-free supply chain, realizing the transition from enterprise-centered to user-centered. Initially driven by the scale-free supply chain, enterprises change, providing employees with entrepreneurial platforms. Employees start businesses to meet users' personalized needs, which in turn drives enterprise-level changes, forming a virtuous cycle, and ultimately better serving users with long-term services.

The "Rendanheyi" model breaks through traditional business models by transforming employees from mere dependents on the organization into active creators of value. The organization provides employees with an innovative platform, allowing them to exist as self-driven innovators on this platform. This arrangement achieves a three-way win-win situation among the organization, employees, and users.

3.2. Development Phase of the New Model: Rendanheyi 2.0

Chain clusters are a new organizational form that emerges after the upgrade of micro-enterprises. They are spontaneously formed alliances of various micro-enterprises, characterized by decentralization and user self-trust, forming a community of shared interests. They can meet the deeper needs of users to better serve them. The concept of "chain cluster contracts" was formally proposed in 2019. Here, "chain" refers to an ecological chain, which connects multiple-channel resources and stakeholders through the internet, blockchain, big data, etc., to achieve efficient collaboration among all parties. "Cluster" refers to micro-groups, which are the collection of nodes in the ecological chain. "Contracts" refer to smart contracts, where the purpose of all parties is to achieve co-creation and win-win outcomes, providing the intrinsic drive for the entire "chain" to exist and sustain. Chain clusters can guide enterprises toward meeting the needs of well-known users, creating lifelong users for the enterprise, aligning well with the characteristics of the IoT era, such as experiential and sharing economies.

In the chain cluster contract model, users, employees, and various stakeholders form multiple micro-chain clusters as nodes on the organizational chain. Each represents rights, responsibilities, and benefits, respectively. In this model, Haier breaks down the boundaries between micro-enterprises, integrating resources from various micro-enterprises to realize resource sharing between chains, thereby maximizing the utilization value of resources among chain clusters. At the same time, it fully leverages the role of each micro-enterprise in the chain, closely integrating the micro-enterprises, makers, resource providers, and other stakeholders on the platform, and linking all parties through nodes to form multiple value chains. This creates a mesh relationship in various stages, promoting their interaction. Therefore, the chain cluster contract model further disrupts traditional business models by allowing employees to self-organize and construct new ecological systems. The enterprise's goal shifts from profit growth to value creation with users.

3.3. Expansion Phase of the New Model: Rendanheyi 3.0

In 2021, Zhou Yunjie, Chairman and CEO of Haier Group, proposed the evolution direction of Haier's chain cluster contract— the Chain Cluster Federation. Building upon the foundation of the chain cluster contract, the Chain Cluster Federation further centers around users to achieve self-driven and self-evolving capabilities among various chain clusters. This fosters organic collaboration among chain clusters, thereby enhancing user experience. In the Haier ecosystem, micro-enterprises serve as the fundamental units of innovation, while chain clusters serve as the fundamental units of value creation. The Chain Cluster Federation will emerge as the fundamental unit of ecosystem evolution. It encompasses not only main chain clusters and sub-chain clusters within the enterprise but also external chain clusters. As the external chain clusters expand, the enterprise can establish a more systematic, comprehensive, and high-quality Chain Cluster Federation, promoting the expansion of chain clusters across enterprises and industries. This facilitates the evolution of the covered ecosystem, ultimately maximizing the efficiency of business models in the Internet era.

For instance, Haier's creation of the Industrial Internet platform COSMOPlat serves as a successful practical example in this regard. Initially serving only internal enterprise needs, COSMO platform underwent substantial investment from Haier to undergo restructuring and expansion, transforming it into a platform serving societal needs. It interconnected the data and information flows of manufacturing systems, allowing users to participate in the entire process of product design, research and development, manufacturing, logistics, distribution, and iterative upgrades, truly serving the users' needs comprehensively. The goal of Haier's COSMO platform is to establish an open, industrial-grade platform operating system. This system aggregates and integrates various resources to provide industrial enterprises with a rich array of intelligent manufacturing application services.

4. Conclusion

Against the backdrop of the flourishing platform economy, the research focusing on Haier Group has unveiled crucial practices and explorations in business model innovation for enterprises. Haier's "user-driven integration" business model demonstrates unique characteristics and values propelled by the platform economy. The evolution of business model innovation in digitally transformed enterprises exhibits phased characteristics, evolving through the stages of exploration, development, and ecological expansion, transitioning from a platform mode to a community mode and finally to an ecosystem mode.

Initially, during the exploration phase, Haier emphasized the updating of value propositions, including the exploration of customer needs and adjustments of value propositions under the Haier platform model. Building upon the foundation of micro-enterprises in the exploration phase, Haier, in the development phase, utilized the community contract model as a carrier, continuously incubating new enterprises through the core platform, thus driving the formation of a complete value ecosystem chain. Within the community, collaboration among various entities continuously extended and adjusted the platform to form a value network, enhancing the overall efficiency of value creation and transmission for multiple stakeholders, thereby continually expanding the enterprise's value ecosystem, forming a chain cluster union, and ultimately achieving cross-domain, cross-organizational value co-creation.

This study provides three insights into the construction of management models for Chinese enterprises. First, in the era of platform economy, enterprises should establish a management model based on the production mode of mass personalized customization. For mass personalized customization, enterprises need to integrate the user dimension, production and service dimensions to ensure the effectiveness of the enterprise management model. Second, the enterprise management mode should change with the change of the environment. In the context of the platform economy era, enterprises should fully learn and utilize the Internet of Things (IoT) technology to establish a management mode that matches the IoT technology to ensure the applicability of the enterprise management mode. Thirdly, the innovation of enterprise management mode needs to start from the basic constituent elements of strategic orientation, organizational mechanism and incentive mechanism under the leadership of management philosophy, and the three-dimensional structure of large-scale personalized customization corresponds to these three basic constituent elements one by one, so as to ensure the completeness of enterprise management mode. Meanwhile, in the era of platform economy, enterprises need to continuously optimize and improve these elements under the leadership of management philosophy to adapt to the changing market environment and achieve sustainable development of enterprises.

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Research on the Identification and Control of Supply Chain Security Risks in Xinfadi

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Abstract. The stable operation of the supply chain of agricultural products is of irreplaceable strategic significance to the healthy development of the national economy. In China, especially in large consumer cities like Beijing, the stability and security of the supply chain of agricultural products is crucial. As a major agricultural product distribution center in Beijing, the identification and control of supply chain security risks in Xinfadi market is particularly important. Therefore, this paper analyzes the current situation of the supply chain of the Xinfadi market, uses the method of grounded theory, selects the relevant literature, news reports and data in the past five years, identifies the potential security risks of the current Xinfadi supply chain, constructs a risk assessment system, and proposes corresponding preventive measures for the risk of high coefficient.

Keywords. Xinfadi, Grounded Theory, Risk Identification, Risk Control

1.Introduction

China is a country with a large population, and the average daily consumption of agricultural products is very large. As one of the few cities with a population of tens of millions, it is a major consumer city in the country and even in the world, and the per capita consumption of vegetables and vegetable products in Beijing has reached 122.7 kg in 2020. Megacities consume large quantities of agricultural products, have a generally low self-sufficiency rate, and are highly dependent on foreign countries. In addition, as a political and cultural center and a city with important international influence, it has received a lot of attention in various aspects. As the "vegetable basket" of Beijing citizens, Xinfadi Market has a daily shipment of more than 22,000 tons, accounting for more than 80% of Beijing's total supply. As an important part of the agricultural product circulation system, it plays a very important role in ensuring and promoting the trade and circulation of agricultural products. Therefore, from the perspective of supply chain risk, this paper identifies the supply chain risk of Beijing Xinfadi market, and comprehensively analyzes the risk formation mechanism, influencing factors and prevention and control strategies. On this basis, a supply chain security risk assessment model was constructed to find out the key risk points and weak links of the supply chain in Xinfadi market, so as to provide a basis for risk response.

The structure of this paper is roughly as follows: the first part is an introduction to the full text, which leads to the problems to be studied in this paper, and the second part

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reviews the current literature at home and abroad. The third part of the theory and research background mainly expounds the theory of security risks related to the supply chain of agricultural products, and summarizes the basic situation of the current supply chain of Xinfadi. The fourth and fifth parts will focus on the use of the grounded method to extract risk indicators, and finally form a set of security risk index system. Part 6 will analyze the risks and propose countermeasures, and finally summarize the full text.

2. Related Works

The security and stability of the supply chain of agricultural products has always been a hot topic of social concern and an important research direction. The supply chain of agricultural products is linked to urban consumers and rural residents, which is the integrator and stabilizer of national economic and social development [1]. For a long time to come, the operation mode of agricultural products with the wholesale market as the core will still dominate the supply chain of agricultural products in China [2]. China is the world's largest producer, distributor, and consumer of agricultural products, and the supply chain of agricultural products under the dual structure of large countries and small farmers is many, complex, varied, and long [3]. The supply chain of agricultural products is characterized by complex structure, high uncertainty, and fragile supply [4]. Members of the supply chain are closely intertwined, prospering or suffering together [5].

However, foreign research on the supply chain of agricultural products focuses on demand forecasting, production planning, inventory and transportation management, and the application of new technologies to improve performance, ensure food safety, and reduce losses. Diana and Corina argue that innovative measures are needed to guarantee agrifood security and authenticity in the context of the increasing complexity of agri-food supply chains [6]. In their research, Bosona and Gebresenbet found that a fast, trustworthy system was needed to retrieve the necessary information about their food when it came to food quality and safety [7]. The findings of Lovina et al. suggest that the key factors driving the adoption of blockchain technology in the agri-food industry include ensuring food traceability and transparency, food safety and security, food supply and logistics, food integrity, environmental awareness, and reducing food waste [8]. Agnusdei G P and Coluccia B. et al. identified 4 distinct clusters from the network of keyword co-occurrence and overlay visualizations, and blockchain became a central topic in the field of food safety in the agricultural supply chain[9].Sylvain et al. examined the important role that digital traceability systems play in improving operational efficiency, ensuring food safety, and increasing transparency throughout the supply chain through a multidimensional analytical framework [10]. Krstić et al. identified electronic traceability as a growing trend in the agri-food industry to improve transparency and reduce the risk of foodborne products [11]. Martina and Daniel argue that in modern agricultural settings, there is a need to realize the full potential of data and establish a unified infrastructure to facilitate the sharing and exchange of agricultural data [12]. Anastasiadis et al. looked at the current aspects of sustainable agri-food supply chains and their transition to a circular economy from the perspective of agricultural supply traceability [13]. According to Manikas et al., food security has become one of the most elusive and popular goals globally, and that it is more important than ever to ensure a country's food self-sufficiency during the pandemic [14].

3. Theoretical and research background

The theory of risk management in the supply chain of agricultural products mainly includes the strategies and methods for identifying, assessing, monitoring and responding to various risks that may occur in the supply chain of agricultural products. These risks come from all parts of the supply chain, such as production, procurement, transportation, storage, sales, etc. In view of these risks, the risk management theory of agricultural supply chain mainly includes the following aspects: First, through market research, data analysis and other methods, identify various risks that may exist in the supply chain of agricultural products, second, evaluate the identified risks, and third, monitor all links in the supply chain of agricultural products in real time to discover and respond to potential risks in a timely manner. Fourth, we should adopt corresponding response strategies and measures for different types of risks. Fifth, strengthen the coordination and cooperation of all links in the supply chain to improve the overall efficiency and stability of the supply chain[15][16].

As the hub of Beijing's agricultural product trading, Xinfadi Market has established a planting base of more than 3 million mu across the country, with more than 20,000 tons of vegetables and fruits entering Beijing Xinfadi Market every day, and more than 90% of vegetables are from other places. These supply bases have gradually formed a supply chain of agricultural products with direct procurement, processing and distribution, and community direct sales through orders. Xinfadi Market has built a stable supply location all over the country, and through the long-term cooperation agreement signed with the production base, the stability of the supply source and the stability of the capital's agricultural products have been ensured to a large extent. In the Xinfadi market, up to now, there are more than 2,000 fixed booths and more than 4,000 designated customers, forming a relatively large wholesale and retail network, and becoming a supply chain hub for agricultural products from the production area to Beijing. There are more than 1,500 managers in the market who are responsible for coordinating the storage, deployment and sales of different agricultural products, so that Xinfadi can operate efficiently as a supply chain hub.

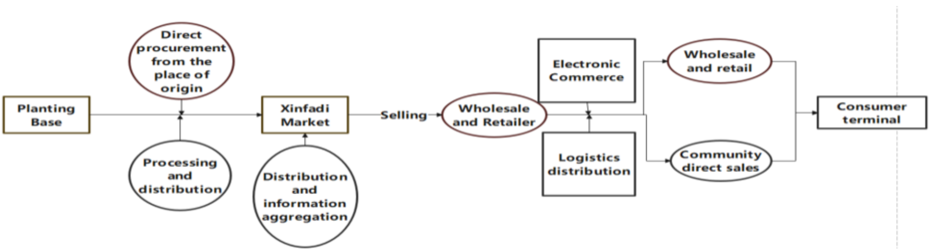

Figure 1. The current situation of the supply chain in Xinfadi

4.Research Methods and Innovations

Although the current supply chain construction of Xinfadi market is gradually advancing, there are still risks and challenges. This paper adopts the method of qualitative research grounded theory, collects journal papers, news reports and other data in the past five years, and uses Nvivo12plus to code the collected data after obtaining the data. Through the three-level coding, the corresponding risks were found, and the risk model of the supply chain of agricultural products in Xinfadi was finally constructed by gradually labeling, conceptualizing and categorizing the original data, and then comparing, inducting and summarizing the original data.

Based on exploratory factor analysis, this paper adopts the method of qualitative research grounded theory to conduct research, aiming to deeply analyze the supply chain risk sources and countermeasures of Xinfadi wholesale market. At the same time, through the mainstream literature retrieval platform, the articles on the theme of "Xinfadi supply chain" or a specific large-scale wholesale market are very scarce and have almost no reference value, which also indicates that the current research on the supply chain risk of this specific large-scale wholesale market is still in a blank state. Different markets are in different regions, with different development processes and supply chain risks, and the Xinfadi wholesale market carries nearly seventy percent of Beijing's agricultural product supply. Therefore, this study has certain innovative and practical significance for improving the supply chain risk management level of Xinfadi wholesale market, and can also provide reference for supply chain risk management in other large-scale wholesale markets.

5. Empirical research on grounded theory

5.1 Xinfadi wholesale market supply chain security risk identification

1)Open coding

A total of 200 material paragraphs and sentences on supply chain risks were compiled based on open coding, and only one example was shown in the article due to space constraints. Table 1 shows an example of labeling.

Table 1 Examples of the process of labeling related articles in supply chain risk journal literature

Source	Labeling, initial encoding
In 2020, the total trading volume of various agricultural products in the Xinfadi market was 12.98 million tons, with a transaction value of 100.6 billion yuan[13], and it was responsible for more than 70% of Beijing's supply of agricultural and sideline products	Most of the agricultural products are supplied through Xinfadi

After labeling, the homogeneous labels of journal literature (named A) and news reports (named B) were sorted out and integrated to form a unified conceptual category, and the results obtained are shown in Table 2. Due to space constraints, only a portion of the labeling and coding process is shown here.

Table 2 Preliminary conceptual categories of labels

Label concept	Preliminary scope
Most of the agricultural products are supplied through Xinfadi;The transaction scale of the Xinfadi market ranks first all year round;	A1 Xinfadi market dominates the circulation of agricultural products.
……	……
The control policy has been increased layer by layer; Policies are needed to guide the smooth transportation of agricultural products; Lack of guidance documents for environmental updates;	A19 Policies are needed to guide the development of agricultural supply chains
……	……

There is a large gap between production and marketing prices; The price of the origin end is low and cannot be sold;	B1 Production and sales prices do not match
… …	… …
The planting facilities in Beijing are relatively backward; The degree of mechanization of production is not high; The area of self-produced vegetables for agricultural products is very low;	B15 It is difficult for Beijing to achieve self-sufficiency in the supply of agricultural products

2) Spindle coding

After the completion of open coding, a total of 34 primary categories were obtained, and the relationship between the preliminary conceptual categories was further studied through the spindle coding for the independent coding categories. In particular, the preliminary concepts in the journal literature and the similar concepts in the news reports are similarly divided to obtain a higher-level conceptual category, so as to identify the risk level of the Xinfadi supply chain. The spindle coding table is shown in Table 3

Table 3 Spindle encoding

Spindle coding	Primary coding
C1 Market size risk	A1 The Xinfadi market dominates the circulation of agricultural products;A8 The concentration of people in the central market poses a safety hazard;A10 The scale of service in the Xinfadi market is too large
C2 Public health risk	A4 The pandemic has caused the wholesale market to be unable to supply normally;B4 The Xinfadi market is prone to environmental health problems
… …	… …
C14 Human factor risk	A16 Food safety rumors have a lot to lose;A17 Property rights interests have become an obstacle to market upgrading
C15 Policy support is insufficient	A19 Policies are needed to guide the development of agricultural supply chains;B3 Policies are needed to guide the smooth transportation of agricultural products

3) Selective coding

Through the spindle coding, the 34 initial categories are sorted out to obtain 15 high-level categories, and these 15 high-level categories are the 15 risk points obtained through grounded identification. Based on the risk theory of agricultural product supply chain, these 15 risk points are further refined, and finally 8 core risk concepts are obtained, as shown in Table 4

Table 4 Selective coding

Core Areas	Main category
Sustainability risks	C1 Market size risk
	C13 Lack of modern information systems
Environmental risks	C2 Public health risk
	C3 Natural disaster risk at origin
	C6 Supply chain hub operational risk
Supply chain disruption risk	C4 Logistics Disruption Risk
	C5 Supply Chain Delay Risk
Risk of information asymmetry	C7 Risk of undersupply
	C14 Human Factor Risk
Food safety risks	C11 Safety risks of agricultural products at origin
Price fluctuation risk	C9 Supply and demand price fluctuation risk
	C10 Demand change risk
Transportation and distribution risks	C8 Traffic congestion risk
	C12 Distribution Transportation Cost Risk
Policy risk	C15 policy support is insufficient

5.2 The construction of the supply chain security risk assessment system of Xinfadi wholesale market

After multiple risks are identified through coding based on grounded theory, these risks are integrated and sorted out to facilitate the evaluation of each link of the supply chain, identify potential risk points, and provide a scientific basis for risk management and decision-making. In order to obtain the weights of each risk, Nvivo software was used to calculate the proportion of coverage ratio, and finally obtained the weights of each level 1 risk and level 2 risk indicators:

Table 5 Risk weight statistics based on grounded theory

Level 1 indicator risk	Weight value	Level 2 indicator risk	Weight value
Sustainability risks	0.0704	Market size risk	0.0347
		Lack of modern information systems	0.0357
Environmental risks	0.2550	Public health risks	0.0900
		The risk of natural disasters at the place of origin	0.0536
		Supply chain hub operational risk	0.1114
Supply chain disruption risk	0.1089	Logistics blockade risk	0.0468
		Supply chain delay risk	0.0621
Risk of information asymmetry	0.1556	Risk of insufficient supply	0.1051
		Human factor risk	0.0505
Food safety risks	0.0624	Safety risks of agricultural products in the place of origin	0.0624
Price fluctuation risk	0.1600	Supply, demand, and price fluctuations risk	0.1049
		Demand fluctuation risk	0.0551
Transportation and distribution risks	0.1129	Risk of traffic congestion	0.0674
		Distribution and transportation cost risk	0.0455
Policy risk	0.0748	Policy support is insufficient	0.0748

Based on the analysis of mathematical weights, it is found that among the security risks of the supply chain of agricultural products in Xinfadi, environmental risks rank first, followed by price fluctuation risks, information asymmetry risks, transportation and distribution risks, supply chain rupture risks, policy risks, sustainability risks, and food safety risks. The top three risks in the secondary indicators are supply chain hub operation risk, supply shortage risk, and supply and demand price fluctuation risk. It can be seen that Xinfadi Market, as Beijing's "vegetable basket", undertakes the function of transiting a huge amount of agricultural products, which has generated potential supply chain operation risks, and its operation model is relatively extensive. Insufficient response measures to possible risks, once this hub and transfer station fails, it will affect the supply of agricultural products throughout Beijing. For example, during the epidemic, the Xinfadi market had several outbreaks of clusters and caused the market to close, which caused the price of agricultural products to rise significantly in Beijing in a short period of time, and the supply exceeded demand [17][18].

Based on the risks identified above and the conceptual categories extracted from grounded theory, the risk assessment system can be summarized as follows:

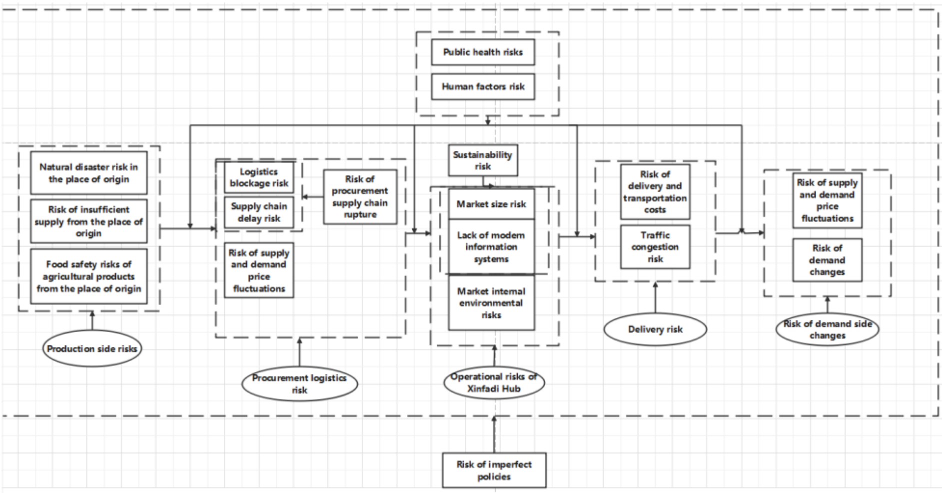

Figure 2: Xinfadi agricultural product supply chain risk assessment system

6. Discussion

According to the obtained risk weights and the data obtained from the above, combined with the data consulted and field investigations, corresponding preventive measures can be proposed for several risks with high coefficients

6.1 Environmental risk prevention measures

For the Xinfadi market, the first thing to do is to prevent environmental risks, improve the market's internal trading platform, strengthen internal operation management, do a good job in sanitation, and improve business conditions and environment. For infrastructure, new sites and spaces can be planned, and the layout of the fresh market can be replanned to ensure that the aisles are wide and unobstructed, and congestion can be reduced. Reasonably divide the sales area of different types of ingredients to improve the utilization efficiency of the internal space of the market. Ventilation systems are added or retrofitted to ensure air circulation inside the market and reduce the spread of viruses and bacteria. In addition, the management of personnel should also be more detailed to ensure that the source of personnel can be traced. Limit the density of people in the market and avoid overcrowding. Finally, regularly inspect the market environment of Xinfadi and strengthen environmental supervision to ensure compliance with relevant standards[19][20].

6.2 Measures to prevent price fluctuation risks

In view of the risk of price fluctuations, it is necessary to establish and improve the price monitoring mechanism and early warning emergency plan. Establish a comprehensive price information collection system, collect data from production, circulation to consumption, and use modern information technology to predict and analyze the supply and price trends of agricultural products. At the same time, based on historical data and current market conditions, set thresholds for key indicators, and once these indicators are abnormal, the early warning mechanism will be activated in time to send early warning signals to the government, enterprises and consumers. In addition, the government, enterprises and the market should jointly formulate emergency plans to clarify the response measures in the event of severe price fluctuations, such as price intervention, increasing reserves, optimizing distribution, and establishing diversified procurement channels to ensure market stability [21].

6.3 Measures to prevent the risk of information asymmetry

Use modern information analysis technologies such as big data and cloud computing to study and judge the market situation in real time, establish a supply chain database, and strengthen the ability and level of dealing with sudden risks. In addition, it is necessary to ensure the stability of the basic vegetable field area in Beijing and consolidate the foundation of local vegetable supply, so as to provide the necessary buffer period for the strategy of ensuring supply and stabilizing prices in the vegetable market in response to emergencies. Select vegetable varieties with moderate price, storage and transportation, and strong market adjustment ability, such as Chinese cabbage, potatoes, shallots, radish, etc., for winter and spring reserves. Through various methods, we will continuously improve the flexibility and resilience of the supply chain of Xinfadi market, ensure supply and price stability when risks come, and ultimately achieve risk prevention and market security [22].

6.4 Measures to solve transportation and distribution risks

As an important supplier of agricultural products in Beijing, the transportation efficiency of Xinfadi Market directly affects the circulation speed and cost of agricultural products. The transportation of wholesale agricultural markets depends on good infrastructure, especially the current rapid development of information technology. Information management plays an important role in improving transportation and distribution efficiency, reducing costs, and ensuring food safety. Using data analysis and optimization algorithms to optimize logistics and distribution routes, reduce transportation time and costs, and improve distribution efficiency. Multiple supply chain channels can also be developed to reduce dependence on a single supplier and increase the resilience of the supply chain.

6.5 Supply Chain Disruption Risk Prevention

In response to the risk of supply chain disruption, implement multi-source procurement to ensure that there are at least two to three major suppliers to reduce dependence on a single source of supply, and ensure that after one supply chain source supplier has a problem, it can get guaranteed products from other suppliers that can support the normal operation of the supply chain. Alternate supply chains can also be established, and alternate supplier lists can be identified and maintained to allow for quick switchovers in the event of major supply chain issues. In addition, technology can be used to improve the visibility of the supply chain and monitor the status of the supply chain in real time.

6.6 Policy Risk Precautions

From the government's point of view, policies should be formulated with continuity and stability to avoid frequent policy changes that bring uncertainty to the market. It is also necessary to develop and update contingency plans and continuity plans for various emergencies to ensure that the supply chain can quickly resume normal operations in the event of policy changes or other external shocks. In addition, big data and artificial intelligence and other technical means can be used to carry out data-driven policy formulation and risk assessment, so as to improve the scientificity and accuracy of policy formulation.

6.7 Sustainability Risk Precautions

In view of sustainability risks, including market size risks and lack of modern information systems, it is necessary to use big data analysis technology to accurately predict market demand, and adjust inventory levels accordingly to avoid inventory overstocking or shortages. Strengthen cooperation with suppliers, manufacturers, distributors and other upstream and downstream enterprises in the supply chain, establish stable cooperative relations, and ensure the stability and sustainability of the supply chain. In addition, the Internet of Things, blockchain and other technologies can also be used to establish a full traceability system for agricultural products to ensure the quality and safety of agricultural products and improve consumer trust. Build a supply chain information sharing platform to realize real-time sharing of information in all links of the supply chain, and improve the transparency and collaboration of the supply chain.

6.8 Food Safety Risk Prevention Measures

First of all, it is necessary to ensure that all agricultural products entering the market have undergone strict incoming inspections, and suppliers are required to provide relevant quality inspection reports and legal source certificates. Establish a sound traceability system to realize the whole process of traceability from the source to the table and ensure that the source and destination of food can be traced. In addition, it is also necessary to be responsible for the cleaning and disinfection of environmental sanitation, cargo transportation, cleaning supplies and other cleaning and disinfection work in public areas, especially the regular cleaning and disinfection of high-touch surfaces. Finally, the market supervision department needs to strengthen the supervision and inspection of the wholesale market of agricultural products and prohibit the sale of livestock and poultry meat that cannot provide inspection and quarantine certificates, and aquatic products that cannot provide certificates of origin and purchase certificates.

7. Conclusion

This paper adopts a grounded theory approach to comprehensively and meticulously identify potential security risks in the supply chain of Xinfadi market. By collecting and collating a large amount of information, the paper identifies environmental risks, price fluctuation risks, information asymmetry risks, transportation and distribution risks, supply chain disruption risks, policy risks, sustainability risks, and food safety risks. These risks were coded and classified, and a scientific risk assessment system was constructed after the coding and classification were completed. Based on the identified risks, this paper uses a combination of qualitative and quantitative methods to establish a relatively complete risk assessment system including risk identification, risk assessment, risk monitoring and risk response. This system can not only assess the risks in the supply chain of the Xinfadi market, but also provide market managers with targeted risk response strategies for subsequent risk assessment and management. At the end of the paper, the corresponding preventive measures are proposed for the risk of high coefficient. In the supply chain of Xinfadi market, there is a close connection and mutual influence between the various links. Therefore, in order to achieve the stable development of the market, it is necessary to strengthen the coordination and cooperation of all links in the supply chain and form a joint force to improve the overall efficiency and stability of the supply chain.

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Research on the Strategy of Innovation and Entrepreneurship Education in Higher Vocational Colleges from the Perspective of Rural Revitalization

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Abstract. The report of the 19th National Congress of the Communist Party of China made a significant and far-reaching strategic plan for rural revitalization and clarified the core position and key role of rural revitalization in building a well-off society in an all-round way and building a strong socialist modern country. As the country's reserve talent training base and the source of technological innovation, higher vocational colleges bear the historical responsibility of national progress and social development and shoulder the important mission of promoting rural revitalization and helping the country prosper. How to cultivate college students' sense of responsibility and social mission and stimulate their innovative and entrepreneurial thinking is a key issue for higher vocational colleges to think about. Drawing upon the present landscape of innovation and entrepreneurship education within higher vocational institutions, this article delves into the strategic positioning of such education within the broader context of rural revitalization endeavors, explores the interplay between innovative entrepreneurship education within higher vocational institutions and the revitalization strategy of rural areas, grounded in theoretical foundations. It establishes a conceptual framework for analyzing this connection, aimed at bolstering the cultivation of rural revitalization talents through innovative and entrepreneurial education in vocational colleges. Furthermore, this investigation proposes practical approaches for implementing such education, with the ultimate aim of fostering the premium development of vocational education, thereby enhancing the overall quality of higher vocational educational institutions.

Keywords. Rural revitalization, higher vocational colleges, innovation and entrepreneurship education, talent revitalization

1. Introduction

The road to national rejuvenation lies in the comprehensive revitalization of the countryside, and the report of the Twentieth National Congress of the Communist Party of China (CPC) clearly pointed out that the work of rural revitalization should be pushed forward in a comprehensive manner, and the revitalization and development of

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rural industries and talents should be promoted effectively.2024 Document No. 1 of the Central Committee pointed out that, in the great process of pushing forward the modernization of China, it is necessary to consolidate the foundation of agriculture in a consistent manner, and comprehensively promote rural revitalization and development. Rural revitalization has been the focus of political and academic attention since its introduction. In promoting the process of rural revitalization, innovative and entrepreneurial talents are crucial. As the cradle of cultural inheritance and fertile ground for talent cultivation, schools bear the arduous and glorious mission of cultivating talents needed for rural revitalization in the context of the new era. Drawing upon the 2023 National Education Development Overview, disseminated by the Ministry of Education's Planning and Development Sector, we observe the foundational landscape of educational progression, in 2023, the proportion of higher vocational schools will be 50.33%; and the proportion of higher vocational enrollment will be 53.26%. Occupational education stands as the educational pillar most intimately intertwined with economic and societal progress. In recent times, China has intensified its efforts towards reforming and modernizing its vocational education system, fostering a model of profound industry-education collaboration. This has steered and encouraged vocational institutions to prioritize crucial sectors, actively engaging with regional economic and social advancements, thereby nurturing a skilled workforce essential for advancing new industrial paradigms.

The promotion of innovation and entrepreneurial endeavors within higher vocational institutions and universities holds paramount significance in achieving the revitalization objectives for rural areas. Its education must be closely centered on the fundamental task of establishing moral character, integrating ideological and political education, cultural literacy education, innovation and entrepreneurship education and social practice training and other aspects organically [1], and forming a good pattern of synergistic parenting [2]. The exploration of innovation and entrepreneurship instruction within vocational tertiary institutions and universities carries immense value in advancing reforms within this educational domain, and in establishing an innovative and entrepreneurial educational framework tailored to the demands of rural rejuvenation; serving the development of the rural economy, actively docking with the needs of rural industries, and promoting the in-depth integration of industry, academia, research and application.

2. Related Works

Since the rural revitalization strategy was proposed, researchers have actively explored the strategies and methods of talent revitalization under the rural revitalization strategy. Some scholars have found that rural industrial economic development is the guarantee of rural revitalization [3]. Promoting rural economic development requires improving the economic system, adjusting the supply-side structure, and using regional advantages to develop characteristic agriculture [4]. The revitalization of human capital serves as the impetus behind the progression of rural agricultural economies. [5]. Cultivate talents with the help of the system, train new professional farmers, set up rural innovation and entrepreneurship parks, mention agricultural entrepreneurship incubation bases for graduated college students, and establish a talent support system [6]. Vocational tertiary institutions and academic universities, alongside undergraduate establishments, propel the advancement of rural rejuvenation endeavors via fostering innovative and entrepreneurial instruction[7,8,9], and through the relevant literature combing, the research on talent revitalization of higher vocational colleges and universities under the threshold of rural revitalization is summarized into two aspects.

On the one hand, the problem of talent stock and flow is the bottleneck of rural revitalization development. At present, there is a strange shortage of talents in rural governance, and it is difficult to recruit and even more difficult to retain talents. In terms of talent loss and retention, Li Ning [10] points out that education, employment, living conditions and other reasons lead to the loss of talent, which makes the talent stock in rural areas insufficient and restricts the transformation and upgrading of the rural economy. In terms of talent cultivation and introduction, Zhao Jianqiang [11] pointed out that the supply of high-level talents in China's countryside is insufficient, and there is a lack of a high-quality, technology-knowledgeable, high-level science and technology research and development team. Li Cuiping [12] pointed out that rural revitalization is faced with the loss of distinctive culture, the lack of public culture and the lack of cultural construction talents. It is necessary to take the socialist core values as the lead, enrich the rural cultural supply, and improve the cultural talent development mechanism to promote rural revitalization.

On the other hand, The matter at hand pertains to the education imparted by vocational tertiary institutions and universities, aimed at fostering the rejuvenation of rural talent pools. Scholarly research has found that Numerous challenges exist within the present situation of vocational education industry-teaching integration quality talent cultivation, and vocational tertiary institutions and universities hold a clear comprehension of the objective pertaining to the nurturing of talents. Zhang Fangshan [13,14] Rural governance, economic development and industrial development are inseparable from the construction of rural talent team, rural talent team construction requires institutions to cooperate with the cultivation of talents. Cheng Weili [15] has emphasized that the quantity of "dual-qualification" educators within vocational tertiary institutions and universities falls short, with a deficiency in hands-on expertise. Consequently, the establishment of a reciprocal teacher exchange framework becomes imperative to enrich their pedagogical experience through practical engagement. Zhu Hua [16] highlighting the importance of fostering talent in vocational tertiary institutions and universities, it is imperative to revolutionize the approach to student administration to align with the demands of multifaceted growth and attain the outcomes of adaptable guidance. A pivotal strategy involves tailoring education to individual strengths and fostering a blend of openness, pertinence, and talent development, all of which are intricately intertwined. Li Yang [17] pointed out that the professional setting of talent cultivation in higher vocational colleges and universities needs to be targeted, focusing on the cultivation of students' native ability, so that the ability cultivated by the school is highly matched with the ability of job demand.

Based on the theoretical foundation of rural revitalization and vocational education theory, this paper constructs a theoretical framework at innovation and entrepreneurial education methodologies within vocational tertiary institutions and universities to empower talent revitalization and talent revitalization to promote rural revitalization, which has a certain contributing role in perfecting the landscape of innovation and entrepreneurial education in vocational higher learning. Ultimately, it contributes to shaping a novel paradigm of talent nurturing in these institutions, one that is geared towards empowering the revitalization of rural areas.

3. Theoretical Background

3.1 Vocational education theory

The theory of vocational education is the sum of systematic understanding of the attributes, principles, methods, objectives, mechanisms, modes and other fundamental issues of vocational education. Practice is the sum of human behavioral ways of transforming the world, and the relationship between the theory and practice of vocational education is organic unity. Vocational education is based on the method of education, takes the vocational life as the object, aims at cultivating vocational knowledge and skills, vocational ethics and professionalism, is oriented at promoting employment, improving the quality of employment and making up for vocational needs, and aims at realizing the ideals of job-seekers and practitioners and engaging in the work that is beneficial to the individual or to the society. The distinctive features of vocational tertiary education embody a harmonious blend of higher educational ideals and practical vocational training elements.

3.2 The theory of integration of industry and education

The integration of industry and education embodies a novel educational paradigm where vocational institutions intertwine the socioeconomic advancements of the society or region with the evolutionary trajectories of various industries and provide quality training services with each other through close collaboration and mutual promotion to jointly promote the cultivation of talents, so as to realize the win-win situation between the industry and education. This education model aims to cultivate professional skilled talents with high practical ability and innovative spirit to meet the needs of social and economic development. The theory of integration of industry and education emphasizes the interrelationship with practice, and the research on the theory and practice of integration of industry and education has a long history both at home and abroad. In recent years, as the country's degree of vocational education continues to rise, a growing number of vocational institutions and universities have embarked on investigating an educational paradigm that fosters the seamless fusion of practical experience and academic instruction. The hallmarks of this industry-education integration encompass collaborative endeavors between schools and enterprises, hands-on learning experiences, the communal utilization of educational assets, and the enhancement of talent development standards. Furthermore, integration underscores the intimate bond between vocational training and industrial progression, signifying a pivotal trend in the evolution of vocational education. This approach to education not only aligns vocational curricula with industry demands but also ensures that graduates are well-equipped to contribute to the growth and innovation of their respective sectors, through the integration of industry and education, can effectively dock the teaching and the production and management of agriculture and rural areas, and cultivate talents for the revitalization of the countryside [18].

3.3 Rural revitalization theory

The theory of rural revitalization is based on strategic management theory, rural governance theory, ecological economic theory, urban-rural integration theory and industrial development theory. For rural revitalization, education is important, and talents are the first priority. Vocational colleges and universities are the main position for talent training, and enterprises are the main platform for talent growth. Only through the integration of industry and education and school-enterprise cooperation can we truly grasp the demand for talent training for rural revitalization and play a leading role in rural revitalization with applied talents [19]. Vocational education can drive the cultivation of the rural ecological civilization concept and the construction and development of ecological industries with the help of the basic attributes of educational, economic and vocational. Vocational education can make full use of its own characteristics and deeply participate in the construction of grassroots governance patterns in rural revitalization demonstration areas.

4. Methodology

In the realm of higher vocational education, fostering innovation and entrepreneurship serves as a pivotal approach to achieving the rejuvenation of talent pools, as well as a strategic model for advancing rural revitalization efforts. By combing the relevant theoretical basis and studying its internal connection logic, this paper constructs a theoretical analysis framework of educational initiatives focusing on innovation and entrepreneurship within higher vocational institutions serve to empower and enhance the cultivation of talents aimed at revitalizing rural areas, as illustrated in Figure 1.

5. Empirical Research

5.1 Supply and demand structure does not match

Although vocational and technical colleges have taken into account the needs of rural revitalization talents in the opening of majors and courses, there is still a big gap between them and the actual situation of rural revitalization talents' needs. First, the professional talents cultivated by vocational and technical colleges do not meet the needs of rural talents. It is reflected in the theorization of professional knowledge and skills, and students lack practical experience and practical operation, and are unable to combine theory and practice. Secondly, the technical talents needed by the countryside are not cultivated by higher vocational colleges. vocational and technical colleges professional settings, curriculum selection, selection of teaching materials, etc. are not closely linked with the development of digital countryside, the countryside needs new agricultural technology talents vocational and technical colleges have not been cultivated.

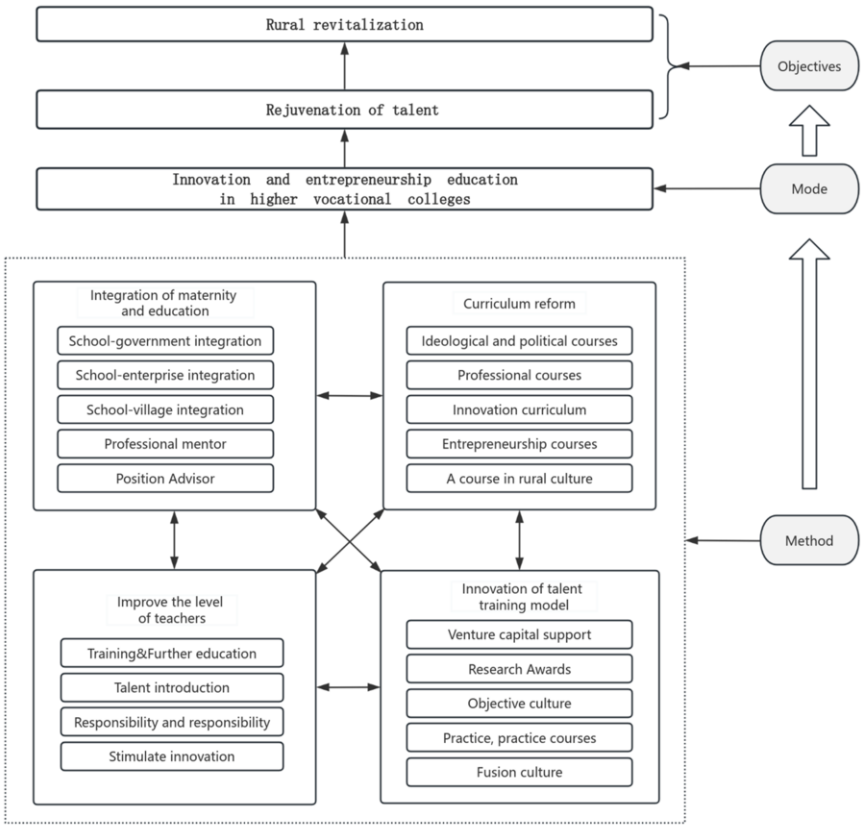

Figure 1. Innovative Entrepreneurship education in higher vocational colleges to enable rural revitalization of personnel training framework

5.2 The curriculum structure is not scientific.

Vocational and technical colleges have failed to deeply understand the talent needs and problems of villages. The goal of what talents to cultivate and how to cultivate talents is not clear. Innovation and entrepreneurship education of vocational and technical colleges and professional education of countryside technical talents are on their own and poorly undertaken. Innovation and entrepreneurship education and rural technical personnel professional education have a low degree of fit, insufficient resource integration and linkage. In the curriculum system involved in vocational and technical colleges, there are insufficient courses related to rural development, and the curriculum citation system of new technologies, new business forms and new modes is not perfect. Vocational and technical colleges lack the realm of enhancing students' innovative and entrepreneurial capabilities, a comprehensive, top-tier design is conspicuously absent, resulting in a noticeable lack of substantial cultivation in both their awareness and aptitude for innovation and entrepreneurship. Vocational and technical colleges pay too much attention to course scores and weaken the importance of practical teaching. It is detrimental to fostering students' creativity and entrepreneurial spirit, thereby hindering the effective nurturing of innovative and entrepreneurial capabilities.

5.3 The level of teachers to be improved

In the innovation and entrepreneurship education of vocational and technical colleges, teachers play a crucial role, and their influence is far-reaching and extensive. At present, there are problems such as structural imbalance, insufficient teaching ability and knowledge reserve, and low professional standard in the teaching team of vocational and technical colleges, resulting in the inability to fully stimulate the innovation potential and entrepreneurial passion of students, and it is difficult to give comprehensive and in-depth guidance to students. From the practice of some vocational and technical colleges, most of the teachers of professional courses are halfway, less professional, lack of practical experience in rural development, and unable to penetrate the professional knowledge; teachers of innovation and entrepreneurship courses are mainly counselors, lack of innovation and entrepreneurship experience, and unable to promote the development of students' innovation and entrepreneurship thinking. There is a serious lack of teachers with close links to the rural revitalization industry, this has emerged as a pivotal hindrance to the nurturing of individuals with innovative and entrepreneurial prowess.

5.4 The training mode has shortcomings.

The training model of vocational and technical colleges should ensure that every student can learn something, so the training model should be combined with the development of the academic situation and the training objectives. High in talent cultivation program, the student source has complexity and diversity, but the cultivation program is unified and lacks differentiation. The unified cultivation program restricts students' individualized development and innovative thinking development. It is difficult for the cultivation program to meet the interests, abilities and career planning needs of different students. In terms of teaching methods, teaching methods are single and dominated by traditional lectures. Practical courses or practical activities are formalized, students' practical theoretical knowledge is insufficient, and there is a lack of innovative teaching methods to stimulate students' enthusiasm and initiative. Addressing these challenges is detrimental to fostering the development of high-caliber rural revitalization professionals within vocational education institutions and universities, thereby impeding the effective nurturing of skilled individuals vital for rural renewal.

6. Recommendations

6.1 Integration of maternity and education

In order to better serve the rural revitalization strategy, vocational and technical colleges can build a rural revitalization service base with local governments, enterprises and social organizations, combining the educational resources and technical advantages of vocational and technical colleges with practical platforms, and providing all-around support and services for rural areas. Vocational and technical colleges should deeply understand the actual needs of countryside areas, establish cooperative relationships with local governments, enterprises and social organizations, and jointly formulate the development plan of the rural revitalization service base. By integrating the resources of all parties, a comprehensive platform integrating education, training, practice and innovation and entrepreneurship is created [19]. On the integrated integration platform, vocational and technical colleges can carry out a series of activities such as education and training, practice and internship, innovation and entrepreneurship support, technology development and promotion, and resource sharing [20,21].

6.2 Curriculum reform

Focusing on the strategy of rural revitalization, vocational and technical colleges are refining their curricula frameworks for fostering innovation and entrepreneurship education: firstly, clarifying the course objectives. Combined with the needs of the countryside revitalization strategy, it cultivates compound talents with innovative thinking, entrepreneurial spirit and practical operation ability. Second, improve the innovation and entrepreneurship education course system. It covers multiple levels of general education, professional education and practical education. General education emphasizes innovative thinking, entrepreneurial awareness and teamwork spirit. Professional education combines the needs of rural economic development and strengthens professional knowledge and skills [23,24]. Third, optimize the curriculum content. Increase the course content related to rural economic development, such as agricultural science and technology, rural tourism, agricultural product e-commerce and so on. Focus on updating and improving the course content and introducing new technologies, new business forms and new modes [25]. Fourth, strengthen the practical teaching link. Build practical training bases, entrepreneurial incubation bases and school-enterprise cooperation platforms to provide students with rich practical opportunities and high-quality teaching resources.

6.3 Improve the level of teachers

In view of the multidisciplinary and multidisciplinary characteristics of this education, the quality requirements for teachers are also increasing [25]. Teachers not only need to carefully craft the instructional material while adeptly applying a diverse array of teaching methodologies, and effectively organize the teaching ability of classroom teaching, but also need to combine their own practical experience and professional ability and be able to well integrate a variety of teaching resources for teaching. First, vocational and technical colleges should actively improve the ability and level of serving teachers. Provide regular professional training, academic exchange activities, and encourage teachers to go to high-level colleges or institutions for further study. The second is to stimulate the enthusiasm and creativity of teachers to improve their teaching level. By organizing various teaching competitions and setting up special topics and rewards, teachers are incentivized to carry out research related to education and teaching in order to fostering the transformation of pedagogical practices, scholarly research, and scientific discoveries. Furthermore, its aim is to bolster the integration of innovative and entrepreneurial education with hands-on experiences, thereby enhancing the practical application of theoretical knowledge. Thirdly, vocational and technical colleges should clarify the responsibilities and duties of all teachers in innovation and entrepreneurship education. By formulating specific work plans and division of labor, it is ensured that each teacher can play an active role in his/her professional field.

6.4 Innovation of talent training model

In the context of the strategy of countryside revitalization, college students are guided to deeply understand their key mission and responsibility in the development of society, and their sense of social responsibility and entrepreneurial enthusiasm are stimulated. First, clarify the core objectives of innovation and entrepreneurship education. Aligned with the necessities dictated by the rural revitalization strategy, make use of educational resources and professional advantages to formulate practical training objectives. Secondly, realize the integration of school-enterprise, school-rural and school-political training. Co-construct specialties with common cultivation subjects and precisely formulate talent cultivation programs. Third, increase the proportion of practical courses and internship courses. Expand practical teaching resources and establish stable cooperative relationships with enterprises and villages. Fourth, build a perfect innovation and entrepreneurship education system and support mechanism. Give support to college students from the levels of policy support, financial guarantee, project matching and so on. Help college students overcome the challenges in the process of entrepreneurship. Closely centered on the thesis of regional development [26], the prosperity of talents, economic upgrading and the progress of the overall level of society. With the essential goal of establishing moral character, we improve students' comprehensive quality and sense of social responsibility.

7. Conclusion

Vocational and technical colleges, as the national reserve genius training base and source of technological innovation, carry the historical responsibility of national progress and social development, and shoulder the important mission of promoting rural revitalization and contributing to national prosperity. In the current strategic context of promoting rural revitalization, it is necessary to deeply understand the key role of talents in rural revitalization, regard the work of talents as a vital project, and commit to building a team of talents full of enthusiasm, professional skills and innovative spirit in order to promote rural revitalization to achieve high-quality development. Innovation and entrepreneurship education in vocational and technical colleges realizes talent cultivation through the integration of industry and education, curriculum reform, upgrading of teachers and innovation of talent cultivation mode, stimulating students' innovation potential, guiding students to go deep into the countryside, understand the countryside and pay attention to the countryside with the fundamental purpose of cultivating morality, fostering students' sense of family and countryside sentiment and sense of social responsibility, improving students' comprehensive quality and competitiveness in employment, and conveying more excellent talents for rural revitalization. Furthermore, it endeavors to attain superior development in rural areas, thereby fostering a holistic rejuvenation of the countryside.

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The Dynamic Analysis of the Policy Change of "Three Educations" Collaborative Innovation Development in China from the Perspective of Multi-Source Theory

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Abstract. The collaborative-innovation development of vocational education, higher education and continuing education (referred as “three educations”) is a key initiative of the Party Central Committee’s comprehensive deployment of “the strategy of revitalizing the country through science and education and strengthening the support of modern talents”. The article constructs a multi-flow theoretical analysis framework by reviewing literature on collaborative innovation and development of “three educations”. Based on the perspective of multi-flow theory, we try to analyze the problem flow, political flow and policy flow. The analysis finds that the coupling of the three sources opens the window of policy, and the collaborative innovation and development of “three educations” becomes a national decision. This national decision aims to promote high-quality development of the collaborative innovation of “three educations” based on the new quality of productive forces in the context of the new era and the new journey.

Keywords. Vocational education, higher education, continuing education, collaborative-innovation development

1. Introduction

The report of the 20th Party Congress emphasized the collaborative innovation of vocational education, higher education and continuing education (here after referred as “three educations”). And it calls for the integration of vocational education and universal education, industry and education, and science and education, and optimizing the positioning of vocational education classification [1]. According to the Basic Information on the development of National Education in 2023, the enrollment of general and vocational undergraduate and junior college students across the country

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reached 10.4222 million, and the gross enrollment rate of higher education was 60.2%, achieving the goals of the "14th Five-Year Plan" ahead of schedule. The collaborative development of the "three educations" has played a remarkable role. Through resource sharing and complementary advantages, it has met the society's demand for multi-level talents and provided a solid talent support for the country's sustainable development. Inquiring about how the government makes such a decision and exploring the internal black box of the government's policy introduction will help improve the scientific nature of government decision-making and achieve positive social goals.

2. Related works

Academic research on the collaborative-innovation development of the "three educations" is still in its infancy, and there is no uniform connotation definition [2]. Literature review found that the existing research on collaborative-innovation development of "three educations" mainly focuses on four aspects. First research aspect is about the status of the collaborative-innovation development of "three educations". Bie Dunrong puts forward the realization path of the collaborative-innovation development of "three educations", noting the objective necessity and internal unity of it [3]. Gavin Moody argues that the conversion and mobility of students between two types of institutions is more important than the transfer of credits, and that student mobility should be considered the key solution for the integration of vocational education and higher education [4]. Lucas Graves proposed that strengthening the integration of vocational education and higher education is conducive to guaranteeing educational equity and creating more opportunities for students to make educational choices [5]. The second studying field is about the international comparative research on the collaborative-innovation development of "three educations". Based on international comparative research, Xie Qingsong promotes a collaborative innovation model from the ontological and methodological perspectives [6]. Through studying the advanced experience of Germany's "dual system" vocational education in teachers' training, teaching materials construction, and pedagogical reform, Tang Jianhao puts forward the useful inspiration for the innovation and reform of vocational education in the new era [7]. Another study area is empirical research on the innovative collaboration development of the "three educations". Based on empirical analysis, Hu Yong uses the theory of synergy and puts forward the path of collaborative innovation in order to achieve the effect of 1+1+1＞3 of "three educations"[8]. Based on the perspective of collaborative innovation, Ning Qiyang clarifies the dilemma of the relationship between multiple synergies of higher vocational colleges and universities, and proposes that the development of higher vocational colleges and universities will be led by the collaborative-innovation approach to lead the synergy of resources, promote the synergy of the main body to enhance the adaptability of vocational education, optimize the synergy of goals to achieve the comprehensive development of people, and reach the synergy of governance by digital transformation as the path to realize the innovative integration of multiple subject resources and the deep leap of the effectiveness of human education[9]. The last studying field is the policy research on the collaborative-innovation development of "three educations" based on the theory of multi-source flow. Zhou Zhiying analyzes the policy issuing of the integration of industry and education and proposes proper suggestions by using the multi-source flow theory [10]. Based on the perspective of multi-source flow theory, Han Tong analyzes the issuing process of "The Vocational Education Law" [11]. Based on existing research results, this paper integrates research perspectives, directions and methods of different scholars, and tries to analyze how the collaborative-innovation development of "three educations" has become a national decision-making on the basis of multi-source flow theory.

3. Theoretical Background

In 1984, American policy scientist John Kingdon put forward the theory of multiple streams in Agenda, Alternatives and Public Policy [12-15], which parenthesize the "back-room" operation in the process of policy making and effectively reveals the internal mechanism of policy introduction and change [16]. Multiple streams theory illustrates that the three sources of problems, policies and politics jointly contribute to the inclusion of public issues in the policy agenda. The source of the problem focuses on the identification and establishment of social problems, which is the process of attracting the attention of decision-makers. The source and flow of policy mainly involves the design and selection of policy programs, which is the process of the generation, discussion, redesign and attention paid to policy suggestions. Government officials, parliamentarians, academicians and interest groups form the "policy community" that advocates policy proposals. Political sources mainly involve the influence of political factors on policy agenda setting, which refers to the political process that has an impact on problem solving. When the three sources converge and open the "policy window", public problems are identified, policy programs are adopted, and policies are jointly promoted into the agenda setting to achieve scientific and effective policy making [17].

At present, the multiple streams theory is widely used in the policy analysis of education, health care, transportation, telecommunications and finance. This paper holds that the theory can also be used to analyze the decision-making process of the "three educations" cooperative policy in China. According to the practical policy of the "three educations" in China, this paper makes proper adjustment of the multiple streams theory and constructs a multiple streams analysis framework (Figure 1).

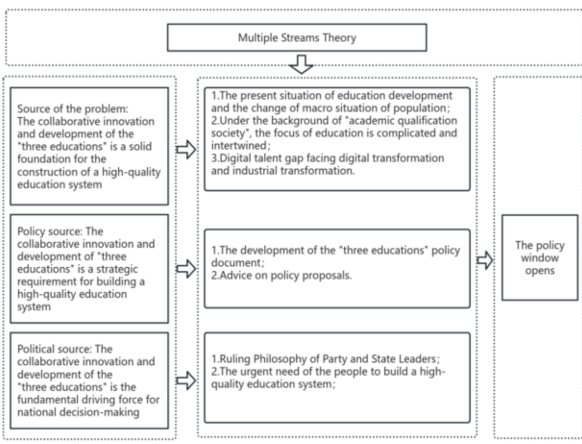

Figure 1 The Multiple Streams Theory analysis framework for the collaborative-innovation development of "three educations"

4. Methodology

The paper adopts the qualitative analysis method. Based on the systematic review of the relevant research literature on “three educations”, this paper summarizes the existing research results of scholars, extracts relevant viewpoints and argumentation materials, and makes a literature review. In addition, through searching on the official website to find relevant policy documents, the authors try to get more effective practical support for this research. By collecting relevant data and literature on the collaborative-innovation development of the “three educations”, the paper constructs a theoretical analysis framework of multiple streams theory, analyzes the problem source flow, policy source flow and political source flow, and concludes that the coupling of the three sources opens the policy window, and the collaborative-innovation development of the “three educations” becomes a national decision.

5. Multi-source flow analysis of the collaborative-innovation development of the “three educations”

5.1. Source of the problem: The existing education model cannot fully meet the demand for talents

5.1.1Key indicators: changes in the current state of education development and the macro demographic situation

On the one hand, the status quo of China’s education development has undergone fundamental changes, and the increase in the level of popularization of education at all stages has put forward a new development direction for the collaborative-innovation development of the “three educations”. At present, China has built the world’s largest education system, the level of modernization of education ranks among the world’s middle and upper ranks, laying a solid foundation for the construction of a strong educational country, and is committed to doing a good job of people’s satisfaction with education. From 2020 to 2024, the scale of college graduates grew from 8.74 million to 11.79 million [18]. At present, China’s higher education has entered the “popularization” stage. Scale extension of higher educational institutions mainly brings profits in fulfilling the talent gap, meeting people’s educational needs, and optimizing human resources allocation. However the extension often ignores problems of cultivation quality and employment difficulties incurred by lack of content construction, which is followed by a series of “supply and demand obstruction” phenomenon.

On the other hand, due to the changes of national population distribution pattern, there is the need for “three educations” synergistic innovation and development in order to improve the ability to cope with the situation. At present, China’s population macro situation mainly presents four characteristics: First, the total population is huge. “World Population Prospects 2022” made a prediction of China’s population: 2022 is the first year of China’s negative population growth, and it is expected that China’s population will be 1.416 billion in 2030[19]. Secondly, the aging of the population is aggravated, and as of the end of 2023, China’s population of 60 years of age and older is more than 290 million, accounting for 21.1% of the national population, of which 217 million are aged 65 and above, accounting for 15.4% of the national population [20]. Thirdly, the total population continues to grow negatively, with a very low fertility rate, and the scarcity of labor resources has intensified. The national population at the end of 2023 was 2.08 million less than that of the previous year[21]. The size of the population of the working age of 16-59 continues to shrink. In 2020, the average years of education for China's working-age population reached 10.8 years and this number is expected to reach 11.3 years by the end of the "14th Five-Year Plan", which means that the average level of education of the working-age population in 2025 in China will reach the level of education above the second grade of high school, which is of great significance for the construction of a modern country and the construction of an educational power[22].

5.1.2 Focus event: Under the background of "academic qualification first", the problem of education internal volume and resource mismatch is intertwined

According to Max Weber's theory of social rationalization, the rise of academic qualifications is an inevitable product of the development of capitalism and the construction of the modern hierarchical system. However, Japanese scholar Yakura Hisayoshi analyzed the drawbacks of the "academic society" in his book "Academic Society". On the one hand, focusing on academic qualifications has led to the one-sided development of students' learning and the intensification of the war of exams, which has made many students only sharpen their examination techniques without really improving their thinking power. On the other hand, when selecting talents, various administrative bodies and organizations only take scores as the order of priority, which is not conducive to the selection of genuine talents.

In today's society, excessive rivalry in educational background and mismatch of focuses have become complex and intertwined, with far-reaching impacts on the growth and development of individuals, as well as a severe test of the entire education system and talent cultivation mechanism. First of all, the problem of excessive rivalry in educational background has become increasingly serious. In the context of the academic society, academic qualifications have become an important criterion for evaluating the ability and value of individuals, which makes people pay more attention to the acquisition and improvement of academic qualifications. However, the excessive pursuit of academic qualifications and achievements has neglected students' actual abilities and all-round development, leading to the waste of educational resources and one-sided cultivation of talents. Secondly, the problem of mismatching focuses has also become more and more prominent. Specifically manifested in one is the unbalanced distribution of education resources, with too many resources concentrated on quality education; the second is that the education contents fail to meet market demand, individual growth and development; the third is the mismatch of education objectives, favoring knowledge transfer and test-taking ability, however ignoring the development of students' comprehensive quality and innovation ability. As a result, those problems lead to prominent contradiction between employment supply and demand in the labor market.

5.1.3 Demand feedback: The technological revolution has created a huge digital talent gap

The global economic landscape is undergoing profound adjustments. As the new round of scientific and technological revolution and industrial change is deepening day by day, digital technologies such as the big data, cloud computing, artificial intelligence and blockchain continue to make breakthroughs, and the importance of data resources as an emerging key factor of production is becoming more and more prominent, and it is profoundly transforming the social productivity and way of life. The 20th Party Congress emphasized that digital transformation and technological innovation have become important driving forces to accelerate the construction of a new development pattern and to promote high-quality development. The Industry Digital Talent Research and Development Report (2023) predicts that the scale of China's digital economy will be close to 16 trillion U.S. dollars in 2035, equivalent to 105 trillion yuan. Digital transformation is deepening in all industries, giving rise to a large number of digital and intelligent positions, and the demand for digital talents is surging. It is estimated that the current digital comprehensive talent gap is about 25 million to 30 million, and will continue to expand in the future, becoming a key element restricting the development of the digital economy [23].

5.2 Policy source: The collaborative innovation and development of "three educations" is a strategic requirement for building a high-quality education system

5.2.1 The previous policy has laid a solid foundation for the collaborative innovation and development of the "three educations"

Since the end of the 20th century, with the rapid development of China's economy and society, the demand for the quality of labor has been increasing, and the people's desire to receive education has become stronger and stronger. The state has successively issued relevant policy documents, which clearly put forward the requirements of "mutual convergence" and "mutual communication" between different levels and types of education, prompting the "three educations" to gradually move towards a new stage of mutual communication and convergence. In 1985, the Decision of the CPC Central Committee on the Reform of the Education System emphasized that the synergistic development of higher education and vocational education was aimed at optimizing educational resources and improving the quality of education [24]. In 1991, the Decision of the State Council on Vigorous Development of Vocational and Technical Education further put forward the idea of integrating basic education, vocational education and continuing education in rural areas to meet the demand for diversified talents for rural economic and social development, and to promote fair and balanced development of education.

Since the 21st century, the cooperation of "three educations" has been continuously promoted, forming the mode of adult education bachelor's degree of higher vocational colleges and undergraduate colleges and universities jointly cultivating higher vocational specialists, as well as the mode of jointly organizing the specialties of general undergraduate education in higher vocational colleges, and the mode of "3+4" through talent cultivation of intermediate and undergraduate colleges and universities, respectively. In 2022, the "Opinions of the Ministry of Education on the Implementation of the Reform of Continuing Education in the New Era of the Academic Qualifications of Ordinary Schools of Higher Learning" called for the promotion of the standardized, orderly, and healthy development of continuing education of higher education, in order to meet the demand for lifelong learning for all learning needs. At the same time, the Opinions on Deepening the Reform of the Construction of Modern Vocational Education System was launched to coordinate the synergistic innovation of the "three educations" and provide solid support for economic and social development and the comprehensive development of human beings. It can be seen that the integration of the collaborative-innovation policy of “three educations” is not proposed overnight. Each was independent of the others at first, and then came the connection and communication within them, and now the synergistic development of the three are proposed and updated in continual policies and documents. In the process of China’s “three educations” from independence to communication and then to the integrated and coordinated development, both the discourse system of education policy is constantly adjusted and updated, and the policy text is launched, so as to create favorable conditions for the collaborative-innovation development of “three educations”.

5.2.2 Policy proposals and suggestions help accelerate the introduction of policies

During the two sessions, various motions, proposals and suggestions entered the policy stream, promoting the collaborative-innovation development of “three educations” into the national decision-making process. By checking the information disclosure column on the official website of the Ministry of Education, it can be found that the Party and the State attach great importance to the collaborative-innovation development of the “three educations”, and members of the CPPCC have made suggestions and put forward hundreds of proposals on this topic. Those proposals include strengthening school-enterprise cooperation to promote the development of vocational education, the strategic transformation of continuing education in ordinary colleges and universities, and building a lifelong learning system through the coordinated development of the “three educations”, etc. It can be seen that CPPCC members play an important role in the flow of policies and their advice is an extremely important part of the flow of policies for the coordinated and innovative development of the “three educations”.

5.3 Political source: high-level attention and public demands are the fundamental driving force for the decision-making of "three educations" collaborative innovation and development

5.3.1 Party and state leaders attach great importance to the collaborative innovation of the three religions

As the core of the policy-making system, the important instructions of the Party and state leaders on the collaborative-innovation development of “three educations” is an important political element that drives the related policy agenda [25]. In 2014, the State Council promulgated the “Decision on Accelerating the Development of Modern Vocational Education”, which proposes to explore undergraduate vocational education, opening up new horizons in the development of vocational education; the report of the 19th CPC National Congress clearly pointed out that China’s economy has shifted from high-speed growth to a high-quality development stage, and the reform and development in the field of education have also shown a new trend; in 2019, the Implementation Plan for the National Reform of Vocational Education established vocational education on an equal footing with general education, and initiated a pilot project for undergraduate-level vocational education, which has injected new vitality into the development of vocational education; In 2020, the Fifth Plenary Session of the Nineteenth Central Committee of the Communist Party of China (CPC) explicitly proposed the construction of a high-quality education system, pointing out the direction for the long-term development of China's education; in 2021, the Education Law of the People's Republic of China was revised, emphasizing the implementation of a continuing education system, encouraging the development of various forms of continuing education, promoting the mutual recognition of learning achievements and articulation, and promoting lifelong learning for all; the report of the 20th CPC National Congress pointed out that the collaborative innovation of the "three educations" aimed at optimizing the positioning of the type of vocational education, and building a learning society with lifelong learning concept for all people; in May 2023, General Secretary Xi once again emphasized the coordinated development of the "three educations" in the fifth collective study of the Political Bureau of the CPC Central Committee, highlighting the importance of our country's development in the field of education and China's firm determination to promote the integration of vocational and popular education, the integration of industry and education, and the integration of science and education. The party and state leaders attach great importance to creating a favorable political environment for the collaborative-innovation development of "three educations" to become a national decision. And all the efforts aim to promote China's "three educations" from the state of independence of one another to the communication and connection stage and then into a new stage of coordinated innovation and development.

5.3.2 The people are calling for a quality, efficient and fair education system

When the government pays attention to specific issues, the main driving force behind these issues is that they have widely attracted deep concern of the general public. In the vein of political decision-making, national sentiment is regarded as the common concern and deep thoughts of the majority of the people in a country on the current issues, which is usually displayed in the form of public opinion and amplified by the mass media, thus influencing the basic framework and orientation of policy making. In China, the Communist Party of China (CPC) has always adhered to the principle of "people first", promoted education development with the people in mind, and is committed to building a high-quality education system that meets the needs of the people. From the point of view of China's actual socio-economic and educational development, "doing a good job of education to the satisfaction of the people" is mainly reflected in two aspects: one is to ensure a wide range of basic educational opportunities, and the other is to make the people satisfied with educational services through the allocation of scientific educational resources and the implementation of mechanisms. In the face of the current situation, it is necessary to accelerate the collaborative and innovative development of the "three educations", optimize the positioning of vocational education, promote the connotative development of higher education, and develop an open and flexible education system to meet the needs of individualized learning, and build a lifelong learning society for all [26]. In addition, the construction of a learning society and a skill-based society, and the improvement of the lifelong education system are also a positive response to people's mood and the fulfillment of their needs.

5.4 Coupling three streams: "Ensemble" opens the policy window

In 2023, the "Special Action Plan for Standardization Personnel Training (2023-2025)" jointly issued by the National Standards Commission and other five departments stressed that it is necessary to strengthen standardized general higher education, promote standardized technical vocational education, and promote the integrated development of vocational education and continuing education in the field of standardization. By promoting the communication and convergence between vocational education, general education and continuing education, it provides macro policy guidance and development guidelines for the integration of “three educations”[27], emphasizing that it is necessary to promote the coordinated development of various types of education through various ways, so as to achieve the goal of educational modernization and meet the needs of diversified talents for economic and social development.

6. Conclusion

Based on the perspective of the Multiple Streams Theory, and by constructing the analytical framework of the Multiple Streams Theory, this article explores why the collaborative-innovation development of “three educations” has become a national decision. In terms of the source of the problem, the contradiction between the urgent demand for compound and professional talents in economic and social development and the current single type of education has led to a series of problems. In terms of policy sources, policy documents and proposals for the collaborative innovation and development of the “three educations” continue to emerge. In terms of political sources, the governing philosophy of the Party and state leaders, as well as the urgent need of the people to build a high-quality education system, jointly promote the coordinated innovation and development of the “three educations” to become the fundamental driving force for national decision-making. The coupling of three sources “ensemble” opens a policy window, making the collaborative-innovation development of the “three educations” a national decision.

In the future, we will try to carry out more in-depth research from different perspectives. One is to focus on the application and challenges of new technologies in the field of “three educations” and explore how technology can effectively empower the “three educations” field under the background of new quality productivity. The second is to strengthen international exchanges and cooperation, pay attention to the comparative study of international “three educations” development, learn from international advanced experience and practices, and provide useful references for the development of “three educations” in China.

Although this study makes a qualitative analysis of the development of “three educations” from the perspective of multiple streams theory, there are still some limitations. This paper makes a qualitative study based on literature and real data, but the data source is relatively limited, and the empirical analysis is lacking. Future research can obtain first-hand data through questionnaires, in-depth interviews and other methods to improve the accuracy and reliability of the research.

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From Vision to Well-Being: A Functional Classification of Leadership Studies in Healthcare

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Abstract. Leaders provide a clear vision of what they want to achieve and set the overall direction for a company or team in order to be successful. More specifically leadership in healthcare is crucial for ensuring high-quality patient care, staff well-being, and the overall success of healthcare organization. This is especially challenging in healthcare setting where patients are considered as unique category of customers and sometimes physicians have dual roles as doctors and leaders. The aim of this research is to identify type of leadership studies conducted in healthcare setting. The methodology used was rapid review. The results show that there are three types of studies: studies with focus on transformational and transactional leadership theory in the healthcare industry, studies with focus on effectiveness of leadership in healthcare and studies related to contemporary leadership for change in healthcare. The abovementioned classification about leadership in the healthcare setting provide solid basis for recommendations about better informed choices and better coordination, streamlined processes, and ultimately, improved patient outcomes in the healthcare industry.

Keywords. Leadership; Healthcare; Functional Classification, Rapid Review

1. Introduction

In general, healthcare management deals with the quality of service and safety in healthcare. Scholars explain that management and organization of professionals in this sector rely on different approach from the one used by, for example, bureaucracies [1]. There is an ongoing debate whether leaders in the healthcare industry can improve service quality and patient satisfaction. Apart from that, there is less available research on leadership for change or providing better services. Scholars argue that factors such as leadership qualities and employee well-being are associated with their work under a complex relationship [2]. More specifically, these factors are strongly linked to the context. Difficulties faced by leaders, as individuals, in handling their workplace include informal and formal demands, low decision latitude, poor management support in

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everyday matters and unusual problems, as well as less opportunities to communicate issues or problems related to work to employees who were in charge of making strategic decisions. Leaders used strategies to maintain trust on horizontal or vertical level, e.g., make the position stronger through usage of different strategies (formal or informal), filtering communications, or through supporting or encouraging staff [3]. Further, it is argued that the leader's strategic involvement is usually linked to efficiency and quality in the provision of healthcare [4]. However, scholars have debated that usage of some of the mentioned strategies could be counter-productive regarding efficiency and making decision in organizations. It is highly disputable whether physicians have relevant management experience and knowledge and understanding of the clinic's activity as economic and financial interactions as these are not necessarily aligned with medical priorities. Apart from that, the relevant literature doesn't provide much information on empirical studies on leadership in healthcare. The purpose of this paper is to find out what kind of studies are present in literature on leadership in healthcare and to find a common denominator on grouping the abovementioned studies. Also, this is a contribution to existing knowledge by providing a new functional classification that can be used by researchers. At present, there aren't functional classifications of leadership studies in healthcare and clearly there is a gap that needs to be addressed. Having in mind all of the above-mentioned arguments, it can be concluded that leadership is a research challenge in the health sector. On the other hand, healthcare is very unique and different from other sectors, and researchers need to consider these points and focus on how leadership can help in improvement of services and patient satisfaction. Therefore, the purpose of the paper is to shed light on the role of leadership in healthcare. More specifically the research question aims to examine what kind of studies are conducted regarding leadership in healthcare.

2. Leadership in Healthcare

At the start it should be noted that the issue of health system leadership has not received significant attention in the literature. The health system usually consists of primary (everyday needs of patients), secondary (specialist intervention) and tertiary care (treatment of complex medical conditions). Scholars debate that management and failures in healthcare settings are not considered useful practices for organizational or leadership learning [5; 6]. On the other hand, it is important to acknowledge that lack of knowledge on how to improve leadership and management practices in health is evident [7]. Moreover, healthcare organizations are faced with different organizational and regulatory factors that make the leadership role even more different from that of managers or leaders in other areas. In that vein, [7] the author argues that, most often, these types of organizations, i.e. healthcare services, are facing fragile budgets and need for reallocation of more resources to provide the best care for patients. Unlike other customers, patients who use health services and receive information from healthcare professionals are considered a unique category of customers [8]. Therefore, the leadership role of healthcare professionals is observed as unique need for providing services to patients and controllers of management settings [7]. Moreover, the healthcare industry is considered to be lagging behind other industries in respect to leadership development practices and other human resource functions. On the other hand, the literature argues that healthcare leadership is considered a challenge in research methodology with tendency to be improved, especially as this sector is perceived as very unique and different from other concepts, necessitating researchers to consider these differences [9]. In particular, healthcare managers are faced with many interruptions, demands and non-constant work on management [10]. There are different proposed frameworks with the purpose of assessing the impact of the leadership in relation to organizational phenomena and culture. One study shows that focus on achievement and adaptability within the company culture directly improved performance [11]. Another study showed how different subcultures within an organization interact online, and how both internal and external audiences perceive the company's overall culture in this digital landscape [12]. Different studies confirm that conducting leadership research in healthcare is a very useful and important segment [13]. Apart from these aspects (managing complex healthcare organizations and supporting their transformation into environments conductive to good leadership), it is vital to preserve the work-related health of the leaders. Hence, leadership skills are key psychosocial factors for sustained work-related health among healthcare workers, both among physicians and nurses [3]. In a nutshell, it can be concluded that research on leadership in the healthcare sector has concentrated on issues like role of leadership as predictors of different patient results, burnout, satisfaction or keeping different profiles of health employees, and focus on changes in institutions. [14]. The studies mentioned before acknowledge the complexity of healthcare systems (primary, secondary, and tertiary care) and the distinct challenges faced by healthcare leaders compared to other industries. A common theme is the importance of leadership styles that prioritize patient care and well-being. Also, there are unique organizational and regulatory factors and specific leadership challenges in healthcare (interruptions, demanding workloads, and interaction of different stakeholders). Despite the above-mentioned challenges, the studies agree that leadership research in healthcare is crucial and has the potential to improve performance, patient care and organizational culture. These studies point to the need for leadership models specifically designed for the complex and demanding healthcare environment. Effective healthcare leadership requires balancing patient care, resource allocation and navigating unique organizational structures. This includes the need for leadership styles that are adaptable and innovative and hence the proposed classification will contribute for this purpose. Having in mind that there are many different aspects related to the leadership studies in the available literature, the hypothesis is that there will be different patterns of topics regarding studies that examine leadership in healthcare.

3. Methodology

The methodology employed for this study was rapid review. Rapid review is a simplified systematic review in order to produce timely results [15]. This methodology was chosen because it is transparent and offers focused approach about the specific research question within a broader field. This focus can help to ensure that the included studies are directly relevant to the question at hand, increasing the validity of the review's findings. The majority of papers were collected through Google Scholar for the period of 1987 till 2019, before emergence of COVID. The key reason for this is that there was a specific and different leadership in healthcare during and after COVID. Part of the data were collected in 2022, while the other part and analysis were carried out in April 2024. For this purpose, a several inclusion criteria were used. The inclusion criteria focused were the following: a) Papers written in English language; b) Empirical studies that cover leadership as a primary research topic and managerial target group c) Research exclusively conducted in healthcare setting.

Apart from the inclusion criteria, papers related to leadership in healthcare education were part of exclusion criteria, as well as case studies as they focus on specific organizations. The following terms or their combination were used as search words: leadership, leaders, healthcare, patients, medicine, health and health system. A total of 15 studies were included at the end in the analysis. The analysis sought to identify the type of studies about leadership in healthcare. The classification of type of studies was done through inductive approach (a posteriori) based on the available topics assessing their similarity or relationship to other emerged topics. The main idea that emerged during the process of creating the classification was the purpose of study. Therefore, the authors decided to call the classification functional as it depicts different periods and aims. The first step was identification of the function of leadership studies. In this case three types of studies emerged: studies which supported and explored traditional and transformational approach, studies related to skills/effectiveness of leaders, and studies about organizational changes in healthcare. The next step was to categorize studies based on the leadership function they addressed within the healthcare context. The results (classification of each study) are presented in the next part.

4. Results

In this section, the results of the study are presented. Apart from that, various theories and concepts that were identified are discussed. The results from this examination identified three set of studies: studies about traditional and transformational leadership; studies related to skills and effectiveness of leaders in healthcare and the last set of studies deals with contemporary leadership for change. The results are in line with proposed hypothesis about different patterns of topics in leadership studies in healthcare. The grouping of studies provides a new functional classification of leadership studies in healthcare. While research on leadership in healthcare is limited, the inclusion of older studies alongside those meeting our specific criteria offers a valuable long-term perspective. This provides view on evolvement on leadership practices, while identifying core principles that remain relevant in today's healthcare landscape. The results outlined in the proposed classification as outcome of the study are given in the table below.

Table 1. Functional classification of leadership studies in healthcare

Classification of studies	Specific studies
Studies about traditional and transformational leadership in healthcare	Bass (1995); Lowe et al. (1996); Gellis, (2001); Bagheri, 2018.
Studies about skills and effectiveness of leaders in healthcare	Brown and McCool, 1987; Dienemann and Schaffer, 1993; Helfand et al., 2005; Alexander et al., 2001; Upenieks, 2002; Upenieks 2003; Gilmartin et al., 2007.
Studies about contemporary leadership for change in healthcare	Martin et al., 2015; Pearce and Conger, 2003; Bligh, 2017; Llewellyn, 2001

The first round of studies generally shed a light on transformational and transactional leadership in the healthcare industry. These studies were conducted in hospital settings and used data collected from nurse managers and nurses. According to Bass [16], research studies modelled on transformational leadership in healthcare organizations showed that transformational leadership falls across organizational levels and studies found that managers who had higher position in the hierarchy demonstrate more transformational behaviours than managers who were lower in the hierarchy [17]. Nonetheless, it is argued that Bass transformational leadership model is appropriate to healthcare settings. As noted by other authors [18], such a model is applicable to leaders in non-profit organizations. Apart from that, the organizational structure and culture played a great role a great deal, while the proposed model mattered when it comes to change resistance among staff members. One study found that leadership model showed an association with the leaders' use of contingent reward systems, whereas the use of such systems in non-healthcare studies is linked to transactional leadership style [19]. Another study conducted among medical professors at Imperial College in London, shows that leadership styles are related to typical measures of academic performance (publications and citations), while correlated to transformational leadership style [20].

The next (second) set of studies focuses on examining the best skills for effective leaders among physicians and training programs to implement and develop such skills. Main methods of investigation were surveys among healthcare practitioners [21; 22]. These studies demonstrate effective leadership competences in seven areas: (a) interpersonal relationships; (b) communication; (c) finance and business acumen; (d) clinical knowledge; (e) collaboration and team building; (f) change management; and (g) quality improvement. Another study argues that managers with advanced education are more effective in leadership roles [23]. A similar study shows a very relevant point that new managers value different competencies unlike more experienced managers, especially with new nurse managers who demonstrate very good communication skills [22]. Similar to these studies, the set of studies on leader effectiveness mostly used qualitative methods which examine attributes, behaviours, and values of leaders who were effective [24; 25;26]. Scholars argued that these studies on leadership effectiveness very fairly support theories on the importance of leaders in healthcare settings who provide vision and performance standards while ensuring quality of care and being flexible in their approach [13].

The third set of studies focuses on contemporary leadership for change. In particular, the idea behind distribution of leadership and further empowering of experts throughout the system may be seen as answers to some criticism targeting traditional leadership [27]. Scholars recognise different options of distributed leadership, including shared leadership [28], team leadership and "followership" [29]. Moreover, two dimensions are identified. These two dimensions that distinguish distributed leadership from other forms of leadership are: concretive action and conjoint agency. According to the literature on contemporary leadership for change in healthcare, performance affects the work of managers. Research scholars have labelled it as "two-way window" for experienced leadership role of clinical professionals, in the sense that clinical leaders concurrently work with ideas from both their clinical and managerial work [30]. However, their clinical competences are valued more highly than their financial management competencies, and this can result in vulnerable position for leaders.

5. Conclusions

The importance of leadership in healthcare comes from the perception that healthcare is perceived as one of the largest industries and largest employers. Healthcare still poses a challenge in the literature in terms of advancing knowledge and effective leadership, especially in respect to theories of leadership and organizational management [31; 32]. As illustrated by Gilmartin et al. [13], scholar literature focuses on: transformational and transactional leadership; leadership and nurse job satisfaction, retention and performance, leader effectiveness, and leadership development programs. The outcome of this study is a classification of studies in three different types: studies about traditional and transformational leadership; studies related to skills and effectiveness of leaders in healthcare and the last set of studies deals with contemporary leadership for change. The new functional classification is a novelty in leadership studies and as such provides solid ground for future researchers on leadership. The limitation of this study is that it includes studies that deal exclusively with leadership in healthcare and it is not a systematic review. Another limit is the lack of current studies (studies only in certain period), but the gain was new classification and the study was related to the specific examined timeframe. Future research studies should include studies in other industries and studies that do not include leadership in healthcare directly. Another important point for future studies is usage of the proposed classification as a starting base in the research on leadership in healthcare and other different industries. The value of this study is reflected in the new proposed classification which can help researchers when they plan their future studies. The results can be used as input into analytical approach when operationalizing potential topics that managers would like to test [33]. This approach fits to statements made by certain authors [34] that visionary leadership paves the way for the future of organizations. Another application of the classification is to assist leaders through raising awareness about the different approaches. This is especially important as organizations nowadays increasingly embrace instant messaging as real-time communication with key clients [35]. Healthcare landscape is constantly evolving, with new technologies, regulations, and patient needs are emerging and evolving. Strong leadership is essential for navigating these changes and making sound strategic decisions. Leaders can improve coordination and processes and make informed choices to ensure the organization remains competitive and adaptable while keeping patient satisfaction high. Strong leaders set clear goals for patient care, thus creating a vision which ensures that everyone is on the same page in delivering the best possible healthcare service.

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Vision Versus Trust in Healthcare: Qualitative Study About Identification of Leadership Types in N. Macedonia

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Abstract. Leaders play a vital role in healthcare because of constant industry changes. Identification of leadership types is of crucial importance as it can improve organizational culture and patient care. The methodology used was qualitative research. A total of 4 interviews conducted in both private and public healthcare institutions. The transcripts from interviews were analyzed using the software Atlas.ti to identify inductively and deductively emerged codes. The results show that there are two types of leadership types: leader focused on vision and leaders focused on trust. The findings of the study offer important insights from healthcare professionals about future leadership programs, improving care quality, and managing changes in healthcare. They highlight the need for leadership programs that focus on vision and trust, crucial for reshaping organizational culture. Vision guides where organizations should aim, while trust in people is key for managing these complex changes. Application of these insights can help healthcare organizations build a leadership culture that adapts to healthcare changes and improves effectiveness and patient care at the same time.

Keywords. Leadership; Healthcare; Vision, Trust, Types, N. Macedonia

1. Introduction

Leadership theoretical concept is multifold based on traits, styles, contingency perspective and other aspects. The scholars link the leadership phenomenon to the organization management. Yet, nowadays there is a need of more than being a traditional manager in order to become competitive on the global market. Thus, leadership is a crucial factor to sustain as a successful company [1]. On the other hand, some authors [2] argue that leadership is a process and a characteristic, where the process is delineated as usage of influence to direct and coordinate people for certain goal in one group; whereas the characteristic is a set of qualities with the ability to influence subordinates in order to perform the activities successfully. Exploring leadership is important because leaders are the ones who set the tone in one

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organization. Abovementioned viewpoint affects the quality of outputs, patient care, safety and organizational success. This is especially important in healthcare as a unique and specific industry because it deals with health which is the most important aspect of human lives. As such healthcare leaders make a significant impact on the health and well-being of communities. At the moment there are a lot of leadership studies in different disciplines, but there is a lack of leadership studies in healthcare. Apart from that there is a lack of research in general which is conducted in the context of N. Macedonia. In order to address this gap, the authors carried out the study to explore which leadership styles are present in healthcare industry in the country. The next part focuses on theoretical aspects of leadership in healthcare.

2. Theoretical background

There are different types of leadership examined in the literature. When it comes to different types of leadership in healthcare, the literature review revealed the following types: transformational, transactional, dynamic, servant and complexity leadership [3]. Other authors [4] analyzed the top 100 most influential articles for three leadership styles using a method called bibliometric analysis. They searched the Scopus database using different keywords like "leadership" or "leadership style" along with "transformational," "transactional," and "complexity." The articles were ranked by how many times they had been cited. The authors calculated the median citation values for each search and used a statistical test called Kruskal-Wallis to check if there were significant differences in citation numbers among the three styles. They also looked at the total number of results for each keyword and calculated how often articles were cited relative to the total results. The findings suggested that complexity leadership was more popular in academic interest compared to traditional styles focused on rewards or simple motivation. This supports the idea that complex concepts, like leadership in organizations, can't be explained by straightforward cause-and-effect models. Instead, they require more flexible and detailed leadership approaches.

Another study [5] aimed to see if different ways of leading in healthcare affect how well patients are cared for. Researchers searched for information in the Medline and EMBASE databases from 2004 to 2015. They wanted to answer the question: "Does the way leaders behave in healthcare affect how good the care is?" They found eighteen articles that were useful for answering the specific question of interest. The research showed that leadership styles strongly connect with how good the care is and other related measures. Good leadership was seen as crucial for making sure care is well-organized and works smoothly for patients and healthcare professionals.

Some authors [6] stress that usage of good leadership methods like democratic and transformative styles leads to better results throughout organizations. Learning these skills is helpful for medical professionals no matter how long they've been working. They can learn these skills through mentoring, formal classes, workshops that focus on specific areas and detailed tests that match their personality. Their conclusion is that in order to make sure healthcare professionals become good leaders, it's important to spend enough time and money on training them. Additionally, as it was noted in one paper [7] leadership training should be included in the education of all healthcare professionals. A new kind of leader is becoming more common: someone who shows how to balance independence and responsibility, stresses teamwork, and aims to make patients better. Leaders in healthcare education need to cooperate well across different fields and organizations, even when their job titles don't directly imply leadership.

Other authors [8] write that although leadership has been widely studied in medicine and nursing, but research in physiotherapy is limited. Therefore, they conducted a study with aims to explore and analyze existing research on leadership qualities in physiotherapy. The researchers conducted a scoping review following PRISMA guidelines, examining databases like MEDLINE, Cochrane Library, PEDro, Embase, CINAHL, Web of Science, and Scopus from January 1, 2000, to June 30, 2022. They included quantitative studies that addressed leadership characteristics in physiotherapy. The results were analyzed using Bolman and Deal's framework for leadership studies. From eight studies reviewed, physiotherapists were found to highly value characteristics such as effective communication, a commitment to continuous learning and improvement, credibility, and professionalism. Their conclusion is that leadership is crucial in physiotherapy, with professionals accenting the importance of having vision and leading change within their profession. Other qualitative study [9] used a qualitative approach called phenomenology (recorded and fully transcribed semi-structured interview) in order to investigate the leadership roles in physiotherapy. This study aimed to explore the leadership styles used by physiotherapists who lead teams, focusing on the challenges they face and the strategies they use to overcome these challenges. The research took place at a large National Health Service Foundation Trust in Northeast England. The target group was composed of team leaders from the field of physiotherapy, chosen intentionally based on their roles. The results proposed a theoretical framework of leadership that highlights the daily struggles experienced by physiotherapy team leaders as they balance between transactional and transformational leadership styles. Within this framework, three main themes emerged: individual challenges, team dynamics, organizational factors, and broader influences. The results suggest that senior leaders should support clinicians in developing more transformational leadership styles, which could enhance staff well-being and patient care.

A systematic meta review on leadership [10] in hospitals looked at various ideas about medical leadership, including what doctors do and what roles different types of medical leaders have. Methodology included PRISMA guidelines and searched seven databases to find articles published from February 1, 2017, to July 20, 2020. They found a total of 685 articles and narrowed it down to 432 relevant ones. Finally, they selected eight articles that ranged from quantitative studies to systematic reviews. Their results show that most of the studies they looked at were systematic reviews that covered healthcare situations around the world. The finding stress that found that type 1 medical leadership was most common. This type refers to doctors who currently have leadership roles, like managing medical teams or leading medical departments. The review identified several challenges that medical leaders face, such as unclear roles, lack of support and time, and dealing with different priorities in hospitals. The conclusion is that these factors influence how medical leaders carry out their responsibilities in specific contexts.

In recent studies on healthcare leadership, various leadership styles such as transformational, transactional, servant, dynamic, and complexity leadership have been explored. Some of the analysis revealed that complexity leadership is gaining more academic interest compared to traditional styles focused on rewards or simple motivation. Research shows that leadership styles strongly influence the quality of healthcare and organizational outcomes, emphasizing the importance of effective leadership in ensuring well-organized patient care. Studies also highlight the need to integrate leadership training into healthcare education to cultivate leaders who promote teamwork and patient-centered care, even in roles not traditionally associated with leadership. Apart from that, training in democratic and transformative leadership methods is seen as beneficial for improving healthcare outcomes and therefore investment in leadership development is important for healthcare professionals. Having in mind the importance of leadership in healthcare, the aim of this paper is to examine what kind of leadership types are present in the healthcare setting in N. Macedonia.

3. Methodology

The research was conducted in July, 2019 in 2 health care organizations in Macedonia. The researchers used "semi-structured interviews" for this research. In the interviews, open-ended questions were asked that allowed the participants to provide more detailed information. Also, the "probing" technique (asking follow-up questions to get additional details and information from the participants) was used during the interviews [11]. The researchers first tested their interview questions with other healthcare leaders and organizations in the local area. This helped them improve the questions before conducting the actual interviews. The questions from the interview tool addressed organizational culture, motivation, business strategy and leadership. The duration of the interviews was around an hour on average. Before the start of the interview, participants were briefed about the purpose of the study and informed consent was obtained. In order to protect the privacy and confidentiality of the study participants, the researchers did not use the participants' real names in the transcripts of the interviews. Instead, they assigned each participant a made-up name (pseudonym). Using the approach, the interview transcripts could not be connected back to any personal information about the individual participants. Their identities were kept confidential. The qualitative research included a total of 4 interviews conducted in both private and public healthcare institutions. A qualitative research method was chosen because there is not much existing research and at the same time the study would shed a light on nuanced aspects in the relationship between organizational culture and leadership concept in a health care setting. Apart from that, qualitative research allows for in-depth exploration of experts' and organizations' perspectives on leadership development, which would be difficult to capture quantitatively [11]. Participants reflected on their opinions and perceptions on leadership phenomena in health care organizations, thus including their opinions in the research process. Health care providers were included in the study because their voice is valuable and influences management and leadership.

This study was explorative which enabled to detect the perceptions and opinions of healthcare providers. Another relevant issue to our qualitative approach is the acknowledgement that researcher is not the expert and his perceptions represent one amongst the rest [12]. Purposive sampling was used in order to reach health care providers from primary health care level. This type of sampling aims to recruit individuals who can provide valuable insights and data for the study. The participants were selected based on specific criteria that were relevant to the research question. Participants were purposively selected, while the process was based on the reputation each participant had in the healthcare industry. The first criterion was the participant to be a doctor who is in managerial position now or had one in the past for at least 3 years.

Another aspect was to have held at least two different leadership positions (e.g. different levels or different organizations) in the past. Some of them included membership at professional associations, consultancy, positions at different providers and teaching positions at university.

The researchers used a qualitative data analysis software called Atlas.ti analyze the interview transcripts. A method called constant comparison is used to inductively identify emerged codes. In the next step, the researchers grouped related codes together into "code families" and looked at how the code families were connected to each other. This helped them identify the main themes (Vision and Trust) related to leadership in healthcare organizations in North Macedonia. The coding process occurred in two main cycles. First the researchers identified codes from the interviews based on the study aims and started with inductive codes. Later, codes were compared and a structure for the codes was developed. This back-and-forth iterative process allowed the researchers to explore the themes that came up in later interviews. This approach enabled the researches to see how ideas evolved and were connected across the data.

4. Results

The results of the study showed that two main themes emerged related to the challenges of leadership development in healthcare organizations. The researchers later discussed these two themes with the study participants. This helped confirm that the themes accurately reflected the perspectives and experiences of the people involved in the study. In other words, the participants agreed that these two themes captured the key leadership development challenges faced by healthcare organizations.

Verbatim quotations shown in next paragraphs have been selected as a representative quote from the data. The two distinct topics were: Vision oriented leader and Trust oriented leader. The next part will show vision-oriented pattern first, while the second part will be about trust oriented leader. Part of the answers which show visionary leadership re reflected in the following quotes:

“A leader is someone who has the bigger picture and creating new planes for the work”. He/she has to be with “political” skills and to know how to manage people around, to know how to cooperate with the others, [...] to have developed network with relevant organizations”.

As vision’s leadership is very dominant medium, not just a simple message or perception, the participants reported that one leader with a vision needs to make changes in the health care system. Other quotes are shown below:

“*The leader has to be part of the changes in the health care system”.*

“Leader uses vision to gain the support from various groups, which encounters in the daily work, and the need for a leader with a vision in health care settings, is recognized with a priority. “

“*A leader is someone who has a vision and sees the big picture”.*

Regarding vision-oriented leader, most of the managers noted that vision is a must for this type of leadership and should be accompanied with changes. This view for the leader in the health care environment is very consistent and relevant for a complex health care organization with its multi departments and practices.

Trust oriented leader was the second theme that emerged across study participants and it was about the traits and characteristics of the leader. Part of the answers which show trust are based on the following quotes:

”Good management skills and very important for someone to be the person of trust, a trust from the employees”.

“Leaders with trust plays important role in gaining good quality of services”

“Leaders must play important role in gaining trust among the colleagues and also by the patients or clients.”

Based on the interviews, the researchers found that healthcare organizations are not the only type of organization that faces leadership development challenges. However, the healthcare organizations that participated in the study often made comments indicating that they face particular difficulties in this area, such as:

“In a specific area that we work in, trust is of utmost priority among all stakeholders in the system. This starts from patients, doctors and goes all the way up to top managers”.

The conclusion from this part is that managers that were part of the study were more prone to be able to build leadership with trust and to promote it within the counterparts.

5. Conclusions

The overall findings of the study, including the main themes that emerged, suggest that leadership in healthcare organizations requires a somewhat different set of perspectives, orientations and skills compared to leadership in traditional organizational structures. The study indicates there are unique aspects to leadership in the healthcare field. A good and effective leadership under these conditions distinguishes the need for appropriate balance—between interpersonal trust and vision-oriented leadership. In conclusion, this study has identified two significant types concerning leadership development challenges within healthcare organizations: vision-oriented leadership and trust-oriented leadership. Regarding vision, research clearly shows the link between clearly articulated vision and performance [13]. Having in mind the findings of this study it can be concluded that vision is of critical importance and leaders who possess a clear vision have the ability to conceptualize the broader goals of delivery in healthcare systems. Apart from that, the participants emphasized the necessity for leaders capable of navigating the complexities of healthcare environments, creating strategic partnerships, and thus creating impactful change. On the other hand, the study highlighted the other essential role of trust-oriented leadership in healthcare settings. Participants stressed the importance of leaders who demonstrate integrity, transparency, and the ability to build trust among colleagues and different stakeholders. The concept of trust was seen as foundation for creating and sustaining a supportive work environment which supports service quality as a crucial factor in the delivery of effective healthcare. There are many studies which accent trust as foundational element and crucial for leadership [14, 15]. Apart from these findings, the study of Top et al. [16] revealed that organizational trust and job satisfaction, specifically in terms of rewards and communication, were strong predictors of organizational commitment. The conclusion is that trust is needed for voluntary followership which contributes to success and openness for change. On the other hand, according to Kitch [17] it is essential for leaders in healthcare to develop healthcare systems that prioritize patient-centered care by ensuring a seamless, coordinated approach through vision across all levels of treatment. The impression is that both topics sometimes overlap and therefore it is crucial to further examine the mechanism between vision and trust in future studies.

Overall, both themes reflect the multifaceted nature of leadership in healthcare, where both visionary insight and interpersonal trust are integral to organizational success and provision of high-quality care. Future leadership development efforts in healthcare should consider these findings to cultivate leaders who can effectively navigate the complexities of the industry while inspiring trust and collaboration among diverse stakeholders. Apart from these main results, the exploratory study finds that healthcare organizations experience major challenges in creating and building leadership in health care environments. This study is the first of its kind which focuses on evaluating attitudes and perceptions of health care professionals about leadership in N. Macedonia. The overall study provided several important points regarding healthcare. Firstly, data were collected from manager profiles who were also working as physicians in the health care organizations in order to gain rich perspectives about the organizational culture. This paper provides rich material from the health care professionals to understand better organizational concept in assuring quality of care and the importance of the context in leadership and management studies. Quality of care and services are reflected on the micro level of one context and this is where the two specific types of leadership play a role. The limitations of this study are that it is focused on healthcare and only within two health organizations. Future studies should include identification of leadership types in different organizations and industries and should examine the link between vision and trust. Apart from that quantitative studies can be used to confirm the findings. Another study could combine findings from this study with a proposed framework for managers [18] regarding decision making related to safety. Nevertheless, the results of the study provide valuable insights from professionals' perspective on future healthcare leadership programs, organizational culture, quality of care and change management. The results are useful for creating leadership development programs with focus on vision and trust and these should be the aspects to tackle when reinventing organizational culture. The role of leaders is a paramount in managing healthcare organizations because there is continuous change in the industry and as such vision (where to go) and trust (human capital) is crucial for change management (implementation of new technologies, organizational challenges, communication for change). The application of the abovementioned recommendations in healthcare settings can help healthcare organizations create leadership culture that can address the continuous changes in healthcare and this ultimately will improve organizational effectiveness and patient care.

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The Role of Organizational Culture in Healthcare: A Rapid Review

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Abstract. The paper examines the concept of organizational culture within the healthcare sector. Inspired by different compelling evidence in management literature, the authors explore the link between the organizational culture in healthcare and different theoretical concepts. The purpose of this paper was to investigate the function of organizational culture in the healthcare industry through a rapid review of the literature in an attempt to determine the links between culture and other concepts within healthcare. The review identified 20 relevant studies, focusing on research directly related to healthcare. The conclusions from the rapid review shed light on the role of organizational culture in healthcare ultimately revealing its importance as a success factor for healthcare organizations. There are three types of studies which examine organizational culture in healthcare: studies related to performance, consequences for employees and studies which describe different cultures. The study suggests that healthcare organizations should focus on understanding organizational culture and its various types and consequences. These aspects are crucial for improving the well-being of both patients and healthcare professionals. By promoting an environment where healthcare professionals feel valued and supported, organizations can enhance patient care outcomes, reduce stress, and improve overall organizational efficiency.

Keywords. Organizational Culture; Healthcare; Rapid Review, Wellbeing, Topics

1. Introduction

An organizational culture in healthcare is a topic which has not received much attention in the existing literature. Having in mind that healthcare is a specific industry and patients are specific clients where health as the most important aspect of their lives is treated. Organizational culture does play a role in overall quality of each specific health system and therefore this paper aims to explore further the role of organizational culture in the healthcare sector. In the words of Shanafelt et al. [1] US physicians have faced significant changes in the past decade. Many feel that the healthcare system hinders rather than

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facilitates high-quality care. While physician distress and its causes are well-known, much of it stems from underlying cultural issues within the medical profession, healthcare organizations, and the healthcare delivery system.

The first part starts with defining organizational culture and continues with different areas which have examined the link between organizational culture and employee attitudinal outcomes like performance, commitment and satisfaction. To begin with, Schein defines the organizational culture as a set of beliefs, values, behavioral patterns, and assumptions shared by members of an organization. Studies have shown that a positive organizational culture is a crucial factor that not only fosters employee satisfaction and well-being, but also improves their overall performance [2]. Additionally, the organizational culture results in positive outcomes for the healthcare service delivered to patients, namely in terms of the overall experience, satisfaction, and sense of security felt by the patients [3]. Another study shows that emotions and attitudinal outcomes such as organizational commitment are related to safety at work [4]. Liu et al. [5] conducted a study to test the effectiveness of a tool designed to assess organizational culture in primary health in Ethiopia. They believed that organizational culture is a significant factor in healthcare system performance and outcomes. Based on theoretical principles, they identified five key domains: learning and problem-solving, psychological safety, resistance to change, time for improvement, and commitment to the organization. The resulting scale offers a broader perspective on organizational culture compared to the narrower safety culture measures commonly used. While the study has not yet evaluated the tool's ability to predict primary healthcare system performance, the importance of organizational culture in shaping performance is well-established. In another study, Cameron and Quinn [6] categorized organizational culture in healthcare into four distinct typologies: Clan, Adhocracy, Market, and Hierarchy. Each category possesses distinct attributes and consequence. Each culture type has implications for organizational behavior, employee engagement, and overall performance. Understanding these cultural dimensions can help leaders and managers align their organizational strategies, structures, and practices to achieve their desired outcomes in different contexts and environments. The critique of this study is that it is a rigid categorization and that this four-type model might oversimplify the complex and multifaceted nature of organizational culture. The model does not capture the subtle variations and nuances within each typology.

The literature provides some empirical evidence that certain factors of the organizational culture could be considered as crucial to healthcare quality [7]. Apart from this, various scholars have examined the concept of organizational culture and possibility to impact performance and services of an organization, i.e. healthcare organization [8–10]. The connection between organizational culture and patient satisfaction is well-documented. Extensive research in the United Kingdom and the United States has demonstrated how organizational culture influences both patient satisfaction and healthcare performance[11]. Similar studies have been conducted in China [12, 13] and Greece [14], further highlighting this link. Despite the numerous cultural layers within the healthcare sector, there are fundamental human values that are universally shared. These values, such as empathy, respect, and compassion, serve as a crucial common ground when discussing organizational culture in healthcare. Recognizing and emphasizing these shared values can provide a solid foundation for fostering a positive organizational culture that transcends cultural differences. Research supports this notion, indicating that when healthcare organizations prioritize these core values, they can enhance both patient satisfaction and staff well-being [15, 16]. This further supports the idea that fostering a strong organizational culture in healthcare is essential. The abovementioned researches summarize the existing literature on the relationship between organizational culture and healthcare quality. However, these studies did not explain the mechanisms and factors which underlie organizational culture and how they are empirically linked to healthcare outcomes. Additionally, some of the potentially mediating or moderating variables that may influence the relationship between organizational culture and patient satisfaction are not tackled.

The previous studies examine organizational culture in healthcare and its link to different employee outcomes. As some of the results show, there is a correlation between a positive organization culture and employee success, encompassing job satisfaction, engagement, commitment, and along with voluntary effort for better performance in the organization. The main reason for exploring organizational culture are the arguments made in available management literature on the link between organizational culture and patient satisfaction [11]. Moreover, it is important to highlight that employees in the health sector come in a variety of forms, including administrative, technical, and health employees. These employees have varying perspectives of the organizational culture within the health sector, which can have an impact on their job satisfaction and performance [17]. Another important angle for conducting the study is that the majority of studies that explore organizational culture have been extensively explored in business-related research, using a variety of research methods. Therefore there is a need for summarizing main concepts related to organizational culture in healthcare settings. While many studies have explored the connection between organizational culture and employee outcomes, the underlying mechanisms remain unclear. This knowledge gap presents an opportunity for further research. To address this, the study aims to identify specific topics related to organizational culture in healthcare that can contribute to our understanding of this complex relationship. The research question focuses on exploring the links between organizational culture and various interrelated topics that have been discussed in existing literature.

2. Methodology

The research technique employed in the paper is a rapid review. Rapid reviews are a form of knowledge synthesis in which components of the systematic review process are simplified or omitted to produce information in a timely manner [18]. Rapid reviews offer a faster and more efficient approach to traditional systematic reviews. They are particularly useful when healthcare decisions need to be made quickly. These reviews summarize evidence in a way that is easily accessible to decision-makers, promoting evidence-based decision-making[19]. The goal of this rapid study was to analyze existing research on organizational culture in the healthcare sector. The research question aims to determine the role of organizational culture in healthcare. The identification of the studies was done through inclusion and exclusion criteria. The inclusion criteria focus specifically on studies written in English which examined the link of organizational culture in healthcare to other concepts (meaning there was an empirical study). The focus was on literature published in English between 2007 and 2022 covering a span of 15 years. The majority of papers were collected from Google scholar database. The search strategy was based on several words which were used alone or in combination. The used key terms were: "organizational culture", "healthcare", "health" and "culture". On the other hand, exclusion criteria were related to studies about organizational culture in other industries (not related to healthcare at all). For example if a paper was found to be exploring organizational culture in marketing, it was not taken into account. Regarding study selection, articles were eligible for inclusion in this review if there was an empirical research that explored the link between organizational culture and healthcare. The rapid review identified 20 papers and they are presented in the next part of the paper. The analysis focused on identifying which key topics are linked to organizational culture in healthcare. By grouping related topics and assigning "code families," the researchers were able to identify the three main topics presented in the results section. The overall conclusions are based on a comprehensive review and synthesis of existing research on organizational culture in healthcare. The analysis aims to discover which concepts are related to organizational culture in healthcare, while the hypothesis is that organizational culture in healthcare is linked to several different topics.

3. Results - Review of Organizational Culture in Healthcare

The findings reveal three interconnected topics: organizational culture and performance, culture and employee outcomes, and studies describing different types of organizational cultures. Three were eight studies identified in the first group, seven in the second and five in the third group of topics. The study's conclusions, summarized in Table 1, are centered on these three topics.

Table 1. Topics related to organizational culture in healthcare and explored studies

Topics	Study of interest
Organizational culture and performance.	Sen et al., 2022; Genc, 2017; Ortega et al., 2015; Rovithis et al., 2017; Pilav and Jatic, 2017; Zahra et al., 2012; Aharbi et al., 2014; Carney, 2011
Organizational culture and consequences for employees	Williams et al., 2007; Stone et al., 2007; Mijakoski et al., 2015; Szara et al, 2018; Kourakos and Kafki, 2019; Shanafelt et al., 2019; Sow et al., 2017
Types of organizational cultures	Oveseiko and Buchan, 2012; Minvielle et al., 2008; Mesfin et al., 2020; Shurbagi and Zahari, 2014; Hung et al., 2016

The first group of studies explores the link between organizational culture and performance, productivity and quality of care. Rovithis et al. [20] illustrate that the theoretical model about the “operating cultures” of organizations is not supposed to have direct relationship with their values nor should have influence from the missions and paradigms. Nonetheless, emerging norms and expectations could be influenced by many factors in the organization's structures itself, system patterns, as well as by skills of employees and their experiences. Still, the authors conclude that a detailed analysis of the organizational culture within a specific organization or health system is essential to identify the type of established culture, and what kind of influence that culture has on objectives and performance, and additionally to flag next improvements. To understand the experiences of frontline healthcare workers in India, researchers Sen et al. [21] conducted a study involving 22 prominent healthcare organizations. These organizations were chosen at random to ensure a representative sample. The study relied on responses from 358 frontline employees, providing valuable insights into their perspectives. The results suggest that building a superior culture is a key to maximizing patient satisfaction and ensuring the organization's long-term success. The above-mentioned results require that all employees understand both the dominant culture and any subcultures in the company. The next study [22] about organizational culture analyzed the concerns regarding productivity of management staff. The research included managers in UK hospitals during three periods: 2001/2002, 2006/2007, and 2007/2008. Analysis of study results demonstrated a relationship between productivity and existing organizational culture, whereby the more merged existing organizational culture and desired culture, productivity was higher. Examining this matter, Ortega et al. [23] argue that the organizational culture of a healthcare unit reflects the general image of one culture or the system in one society, which further impacts the society as whole in terms of economical, legal, technological, political, religious and moral issues. It has been observed that, in many healthcare facilities, performance of one unit is noticeably better and staff motivation considerably higher compared to another unit which operates with similar structures and levels of resources. Hence the conclusion that the way healthcare activities are performed is interchangeable of its elements. Furthermore, authors argue that these types of behavioral patterns can be constructive or not which, at a later stage, could lead to behaviors and attitudes that will define how members interact with each other. Pilav and Jatic [7] write that in an effort to improve overall health status among the population, many developing countries have implemented major healthcare reforms and are facing healthcare challenges: declining health standards, introduction of private healthcare, lack of financial resources, inability of organizational and management structures to ensure efficient and effective provision of health services, as well as gaps between healthcare needs and demands. The conclusion is that cultural features of the healthcare system are considered crucial for provision of good services to patients. The study conducted by Zahra et al. [24] found that nurses perceived the organizational culture in the selected hospitals to be moderately positive. While the highest scores were for control, the lowest scores were for conflict tolerance. The findings suggest that this type of organizational culture may negatively impact nurses' performance. Improving the organizational culture could enhance nurses' performance and motivation to provide higher-quality care. The study of Alharbi et al. [24] suggests that there is a possible link between organizational culture and patients' health-related quality of life after discharge. While a flexible organizational culture is often seen as beneficial for implementing new healthcare models, the findings suggest that it might not always be helpful in achieving desired outcomes. Carney [25] sought to explore how organizational culture might influence the relationship between cultural factors and quality healthcare. Through interviews with 50 healthcare managers in Ireland, they found that organizational culture is more complex than previously believed. Key cultural determinants for quality care delivery include excellence in care, ethical values, involvement, professionalism, value for money, cost of care, commitment to quality, and strategic thinking.

The second group of studies explores organizational culture and consequences for employees. The MEMO study by Willimas et al [24] examined the relationship between organizational culture, physician work attitudes, and patient safety. They found that while organizational culture plays a less significant role than initially hypothesized, a strong emphasis on quality within the culture is crucial for positive patient outcomes. Stressed, burned out, and dissatisfied physicians are more likely to make errors and deliver suboptimal care. Therefore, creating a supportive organizational culture that prioritizes quality and supports the well-being of healthcare providers is essential for the healthcare system. Another study that attracts attention [26] is the one analyzing organizational culture in health assessed in the United States among nurses in 13 hospitals. Results of that study show positive correlation between negatively evaluated organizational climate and occupational burnout among nurses assessed through Maslach Burnout Inventory (MBI) tool. It showed that the organizational climate influences the sense of personal achievement, emotional exhaustion, and the sense of depersonalization. The research team led by Mijakoski [27] investigated organizational culture in relation to occupational burnout, engagement in work and performance quality of professional duties. Target participants were physicians (138) and nurses (148) employed at a hospital in Skopje, Macedonia. The study relied on standard research instruments, as follows: Maslach Burnout Inventory (MBI), Utrecht Work Engagement Scale, and Competing Values Framework. Both groups most often indicated the clan culture as the desired organization culture, abounding in factors that protect against occupational burnout, and conductive to motivation for work engagement. Szara [28] argues that the largest group of available scientific publications on organizational culture in healthcare systems refer to hospital staff, chiefly nurses and physicians. Some researchers, particularly in Poland, have studied the relation between organization culture and “psychological load” which employees in this sector face. Moreover, the study repeated the results that the amount of psychological capacity was related to organizational culture. That would mean that an increase of psychological capacity among healthcare workers in healthcare institutions is conditioned as difference between the current (present) and expected (desired) organizational culture. Kourakos and Kafkia [29] discovered that organizational culture influences all aspects of the healthcare system, significantly impacting both healthcare delivery and decision-making. They found that organizational culture has far-reaching effects on healthcare providers and recipients, affecting factors like work-life balance, organizational commitment, empowerment, job satisfaction, employee turnover, and overall organizational performance and efficiency. Additionally, it can influence patient access to care, patient safety, health outcomes, and patient satisfaction. Shanafelt et al. [1] argue that when cultural challenges arise in healthcare, they often stem from specific subcomponents of the culture, even if the overall culture is generally positive. They propose that cultural issues contribute significantly to the problems facing the healthcare delivery system and the high rates of burnout among US physicians. To address these issues and improve the professional culture, they suggest a framework based on organizational science. Sow et al. [30] studied the connections between leadership style, organizational culture, and job satisfaction in the U.S. healthcare industry. They aimed to understand how transformational leadership and organizational culture can influence job satisfaction in an industry with high burnout and low satisfaction. By surveying 111 American healthcare employees, they found that while transformational leadership initially seemed to impact job satisfaction, this effect disappeared when considering organizational culture factors. The study suggests that healthcare organizations should focus on shifting away from externally focused cultures to improve job satisfaction and social outcomes.

The third types of studies describe different types of organizational cultures. Ovseiko and Buchan [31] surveyed academic physicians and scientists at the University of Oxford and its partner health system in 2010. They found that the health system had a dominant hierarchical culture, with moderate rational and team cultures, and a weak entrepreneurial culture. The university had a more balanced culture, with strong rational and entrepreneurial cultures, and moderate-to-strong hierarchical and team cultures. Both groups preferred a future culture that emphasized team and entrepreneurial cultures, with less emphasis on rational and hierarchical cultures. A study in France by Minvielle et al. [32] was conducted in 26 hospitals. The study, examined the relationship between occupational burnout, productivity and organizational culture. The data shows that there were four types of cultures: adhocracy culture, clan culture, market culture and hierarchy culture. Mesfin et al. [33] conducted a study in Ethiopia. This study found that primary hospitals in the Jimma zone primarily exhibited a hierarchical culture, characterized by rigid rules, well-defined processes, and a controlling management style. The market culture was the second most prominent culture type. The results of this study align with the findings from a previous study done in Greece, which identified hierarchical culture as the predominant organizational culture type, followed by market culture. A further research carried out in Libya revealed that the main culture type was hierarchy, followed by clan culture type [34]. The study of Hung et al. [35] investigated the connection between organizational culture and patient-centered outcomes in primary care. By analyzing data from 357 physicians in 41 primary care departments, the researchers found that different organizational culture types had varying impacts on patient access, care continuity, and overall patient experiences. For example, a "Rational" culture was linked to longer wait times, while "Hierarchical" and "Developmental" cultures were associated with less care continuity, but better patient experiences. These findings highlight the importance of understanding how organizational culture can influence the delivery of patient-centered care.

The abovementioned studies provide an overview of the researches on organizational culture in relation to healthcare and other concepts. The results of the study show three different topics that emerged from this study. The conclusions are outlined in the next part.

4. Conclusions

In the light of this discussion, the study elaborates, in great details, the concept of organizational culture and its definition by main scholars; empirical research on organizational culture and its relation to different concepts. Organizational culture is considered as important strategy of an organization and defines the course for the organization and its employees. A crucial aspect of all the presented studies is their recognition of the complex context within healthcare organizations and the results highlight the complex nature of organizational culture in healthcare. This is in line with previous researches where many scholars clearly demonstrate that complex organizations, such as healthcare units with multiple layers of cultures and cultural schema, are interconnected with a large organization point and are not readily able to accept changes [36]. The quality of care is deeply influenced by organizational culture. The main results of the study show that there are three types of studies which examine culture and organizational variables. Those are: studies about culture and performance, studies about culture and consequences for employees and studies which describe different types of organizational cultures. The findings demonstrate that the role of organizational culture has been proved as important in the complex health system and apparently related to various concepts. Thus, research based on the professionals' perspective helps to shed a light on the immense role that organizational culture has. The limitations of the study are about specific sector in which it is examined. Further research that can provide additional insights about the role of organizational culture in healthcare should focus on longitudinal studies which assess the long-term effects of organizational culture changes or exploring the specific impacts of organizational culture in different types of healthcare institutions. Apart from that, it would be beneficial to create an instrument for organizational culture in healthcare through factor analysis in order to confirm the findings of the study. Another future research could be replication of the exact study in different industries. The study recommends examining organizational culture in healthcare and paying attention to the different types of culture and consequences, as these aspects are important for the benefit of both patients and healthcare professionals.

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The Gender Factor: Does Company Culture Attract IT Employees in N. Macedonia?

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Abstract. Diverse teams bring new perspectives and experiences that lead to greater creativity and problem-solving. Recognizing the increasing importance of gender equality in the workplace, this study explores if gender plays a role in employer preferences in the IT sector. More specifically, the study aims to explore if there is a relationship between employer preferences and gender, especially in the context of IT sector in N. Macedonia. A survey among 173 IT professionals in N. Macedonia was conducted. The tested hypothesis was that there is a significant divergence in the selection of jobs based on company culture and values between genders. The results support this hypothesis, suggesting a need for a more nuanced approach to employer branding that considers gender differences in the workforce. The conclusion is that women place more attention to company culture and values. Recommendations underscores the importance of a nuanced approach to employer branding, considering gender differences in the workforce.

Keywords. Gender Equality; Employer Preference, N. Macedonia, IT, Sustainable Development Goals

1. Introduction

In the increasingly competitive global market, attracting and retaining top talent has become a critical challenge for organizations. Employer branding is essential in today's company marketing and positioning, especially in attracting suitable candidates. It is a crucial strategic approach in the highly competitive Information and Technology (IT) sector. The escalating demand for skilled professionals underscores the need for organizations to establish themselves as preferred employers. Amidst the region's expanding tech industry challenges in talent acquisition and retention, employer branding is an essential strategy for attracting and retaining the talent vital for organizational success. The study of Franca [1] shows that various aspects like company culture, brand awareness, and employee reviews impact an employer's overall brand strength. The findings accent two important aspects that companies should consider. Firstly, employer brand isn't a single factor, but a combination of aspects influenced by different things. Second, while the results are general, they show that

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companies may struggle in specific areas. Strength in one dimension, like a great work environment, might not translate to positive employee reviews online. Lundkvist [2] accents that several authors emphasized that gender equality is a valuable asset in attracting and retaining employees in the current “War for talent”. Therefore, that aspect presents an opportunity for companies to conduct more in-depth research and implement practical strategies to promote gender equality. This is consistent with findings from Bellou et al.'s research [3], confirming the complex nature of employer attractiveness. Employees place high importance on positive workplace interactions, favorable work conditions, and a satisfying work environment. The research accents that there are some gender-specific differences.

The information technology sector is critical to the Republic of North Macedonia and serves as a foundational pillar for the country. Its sustained growth, marked by an ever-expanding roster of IT companies and professionals, underscores its vital role in the nation's economic landscape. One of the biggest challenges facing the Macedonian IT industry is knowledge management [4]. Many IT departments in large companies struggle with both staffing shortages and high employee turnover. This creates a double bind. IT professionals are overloaded with multiple tasks like design, development, and implementation, leaving little time for proper documentation. High turnover compounds the problem. When an employee is the sole source of knowledge for a system or project, that knowledge disappears when they leave. Despite offering high salaries, Macedonian IT companies face stiff competition for skilled professionals due to global demand. Although skilled IT workers sometimes come from abroad, they often leave for better opportunities elsewhere. Intranet systems and collaborative tools can help by providing internal directories and facilitating communication between team members. These factors highlight the critical importance of knowledge-based systems for Macedonian software companies, especially those working on outsourcing projects. Building such systems helps preserve valuable tacit knowledge and protects companies from the impact of employee turnover. Apart from knowledge management, Macedonian IT companies face several key challenges project management, IT reliability, security, and attracting/retaining talent. Despite offering the highest average salary in the country, high employee mobility and turnover plague the sector. Despite competitive salaries, IT professionals in N. Macedonia are increasingly seeking employment with foreign companies due to perceived advantages in work environment. Therefore, it is of crucial significance to explore the factors that could potently attract and retain IT employees.

2. Gender Perspectives

Taking gender perspective becomes more important as research shows that women employees in IT are more likely to switch jobs due to dissatisfaction and this poses important challenges for retention [5]. Annabi and Pels [6] write that a concerning trend persists despite organizational efforts to retain women, significant numbers leave the IT workforce within the first five years. They mention data which highlights a 57% dropout rate, raising questions about the effectiveness of interventions. Apart from the abovementioned factors, there are many challenges that women face in IT industry. Kunda et al. [7] focused on female South African IT workers from diverse racial backgrounds. The aim of the research was to explore the challenges that contribute to women leaving the IT field. The results show that challenges that women face include unfair pay, difficulty balancing work and life, a hostile work environment lacking inclusivity, limited representation, unequal advancement opportunities, and underestimation coupled with resistance. Additionally, there is the fast-paced, demanding nature of the industry, the absence of female mentors, and a lack of early exposure to technology create further hurdles.

Tanwir and Khemka [8] have noticed that despite the high-paying opportunities offered by the IT sector, women in Pakistan, particularly those in urban areas with educational backgrounds, remain underrepresented, especially in leadership roles. This gender gap threatens to widen if left unaddressed. The paper explored the challenges Pakistani women face in entering the IT workforce, along with the potential for increased female participation. While individual empowerment within IT workplaces holds promise, Pakistan's socio-cultural barriers and implicit gender bias in education and employment create significant obstacles.

Even in the beginning of IT education, there are authors who noticed and researched topics like gender equity in the education sector. The study conducted by Reinen and Plomp [9] supports concerns about gender equity in information technology (IT) education. Female students reported lower familiarity with IT, less enjoyment using computers, and more difficulty with software compared to male students. Possible explanations include differences in parental support, computer access, exposure to female IT role models, and school-based activities. These findings highlight the need for educators and parents to address these gender disparities. The additional remarks are that schools often lack policies on gender equity in IT education, and existing policies may not extend to parental involvement. The authors recommended implementing targeted programs and fostering collaboration between schools and parents can be crucial steps in fostering a more equitable learning environment.

Traut and Conolly [10] investigated how societal, organizational, and individual factors affecting gender equity in IT evolve over time. Using a longitudinal study in Ireland, they interviewed 63 women across four decades (1970s-2010s) to understand these changes. Their findings expand the "individual differences theory" by identifying seven key themes influencing the experiences of women in IT. The study reveals that economic fluctuations in Ireland indirectly impacted women through changes in other factors. These factors include environmental aspects (policies, infrastructure, culture), identity considerations (motherhood), and individual circumstances (family). Overall, the research paints a dynamic picture of women in IT, highlighting both gradual and dramatic shifts against the backdrop of Ireland's economic landscape. Lyons and Kuron [11] emphasize that gender differences in job preferences can be attributed to socialization processes that shape distinct value systems and career aspirations among men and women from an early age.

Furthermore, research by Gallup [12] reveals that women are generally more likely to seek out and remain with organizations that demonstrate a strong commitment to diversity and inclusion, while men might place a higher premium on the organization's market position and stability. The comprehensive review written by Kyndt et al, [13] highlights that younger employees often prioritize career development opportunities and work-life balance, whereas older employees might place more value on job security and organizational loyalty. Furthermore, it can be concluded that a one-size-fits-all retention plan is insufficient.

Martin and Barnard [14] aimed to understand the experiences of women in male-dominated occupations, focusing on the challenges they face and their coping strategies.

One significant finding was the prevalence of gender discrimination and bias within organizations, manifested in practices that fail to accommodate women's specific needs. Women's resilience emerged as a key theme, with strategies such as adapting to male-dominated norms, seeking mentorship, and drawing on intrinsic motivation. Authors proposed that in order to address these challenges, organizations should implement policies and initiatives to attract, retain, and support women in male-dominated roles.

A study by Ely and Meyerson [15] explored how organizational culture influences gender diversity, highlighting the significance of values and culture in attracting female employees. Their findings suggest that a more inclusive culture could attract more female talent, pointing to the possibility of a significant difference based on gender preferences.

Another study conducted in India [16] conducted by Devi and Basariya, shows that IT companies face a significant challenge in retaining top talent, particularly women. High turnover rates, especially among high-performing employees, strain resources and hinder organizational success. While women in executive roles demonstrate ambition and a willingness to make sacrifices, many perceive a lack of support for their advancement within corporate cultures. Despite efforts to increase gender diversity at the executive level, most organizations have seen limited progress. In a similar study [5] Begum and Brindha write that the evolving role of women in the workplace has significantly impacted private organizations. Young female employees today demonstrate a higher propensity to leave jobs when dissatisfied, posing retention challenges for employers and HR departments. Therefore, effective retention strategies are essential to mitigate the loss of knowledge and training investments associated with turnover. A one-size-fits-all approach is ineffective due to individual differences in priorities among female employees. HR professionals must tailor retention strategies to address specific needs, such as job enrichment, compensation, working conditions, and professional development. Their conclusion is that creating a gender-neutral workplace culture is crucial for retaining female talent. The recommendations include creating innovative policies and practices that foster a supportive and inclusive environment for women. On the other hand, there are no studies focused on women in IT in N. Macedonia and this provides additional incentive for the study. The hypothesis concerning gender differences in choosing to work for a company based on its culture and values delves into the broader discourse on gender inclusivity and diversity in the workplace. Gender equality is one of the sustainable Development Goals (SDG) [17]. According to UN reports Despite decades of progress, achieving gender equality by 2030 remains a distant goal. The conclusion is that the situation not only violates fundamental human rights but also hinders global peace, prosperity, and sustainability. Having in mind the above-mentioned arguments and studies, this paper aims to explore gender differences in relation to preferences about organizational culture and values. Therefore, in the light of equality and addressing gender gaps, it is of crucial importance to address the gender factor in attraction of employees and explore whether it plays a role.

3. Methodology

The paper is based on quantitative research conducted among IT professionals in North Macedonia. A total of 173 participants finished the questionnaire sent through Google Forms. The fieldwork for the questionnaire was conducted in February, 2024.

Participants were sent invitations via email though friends or colleagues working as IT professionals. A total of 220 email invitations were sent to potential respondents, out of which 173 finished the questionnaire. The minimum number of participants was 80 per gender in order to have sufficient cases for statistical analysis. Participation in the study was voluntarily, without incentives. A convenient sample was used for the survey. The sample consisted of 80 males and 93 females that were included in the study. The survey was based on a questionnaire distributed to Macedonian employees working in the ICT sector (computer programming and IT outsourcing consultancy services sub-segment) at various management levels (top management, executive representatives, first-line managers Leaders, Non-managerial level employees) in several companies. For this research, the questionnaire consisted of two parts demographic profile (gender, age and employment status and a specific question about work preference for a specific company. The question was: "To what extent do Company Culture/Values as factors impact your choice to work in a specific company?". Reflecting on broader discourses that suggest different genders may prioritise varying aspects of company culture and values in their employment choices, this study hypothesised that males and females are significantly different in choosing to work in a company based on its culture and values, suggesting that gender may influence how potential employees value company culture and ethics. The hypothesis was tested using independent samples t-test.

4. Results

This section presents the results of the study. The table below shows the testing with independent samples t-test.

Table 1. Independent samples t-test (Assuming Unequal Variance)

Male	Female	Mean Difference	t-statistic	Significance
3.74	4.14	0.40	-2.600	.010
Levene's Statistic (p-value)			4.515 (.035)	

Table 1 shows that Levene's test for equality of variances is statistically significant, F=4.515, p<0.05. This result indicates that the variances between the two groups (males and females) are unequal. Consequently, the study assumes unequal variances when conducting the independent samples t-test. The following independent samples t-test showed that the difference in the importance of gender differences in prioritizing company culture and values in choosing a company between males (M = 3.74, SD = 1.09) and females (M = 4.14, SD = 0.87) is statistically significant, t (171) = -2.600, p<0.05 level of significance. Therefore, the null hypothesis that there is no difference in choosing to work in the company based on company culture and values between males and females is rejected. It can be concluded that female tends to emphasize company culture and values more than males. Hence, the hypothesis is supported.

5. Conclusions

The section below discusses the findings from the research conducted on differences in employer branding practices within the IT professionals in the Republic of North Macedonia. It should be noted that IT professionals are one of the largest groups in the country. Consistent with the hypothesis testing, the independent samples t-test results demonstrated a significant difference in the valuation of company culture and values between genders, with females placing greater emphasis on these aspects than males. This finding aligns with the narrative in existing literature that emphasises the importance of organisational culture in employment choice, thus supporting the hypothesis. Such outcomes echo the sentiments expressed in previous studies [12, 15] that have explored the nuanced differences in workplace preferences between genders. As it was stated before, the independent samples t-test indicated a significant difference, with females emphasising company culture and values in their employment choices. The explanation can be linked to other studies [11] which attributed job preferences to socialization processes that socialization experiences cultivate specific values and career goals. This highlights the need for a gender-sensitive approach in employer branding. The limitations of the study are that it uses convenient sample and it is conducted among IT professionals only. Further research should focus on specific aspects within company culture and values which attract female employees more and should be conducted among other professional groups (doctors, lawyers, professors). Namely the first step are the results of the study to check if differences between genders exist and the second step is to check which aspects are more attractive to women and which to men. The study validates the literature's emphasis on gender differences in workplace values and the universal appeal of transparency and authentic employer branding efforts. It highlights the strategic imperative for IT companies to adopt holistic employer branding practices that balance competitive remuneration with non-monetary benefits to appeal to a diverse and dynamic workforce. Additionally, analytical approach as proposed by Efremov et al. [18] can be used as crucial tool for rigorously evaluating and selecting viable options for women. The comprehensive overview of the study findings, indicates the importance of gender-sensitive branding strategies in attracting and retaining talent within the Republic of North Macedonia's IT sector. The study underscores the need for IT companies to adopt comprehensive employer branding strategies catering to diverse employee expectations and preferences, enhancing their attractiveness as employers in a competitive industry.

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The Transparency Code: Building Loyalty of IT Professionals Through Employer Branding in N. Macedonia

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Abstract. Building a strong employer brand is crucial for attracting and retaining top IT talent in the competitive IT landscape, especially in a small country like N. Macedonia. The study investigated the link between transparent employer branding and employee loyalty among IT professionals in N. Macedonia. A survey of 173 IT employees from various levels within the computer programming and IT outsourcing sectors was conducted. The study found a significant positive correlation between transparency in company culture and employee perceptions of belonging and loyalty. This suggests that IT professionals' value clear and open communication from their employers. These findings support the importance of employer branding for attracting and retaining top IT talent. Transparency should also be included into employer branding by showcasing company culture and values online, while highlighting how transparency is integrated into daily practices. Finally, fostering employee engagement through inclusive decision-making, feedback mechanisms, and addressing concerns will further foster loyalty. By embracing transparency and building a strong employer brand, IT companies in N. Macedonia can secure a competitive edge in the global IT talent market.

Keywords. Loyalty; Transparency; Employer Branding; N. Macedonia; IT

1. Introduction

In the fast-paced Information Technology (IT) sector, creating a robust employer brand is a crucial undertaking that significantly impacts an organization's capacity to attract and retain high-caliber talent. Employer branding refers to the overall perception of a company as an employer by its current employees, potential applicants, and the wider industry. Crafting a compelling employer brand within the IT industry involves leveraging technological advancements, nurturing a unique company culture, and offering competitive compensation packages. These elements are critical, as the findings of the study conducted by Aldousari et al. [1] revealed a positive association between the implementation of an advanced employer branding strategy and organizational performance. Also, directly related to the topic of this research is the

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study of Tanwar and Prasad [2] study which revealed a positive association between employer branding outcomes (job satisfaction and psychological contract fulfillment) and employee retention. The part below provides basics for understanding the context of IT industry in the Republic of N. Macedonia. A survey conducted by Levkov et al. [3] sheds light on the key demographics of IT professionals in Macedonia. The educational background of these professionals leans heavily towards formal education, with a majority holding bachelor's degrees (65%) and a significant portion possessing master's degrees (27.2%). This finding suggests a strong emphasis on academic qualifications within the Macedonian IT industry. In terms of experience, most IT surveyed professionals fall within the moderate range (83%) with 0-9 years spent working in the field. They primarily work full-time (83%) and demonstrate a high level of job security, with a remarkable 87.4% having never been laid off from an IT position. Interestingly, the distribution of their total work experience closely mirrors their IT experience. Examining the roles they have within organizations, it can be concluded that a substantial number (60%) works directly within IT departments. Others participate in the workforce as contractors (16.7%) or consultants (11.9%). Apart from that, there is an emerging importance of employer branding in the IT sector, where the fight for top talent is incredibly fierce. According to the findings of Blazevski and Blazevska [4], there is an initial adoption of employer branding principles among large Macedonian companies. These companies implement various activities and initiatives to cultivate a desirable employer image, often through social media promotion. Furthermore, the creation of dedicated employer branding positions within HR or marketing departments indicates strategic approach. However, for long-term success, companies in N. Macedonia need to progress beyond these initial steps. The recommendation is that companies must develop more complex and comprehensive employer branding strategies that encompass a wider range of initiatives and touch points. This paper explores the relationship between Employer Branding Practices in the IT Industry and retaining top talent in the Republic of N. Macedonia. There are not many studies conducted in the country on the topic and therefore there is a need for further research to bridge this gap and identify the link between employer branding practices for driving employee loyalty and retention, particularly in the competitive IT industry.

2. Employer Branding Overview

Employer branding is critical in the IT industry, as companies compete for top talent. While it is widely agreed that employer branding is essential to retain and attract top talent, it is necessary to identify which specific practices are most effective. Employer branding constitutes a strategic differentiation approach, establishing a unique Employer Value Proposition (EVP) to distinguish an organization from competitors. Dash and Mohapatra [5] write that the employer brand is basically a company's reputation as a workplace, how it treats its employees, and how it attracts new talent. A big part of this is the Employer Value Proposition (EVP). This is a clear message that explains what makes the company special and why talented people would want to work there (and stick around). It's more than just what people say, it's also about the company culture and overall image. It is a question of how leaders act, how the company is structured, and how the company treats employees. All these aspects contribute to how people see the employer brand. Different departments might even have their own little "mini-cultures" influenced by their size and power in the company, which can make things more complex. The big question is who's in charge of making sure that employer brand is strong? It's important for top management to be on board and to assure employees to believe the company actually lives by its promises. Research by Patra et al. [6] accents that strong Employer Value Propositions are essential for attracting and retaining top talent in today's competitive job market. An EVP clearly communicates what makes the organization unique and why talented people would want to work there. The rise of the digital economy, with its emphasis on knowledge-based work and diverse workforces, has made crafting a compelling EVP even more critical. Digital tools like social media, mobile technology, and cloud computing can be leveraged to build a strong employer brand and effectively communicate the EVP of a company. In a different context, the research of Efremov [7] shows that emotional commitment is positively associated with safety attitudes that employees have in the organization.

Kaliappan and Kavitha [8] write that building trust with employees is essential for a thriving organization. Authentic leadership, open communication, and flexible work arrangements all contribute to a trusting work environment. Trust fosters a sense of security and reduces stress. Employees who trust their colleagues can rely on them to fill in skill gaps which lead to improved productivity. Trust also underpins effective communication, employee retention, and motivation. On the other hand, transparency is a key component of trust. Today's skilled workforce seeks out honest and authentic organizations. The conclusion is that building trust requires more than just recognizing its value – it requires actively cultivating a culture of transparency within your organization. A similar study conducted by Tomlinson and Schnackenberg [9] indicates that employee trust in managers hinges on three key aspects of transparency: how much information is shared (disclosure), how accurate that information is perceived to be, and how clearly it's communicated. Managers who fulfill some transparency aspects but not others may not build the necessary trust with employees. This has practical implications for managers who need to cultivate trust in different situations.

Khan et al. [10] examined how employer branding influences employee retention in the Indian IT industry. This study explored whether an employee's identification with their organization strengthens the link between employer branding and retention. The researchers used a self-administered questionnaire to collect data from a cross-section of IT employees. Their analysis revealed that a strong employer brand can lead to employee retention. More importantly, the study found that strong employee identification with the organization amplifies the positive effect of employer branding on retention. These findings highlight the importance of employer branding and fostering a positive organizational identity to retain employees in the IT sector. Another study conducted among IT professionals by Bharadwaj et al. [11], found a strong employer brand is linked to higher job satisfaction, stronger organizational identification, and ultimately, greater employee retention. Their analysis suggests that a strong employer brand can lead to retention by first increasing job satisfaction and then fostering a stronger identification with the organization. Satisfied employees who feel connected to their company are less likely to leave. In conclusion, employer branding offers a competitive advantage beyond just retention. It can also boost employee morale and create a more positive work environment. This highlights the importance for managers to develop a long-term employer branding strategy focused on both attracting and retaining talent, while also fostering positive employee relationships. The study of Jain [12] highlights the growing challenge organizations face in attracting, engaging, and retaining top talent. The study explored the concept of employer branding and its key components. It also emphasized the critical role of leadership in building a strong employer brand. The author identified five key factors influencing employer branding: organizational fit, perceived reputation, leadership and transparency, strong management, and work atmosphere. Understanding these factors is crucial for organizations to develop a compelling employer brand in today's competitive landscape, shaped by startups, social media, and online communication. Silva and Calisto [13] explore employer branding as a new tool in Human Resources (HR) that strengthens a company's image and fosters relationships with qualified candidates for recruitment and retention. Employee retention is a top priority for HR, as it contributes to business success and profitability. This research investigates how Portuguese organizations retain employees and the practices they use. The study examines whether organizations recognize the importance of retention and how they view employer branding as a tool to achieve higher retention and employee satisfaction. Researchers analyzed eleven Portuguese companies from various sectors and locations using a qualitative approach. Semi-structured interviews with HR representatives explored employee retention practices. The findings suggest that employer branding is gaining traction in Portuguese HR practices. Additionally, the study reveals a growing concern for employee retention, with companies implementing various strategies.

Kumar et al. [14] investigated the link between employer branding practices and employee retention. A strong employer brand effectively communicates a company's unique identity to potential and current employees. This can attract top talent and encourage them to stay with the organization. The study, conducted among 300 employees in Vellore, India, used a descriptive research design. It found that clear communication of HR policies, attractive benefits (superior benefits packages, recognition programs, flexible work schedules, and on-site childcare), and competitive salaries contribute to a positive employer image. These factors can help organizations attract qualified candidates and retain their talented workforce. According to Davies [15], employer branding offers several benefits, including fostering employee loyalty, retention, and satisfaction, while also creating a distinct image compared to competitors. Research by Kim & Sturman [16] highlights the importance of fulfilling the promises made about the employment experience. By motivating and engaging employees, organizations can strengthen employee loyalty and retention. Moreover, Carmeli and Gittell [17] demonstrate that organizational transparency and clear communication of values can lead to higher levels of organizational commitment and lower turnover rates, highlighting the significance of openness in cultivating a dedicated workforce.

The comparative analysis of various approaches to employer branding emphasizes the importance of creating a distinct organizational identity to attract and retain top talent, especially in a competitive industries like IT. A strong employer brand is often built around a clear Employer Value Proposition (EVP) that communicates what makes the organization unique and desirable as a workplace. Effective employer branding involves more than just external reputation; it also reflects internal practices, such as leadership behavior, company culture, employee treatment, and transparent communication. Digital tools like social media and online platforms are frequently used to strengthen the employer brand and engage with potential and current employees. Additionally, practices such as offering competitive benefits, flexible work arrangements, and a supportive work environment contribute to building a positive brand image. The overall effectiveness of employer branding strategies is based on alignment between what is promised to employees and what is delivered, ensuring that the brand is not only attractive but also authentic and trustworthy. This part highlights the critical role of employer branding in the IT industry, where competition for top talent is fierce. While there's agreement on its importance for attracting and retaining employees, a key gap exists: understanding if employer transparency branding practices are most effective in driving employee loyalty and retention. Although it is widely accepted that employer branding is essential for attracting top talent, less is known about the role of transparent employer branding in employee engagement and retention. While the benefits of a strong employer brand are well-documented (loyalty, retention, satisfaction, and differentiation), and the significance of employer branding in enhancing recruitment efforts and employee engagement is acknowledged, there is still a significant knowledge gap regarding transparency employer branding practices that yield the most substantial impact, particularly within the context of the IT industry in the Republic of N. Macedonia. By addressing these research gaps, the aim of the study is to examine the link between transparent employer branding practices and talent retention. Therefore, this study will not only advance academic knowledge but also provide valuable guidance for IT companies in N. Macedonia seeking to attract and retain top IT talent in the global market. The research question of this study aims to explore if there is a positive relationship between transparent employer branding and loyalty among IT professionals in N. Macedonia.

3. Methodology

The methodology section builds up on previous sections (literature review, research question and objectives). This part covers methodology including survey design, data collection process, and the use of Pearson correlation to analyze relationships between variables. Later, the results section presents the findings from the survey, while the conclusions outline the most important findings. For the purpose of this study, a quantitative research method was applied through a survey distributed to IT professionals in N. Macedonia. A total of 173 IT professionals participated in the survey conducted in February 2024. A convenience sampling approach was used, where participants were recruited through invitations sent via email to friends or colleagues working in the IT sector. The survey targeted professionals across various levels (top management, middle management, non-management, and interns) within the computer programming and IT outsourcing consultancy sub-segments of the Macedonian IT industry. The self designed questionnaire consisted of two sections: demographics (gender, age, employment status) and questions about transparency and loyalty. The validation included extensive literature review, consultation with 2 experts. According to the opinion of the experts the questionnaire has content and face validity. The transparency was assessed by asking whether participants would be more likely to apply to a job posting if the employer actively shared their company culture and values publicly. Loyalty was operationalized by assessing the degree to which participants indicated that a sense of belonging and organizational commitment influenced their decision to work for a particular company. The data were continuous based on paired observations. The hypothesis being tested is that employees, who perceive a high level of transparency in the organization's culture and values, are more likely to develop positive attitudes towards staying with the company, enhancing their sense of loyalty and belonging). Pearson's Correlation Coefficient was used to test this hypothesis.

4. Results

This section delves into the study's findings. The following table presents the results of the Pearson's Correlation Coefficient analysis, which was used to assess the relationship between transparency and employee loyalty.

Table 1. Pearson's Correlation Coefficient

Aspects	Transparency in organisational culture and values	
Belonging and Loyalty	0.383**	n=173

** p<.01

As demonstrated in Table 1, transparency in organizational culture and values is positively and moderately associated with the perception of belonging and loyalty (r = 0.437) at p<0.01 significance level. According to the results based on 173 participants, the null hypothesis states that there is no association between transparency in organizational culture and values and employees' perception of belonging and loyalty. The findings support the alternative hypothesis, which posits a positive link between transparency branding practices and employee loyalty and sense of belonging.

5. Conclusions

The analysis underscored a significant association between transparency in organisational culture and values and the perception of belonging and loyalty among employees, supporting the hypothesis. This resonates with the broader academic discourse on the critical role of transparency and authentic communication in fostering organisational loyalty as accented by previous research [10, 11, 13, 15–17]. These results highlighted a moderate yet significant association between transparency in organisational culture and values and employees' perception of belonging and loyalty. The results reinforce the critical role of transparency in fostering a sense of belonging and loyalty within the workforce, which is vital for attracting employees who align well with the organisation's culture and values. The findings fit the narrative in existing literature that transparency is a key to fostering trust and employee engagement, thus leading to a stronger sense of belonging and loyalty, according to Tanwar [2].

Future research should explore which aspects of transparency are beneficial for advanced employer branding practices in N. Macedonia. Studying how cultural factors influence employer branding and how IT companies can overcome these challenges to enhance their attractiveness as employers would be beneficial. Additionally, examining the link of improved employer branding on employee retention and satisfaction could provide actionable insights for IT companies in the region. More detailed studies on the effectiveness of specific employer branding strategies in other countries could also offer valuable lessons for local practices. On the other hand, the limitations are related to the sample (convenient) and the specific IT industry. The recommendations for IT companies with regards to attraction and retention of top IT talent in N. Macedonia's competitive market, shows that prioritizing transparency is of utmost importance. The recommendation is to cultivate a culture of open communication by sharing company information, fostering employee questions, and providing regular updates. Leveraging transparency in employer branding can showcase company culture and values online and emphasize how companies integrate transparency into daily practices. Additionally, the focus should be on employee engagement through inclusive decision-making, feedback mechanisms, and demonstrating a commitment to addressing concerns. By embracing transparency and fostering a strong employer brand, IT companies in N. Macedonia can build a loyal and engaged workforce, securing a competitive edge in the global IT talent market.

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Walk the Talk: Authentic Leadership Through Ethics

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Abstract. A scoping review examined the connection between authentic leadership and ethics, analyzing 20 studies on how these two concepts are related. The inclusion criteria were limited to studies written in English that investigated the relationship between authentic leadership and ethics. The focus was on English-language literature published between 2003 and 2019. The key terms used were "ethical leadership," "authentic leadership," "ethics," and "authentic". The analysis focused on the main topics and how authentic leadership and ethics are connected. The topics which appeared were: general link between authentic leadership and ethical behavior, effectiveness of authentic leadership and qualities of authentic leaders. The results show that the relationship between authentic leadership and ethical behavior is complex and intertwined. The study recommends that organizations foster a culture of authenticity, trust, and ethical leadership, implement training programs about ethics and encourage leaders to share their values. On the other hand, the researchers can use the study's findings for factor analysis and creation of instrument which examines the effects of ethical leadership on organizational outcomes. The end conclusion of the research is evident in the title "walk the talk" which captures the idea of leaders whose moral behaviors are consistent with their promises and values.

Keywords. Authentic Leadership; Ethics; Walk the Talk; Moral; Scoping Review

1. Introduction

Luthans and Youssef [1] provide a concise summary of the growing body of literature on authentic leadership development. Positive psychological states, stable personality traits, and a nurturing, dynamic work environment create authentic leaders. Despite this, positive psychology has been critiqued as the theoretical foundation of authentic leadership. Authentic leaders must be self-aware and have the confidence to do the right thing, which often necessitates a degree of selflessness. As employees and look for leaders who display the attributes previously outlined, authentic leadership theory has grown in popularity [2]. Understanding their mission, practicing solid beliefs, developing associated connections, and displaying self-discipline are all characteristics of authentic leaders. Harter [3] defines authenticity as "owning one's personal experiences, be they

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thoughts, emotions, needs, preferences, or beliefs, processes captured by the injunction to know oneself" (p. 382) and functioning by one's true nature. This definition is consistent with the theory of authenticity as it has emerged within the field of positive thinking [4]. Certain academics argue that depictions of authentic leadership are excessively optimistic to be useful [5] and fail to highlight the challenges faced by leaders in maintaining authenticity when confronted with organizational challenges [6]. Nonetheless, Ibarra [7] asserts that there remains much to learn about the practical manifestation of authentic leadership. As stated by Williams et al. [6], "people in leadership positions would often have to choose between what is expected and thus effective – and what seems authentic." According to Ladkin, Spiller, and Craze [8], the overemphasis on pro-social, good behavior is also regarded as an inappropriate lens through which to assess the authenticity of leaders. Organizations need to meet their obligations to stakeholders for success through robust corporate governance and ethical business practices that are grounded in their values and code of conduct as it is a case [9] of a thriving bank. In the face of growing globalization and worldwide competition, it is critical for businesses to effectively manage their human resources in order to improve their competitiveness [10]. Dospinescu [11] writes that the principles and practices of business ethics help in development of moral judgments and enable correct managerial decision-making. The idea is promotion of social responsibility and reward of ethical behavior by the entire organizational culture. An example is labeling [12] which evolved to help consumers maintain a balanced and healthy diet, fulfilling the ethical requirement of prioritizing the well-being of consumers. George's [13] model of authentic leadership focuses on the various attributes of an authentic leader and claims that showing these qualities or characteristics encourages the followers group to recognize them as such. As a result, their supporters will react positively, and the performance of the organization will improve. On the other hand, some argue that it is unclear how authentic leadership contributes to favorable organizational outcomes and for this reason research about authentic leadership is ongoing [14]. Having in mind the abovementioned arguments, it should be stated that there is a gap in the relationship between authentic leadership and ethics e.g. their link is not clear and therefore it should be explored. In line with that premise, the aim of this study is to see which topics connect authentic leadership and ethics and thus contribute to the existing knowledge. The research question is about exploring the link between authentic leadership and ethics through interrelated topics that are manifested in the existing literature.

2. Ethics and Leadership

The concept of ethical leadership gained popularity and adherence in the second half of the 2001–2010 decade, as scholars noted that a greater convergence between ethics and leadership was needed if the world was to recover from the apparent lack of morality in many 21st-century leaders [15–17]. Over the past few years, authentic leadership has evolved by combining ethics, a positive organizational mindset, and other relevant studies [18–20]. Kelly [21] posits authentic leadership as an evolution of moral leadership, which prioritizes ethical considerations in decision-making. According to De Hoogh and Den Hartog [22], ethical behavior is vital to an organization's existence, and moral failings on the part of the leadership can have a big impact on the company. Therefore, companies should exercise caution when selecting managers who exhibit integrity, act morally, and are neither manipulating nor self-serving. Another author [23] writes that leaders continue to assert that when leadership is ethical, people perceive higher-level management as being more capable and employees show more confidence in the prospects of the company. The four dimensions of authentic leadership (self-awareness, balanced processing, internalized moral perspective, and relational transparency) have been illustrated in the literature review on authentic leadership style [13, 20]. It has also brought another definition that discuss authentic leadership as an honest, transparent, and morally positive style that can be used to effectively encourage positive attitudes and behaviors in subordinates, such as creativity and job satisfaction. In a different study, Efremov [24] found that committed employees have more positive attitudes towards safety and towards the organization. Leadership researchers emphasize the significance of ethics in leadership ([25–27]; while on the other hand, authenticity in leadership seems to be just as important [28]. Previous research indicates that many of the ethical principles of leadership correlate with the characteristics of an authentic leader and that the elements influencing authentic leadership appear to be operationalized in the field of leadership ethics. Although there has been a great deal written in the past on ethics and leadership, the most recent research on authentic leadership emphasizes the significance of ethics in contemporary leadership studies. In conclusion, both ethical and authentic leadership styles share a core focus on ethical behavior and positive influence. While the specific definitions of authentic leadership may vary, its emphasis on ethics aligns well with the broader field of leadership ethics. By delving into this link between ethical and authentic leadership, the study contributes to a more nuanced understanding of both ethical and authentic leadership and their impact on organizations. It was hypothesized that authentic leadership is related to ethical behavior through different topics which lead to positive outcomes in organizations.

3. Methodology

The study employed a scoping review to examine and map existing research on authentic leadership and its link to ethics in existing literature. Scoping reviews are ideal for understanding the current landscape of research on a topic by identifying the volume, types of studies, and key concepts explored. A scoping review was employed to systematically map the existing research on authentic leadership and ethics [29]. This approach allowed for an overview of the literature, identifying key topics and research gaps within the field. The goal of the study was to systematically analyze research on authentic leadership and its connection to ethics. The identification of the studies was done through inclusion and exclusion criteria. The inclusion criteria focus specifically on studies written in English which examined the link between authentic leadership and ethics were included. The focus was on literature published in English between 2003 and 2019. The majority of papers were collected from Google scholar database with cross check in Scopus and Clarivate. The search strategy relied on several words which were used alone or in combination. The used key terms were: ethical leadership", "authentic leadership", "ethics" and "authentic". On the other hand, exclusion criteria were related to studies about leadership related to other types of leadership. For example, if a paper was found to be exploring transformational leadership, it was not considered. For this purpose, English-language studies which explore the link between authentic leadership and ethics were included, while studies focused on other types of leadership were excluded. The search identified 20 relevant papers. The analysis aimed to identify how authentic leadership is related to ethics in the existing literature. The analysis was focused on key topics and mutual relationship of authentic leadership and ethics. The first step was grouping related topics together and then a second step was assigning "code family" in order to show how topics were connected to each other. This helped identify the main three topics which are shown in the results section. Apart from that, contrasting viewpoints on the topic were explored. Overall, the conclusions are based on a review and synthesis of existing research on Authentic Leadership and Ethics. These topics were identified through a close focus on the specific aspects of interest and through grouping of related ideas. Using of the abovementioned analysis on recurring points and grouping related ideas, helped in the identification of the key topics which form the link between authentic leadership and ethics.

4. Results

The results show that there are three emerging topics which intertwined in the results. The following topics were manifested: general link between authentic leadership and ethical behavior; effectiveness of authentic leadership and qualities of authentic leadership. Different studies which explore the specific link between ethics and authentic leadership are presented below. The conclusions of the study are related to these three topics which are shown in table 1.

Table 1. Topics manifested in explored studies about authentic leadership and ethics

Topics	Study of interest
Authentic leadership and ethical behavior	Copeland, 2015; May et al, 2003; Freeman and Auster 2011; Algera and Lips-Wiersma, 2012; Sendaya et al, 2016; Grover and Hasel, 2015; Opatokun et al, 2013; Avolio and Gardner, 2005; Gardner et al, 2005
Effectiveness of authentic leadership	Avolio et al, 2014; Avolio et al, 2004; Brown et al, 2006; Avolio and Gardner 2005; Gardner et al, 2005; Begley and Stefkovich 2007
Qualities of authentic leadership	Walumbwa et al, 2008; Gardner et al. 2005; Gardner et al, 2011; Gardner et al, 2015; Rego et al, 2012; Ayça, 2019

The table shows that there are 9 studies in the first group, six in the second and six in the third group. Two of the studies overlap in more than one group. The first group shows that the concept of authenticity is "being true to oneself" or "acting on one's values" and that authentic leadership emerged from the "ethical corporate meltdown" at an early stage in conjunction with business ethics concerns [30] (p. 247). This was due to analytical researchers' worry that the primary step towards authenticity is being "true to oneself" [31]. Authentic leaders have been questioned about whether they constantly adhere to moral or ethical [32, 33] and whether they are truly being transparent to everyone when they act morally and professionally in business or politics [34]. As a result, more authentic or ethical leaders are more effective as leaders and can thus better guide their businesses, as shown by previous research on authentic and ethical leadership [23]. A study conducted by several authors [35] points the importance of change among educational institutions from being ordinary organizations to healthy learning environments. In order to achieve that, universities must be associated with fundamental moral ideals. In his comparison of ethical and authentic leadership, According to several studies [36, 37], authentic leaders are highly conscious of their thoughts and behaviors and who are regarded by others as having a clear understanding of their own and others' moral perspectives, values, knowledge, and strengths. They also have a clear understanding of the circumstances and are morally upright.

The second group is about effectiveness of authentic leadership. Avolio et al. [18] reviewed the ethical and positive effects that authentic leadership has on the working environment in various types of organizations. They concluded that authentic leadership can be seen as a "root construct" for other leadership processes and that the theory of authentic leadership transcends many or full-range leadership styles by incorporating a moral and ethical perspective. According to Avolio and Gardner [36], leaders are only deemed authentic from a moral standpoint when they engage in activities that align with their inner self-perception and undergo a rigorous process of self-reflection to identify their moral areas. Positive leadership, according to scholars underlying authentic leadership [36], is the theoretical foundation of the authentic leadership style. According to contemporary theories on authentic leadership, the development of authentic leaders can result in the creation of ethically sound environments and long-lasting follower successes [36]. "Authentic leaders exemplify high moral standards, integrity, and honesty," according to Avolio et al. [18] (p. 810), which increases followers' levels of trust. Furthermore, it's thought that followers benefit from authentic leadership by developing a stronger sense of self and confidence. This is mostly the result of the followers' trust in their leaders and the emotional intelligence that the leader has established for their subordinates [16, 38]. In fact, authentic leaders develop a variety of reform agendas while upholding a moral mission founded on values [39]. When a leader demonstrates authenticity, their followers regard him or her as a real leader. By modeling organizational ideals in their own beliefs and actions, authentic leaders earn their followers' trust in the company. Thus, it is evident that authentic leadership improves business performance [40]. Consequently, the worth of employees' lives and their moral well-being are directly impacted by authentic leadership [41]. When working with authentic leaders, some ideas on authentic leadership contend that ethical and good environments can be created in addition to long-lasting follower successes [38].

The third group is about qualities of authentic leadership. According to Walumbwa et al. [42], authentic leadership truly represents a style of leadership behavior that characterizes and expands positive psychological capacities as well as a positive moral atmosphere to foster self-awareness, balanced information processing, an internal moral outlook, and open communication with followers. This leadership style fosters positive psychological capacities and an ethical climate, ultimately promoting follower's development. These authors draw attention to the various characteristics connected to the authentic "self-regulation" process - an additional, little-known but crucial component seen in authentic leaders. Authentic leaders with an extraordinary level of self-regulation may really a) establish their values, b) compare their current values to their actual or potential results, and c) identify alternative solutions that can resolve these differences, as explained by Gardner et al. [38]. Authentic leaders possess strong self-regulation skills, which enable them to control their behavior and consistently uphold their moral principles. The moral perspective in an integrated and internalized way of self-regulation is referred to as internalized regulation. The result of this type of self-regulation is explicit decision-making and behavior that is in line with the internalized ideals. It is bolstered by internal moral standards and values in opposition to group, societal, and organizational influences [42]. Authentic leaders challenge the status quo and seek out the thoughts and perspectives of others [43]. Leaders with strong moral compasses guide strategic decisions based on internalized ethical standards and they consistently act and make judgments in accordance with these beliefs [2], understanding that doing so prevents them from engaging in unethical behavior [44]. Onyalla [28] writes that the elements of authentic leadership may, in fact, come together to create moral leaders and that leadership experts have positioned authentic leadership as the ideal approach for any leader to adopt. Another author [45] claims that positive energy, a clear purpose, a strong moral compass, emphasized self-discipline, a high sense of integrity, sincere concern for others, optimism, trust, hope, and adaptability are just a few of the qualities that characterize authentic leaders.

5. Conclusions

Overall, the examination shows that there is a thin line between authentic leadership and ethical behavior. There are three main conclusions can be drawn about the link between authentic leadership and ethics. The first one is related to authentic leadership and ethical behavior. Authentic leadership is closely linked to ethical leadership. Early research on authentic leadership emerged in response to ethical failures in business. While some argue ethical leaders are always moral, others question if authenticity guarantees ethical behavior. The second conclusion is about the effectiveness of authentic leadership. Studies suggest leaders who are both ethical and authentic are more effective in some aspects. Authentic leadership creates a positive and ethical work environment. This fosters trust, self-awareness, and self-confidence among followers. It also promotes positive self-development. The third conclusion is about the internalized moral perspective are crucial for authentic leadership. Leaders with this perspective prioritize high ethical standards and base decisions on internal values. The findings align with previous research positing authentic leaders as those who cultivate a positive ethical climate and are driven by an internalized moral compass [42]. According to Brown and Treviño [17], ethical leaders are "altruistically motivated, demonstrating a genuine caring and concern for people" and "are thought to be individuals of integrity who make ethical decisions and who become models for others" (p. 600). To put it another way, genuine leaders are more likely to be able to distinguish between good and wrong and to always act in a way that is "true to themselves".

The limitations of this study are related to exclusion of other leadership styles from this scoping review, which prevented comparing the characteristics of authentic leadership with those of other leadership styles. This could have enhanced understanding of the potential obstacles to the adoption of authentic leadership as a substitute for ethical leadership. Future research can delve deeper into this link by exploring the specific ethical aspects most crucial for authentic leaders. The recommendations that stem from this research are for researchers and practitioners. Organizations should foster a culture that encourages authenticity, trust, and ethical behavior among leaders. Apart from that organizations can implement training programs and policies that emphasize ethical decision-making and integrity, encouraging leaders to share their values, and creating a psychologically safe environment where authenticity is valued. On the other hand, researchers can use the three topics as a baseline for factor analysis and creating instruments for ethical leadership in order to explore the effects of ethical leadership on organizational outcomes. Further research should discover which aspects of ethics are crucial for authentic leadership. It can be said that the study of authentic leadership has revitalized the focus on ethics in contemporary leadership research. The final conclusion is stated in the title through the phrase "walk the talk" which is a strong metaphor that resonates with the idea of leaders who live up to their promises and values.

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A Study on the Influence of Peer Initiative on Individual Behavioral Engagement: Based on the Mediating Role of Organizational Climate

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Abstract: This study investigates 984 college students from 10 institutions in the Guangdong-Hong Kong-Macao Greater Bay Area, utilizing SPSS for data analysis and constructing an empirical model through structural equation model (SEM) to explore the relationship between peer initiative and individual behavioral engagement among college students, as well as the underlying mechanism. The research findings indicate that peer initiative exerts a significant positive influence on college students' behavioral engagement, and organizational climate serves as a mediating role in the relationship between peer initiative and student behavioral engagement.

Keywords: Peer Education; Structural Equation Modeling (SEM); Initiative; Organizational Climate; Behavioral Engagement

1. Introduction

College peer groups are informal communities composed of students who share similar statuses, ages, interests, hobbies, values, and behavioral patterns. In terms of educational effect, peer model education often exhibits certain permeable characteristics, which have a positive impact on the internalization and externalization of educational content [1].

At present, research on peer education at home and abroad mainly focuses on connotations, value implications, current status and problems, cause analysis, and path

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improvement. Generally speaking, there is a trend of disciplinary integration and strengthening research from different perspectives. However, there is still room for improvement. First, in terms of research methods, qualitative research is mainly used, and there are relatively few statistical analyses, model constructions, and empirical studies on the initiative of peers. Second, in terms of dimensional content, the relationship between the initiative of peers and organizational atmosphere and behavioral engagement is rarely mentioned. Third, in terms of research objects, more studies are concentrated on working groups. In view of the above situation, this paper takes students from the Guangdong-Hong Kong-Macao Greater Bay Area as the research subjects. Drawing upon survey data from 984 students in 10 higher education institutions, this paper employs structural equation modeling to explore the interrelationships and pathways among proactive behaviors, organizational climate, and behavioral engagement among young college students. Based on these findings, countermeasures and suggestions are proposed to provide an effective reference for peer education among college students through empirical evidence.

2. Research Design and Content

2.1. Research Content and Hypotheses

2.1.1 The Relationship between Peer Initiative and Organizational Climate
Colleagues' behaviors play a pivotal role in shaping the external environment for employees, as the interactions and conducts among peers significantly impact the overall work atmosphere and culture. Proactive behaviors among colleagues can potentially lead to the improvement of the work environment or the current state of work stages and may even usher in more work resources as a result of their proactive behavior. Work engagement may further trigger various proactive behaviors, such as voice behavior and innovative behavior, which in turn have a positive influence on other "colleagues" in the surrounding environment, i.e., sending positive signals to them, thereby fostering a positive work atmosphere within the organization [2].
Based on this, this paper puts forward hypothesis H1: Peer initiative has a positive impact on organizational atmosphere.

2.1.2 The Relationship between Peer Initiative and College Students' Behavioral Engagement
According to Bandura's (1978) social learning theory, individuals learn how to respond appropriately by observing and imitating role models. Seibert pointed out that proactive colleagues can usually achieve better job performance and higher evaluation from leadership, thereby stimulating vitality. This is also the "catfish effect" mentioned in management science [3]. Zhang Ying et al. (2022) pointed out that proactive colleagues would be regarded as role models in the workplace by employees, promoting their intrinsic work motivation. The enhancement of the behavioral engagement of self-motivated individuals can be achieved through the observation-learning process. In this process, the level of behavioral engagement and performance depends on the role of role models around them [4]. Whether the peers around are charming, the complexity of proactive behavior, whether proactive behaviors are rewarded and fruitful, the complexity of role model behavior, and the interpersonal relationship

between role models and observers will all affect the observers' behavioral performance.

Based on this, this paper puts forward hypothesis H2: Peer initiative has a positive impact on college students' behavioral engagement.

2.1.3 The Relationship between Organizational Climate and College Students' Behavioral Engagement

Organizational climate is an environmental attribute perceived by the members of an organization, and this perception can further affect individuals' work attitudes and behaviors. Organizational climate and shared perceptions significantly influence individuals' psychological experiences and behaviors, encompassing their job satisfaction, emotional states, work engagement, and behavioral performance [5]. It is argued that organizational climate represents the shared perceptions among all individuals within an organization, and this group cognition exerts a profound impact on each individual's psychological experiences, which subsequently influences their behaviors [6]. Creating a good organizational climate is the foundation for improving employee engagement. Managers should place significant emphasis on cultivating a conducive organizational climate, particularly focusing on an atmosphere that fosters motivation, with the intention of reinforcing employee work engagement through the creation and control of such an atmosphere. By creating and managing an atmosphere through corporate culture, values, and leadership styles, employees are given a higher level of role clarity, self-worth perception, sense of work meaning, and organizational support, thereby enhancing their work engagement and ultimately achieving a win-win situation for both employees and the enterprise.

Based on this, this paper puts forward hypothesis H3: Peer initiative has a positive impact on college students' behavioral engagement.

Based on the above analysis and research hypotheses, a conceptual model (Figure 1) is constructed.

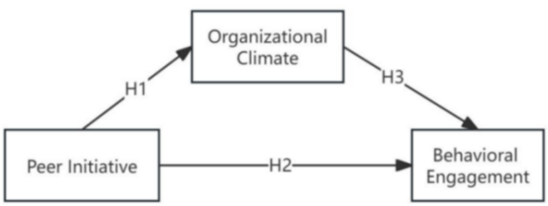

Figure 1. Conceptual Model Diagram

2.2. Scale Design

In terms of proactive behavior, based on its definition and with reference to the classification of proactive behavior by Peng Jun (2023) [7] and others, a total of four items were set up.

With regard to organizational climate, the actual situation of college students is considered.[8] Consequently, four items were set for measuring the organizational climate.

In terms of behavioral engagement, based on its definition, four items were established through expert panel discussions, considering the practical types of engagement among university students, and referencing relevant research findings by scholars on behavioral engagement.

Regarding behavioral engagement, based on its definition, four items were established through expert discussions, considering the practical types of engagement among college students, and referencing relevant research findings by scholars on behavioral engagement.

2.3. Research Subjects

Ten colleges and universities in the Guangdong-Hong Kong-Macao Greater Bay Area were selected, and a targeted online questionnaire survey was conducted among their students via the "Wenjuanxing" platform. In terms of geographical location, there are six schools located in Guangzhou, and one each in Shenzhen, Foshan, Zhuhai, and Zhongshan. In terms of selecting research subjects, targeted communication and precise distribution were adopted, basically covering various majors including science and engineering, as well as business, trade, literature and art. A total of 1083 online questionnaires were collected through Wenjuanxing platform and based on the principles of purposeful sampling and convenience sampling. 99 invalid questionnaires were excluded due to their extremely short completion time and obvious regularity in options. This resulted in a final set of 984 valid questionnaires (table 1).

Table 1. Descriptive Information Statistics

category	option	frequency	Percentage (%)
Gender	female	543	55.2
	male	441	44.8
Education	Junior college	502	51.0
	undergraduate	429	43.6
	graduate student	53	5.4
Region	Guangzhou	608	61.8
	Shenzhen	111	11.3
	Foshan	88	8.9
	Zhuhai	96	9.8
	Zhongshan	59	6.0
	other	22	2.2
Status of Student Cadres	Class cadre	230	23.4
	Youth League Committee and Student Union Cadres	98	10.0
	Other organizational cadres	74	7.5
	nothing	582	59.1

2.4. Data analysis

Using SPSS software, mean and standard deviation analyses were performed on each data point on the Likert scale, resulting in Tables 2-4

Table 2. Research data on initiative behavior

Question items	minimum value	Maximum value	mean value	standard deviation
Eu1. When encountering problems, are they always able to proactively propose ideas or suggestions?	1	5	3.93	0.727
Eu2. When faced with difficulties, are they willing to actively face and solve problems?	1	5	3.87	0.725
Eu3. When things change, are they usually able to immediately seek solutions?	1	5	3.92	0.729
EU4. Despite others' lack of autonomy, they still take it very seriously?	1	5	3.88	0.777

Table 3. Research data on organizational climate

Question items	minimum value	Maximum value	mean value	standard deviation
FU1. It cannot be denied that organizations have become better because of the proactive actions of their peers?	1	5	3.95	0.652
FU2. Members of the organization are able to support and assist each other	1	5	3.92	0.681
FU3. The enthusiasm of peers to take initiative in entrepreneurship is very high, showing a pursuit of excellence and striving for excellence	1	5	3.78	0.746
FU4. Organize a fair and reasonable evaluation of outstanding candidates	1	5	3.9	0.688

Table 4. Analysis of Behavioral Engagement Data

Question items	minimum value	Maximum value	mean value	standard deviation
GU1. Do you participate in summer social practice activities (such as going to the countryside, returning to your hometown, social research, etc.)?	1	5	2.46	1.218
GU2. Do you participate in internship (workplace experience, work internship training, etc.) activities?	1	5	2.96	1.21
GU3. Do you participate in various skill competitions?	1	5	2.59	1.141

GU4. Do you participate in employment and entrepreneurship competitions and activities such as entrepreneurship and entrepreneurship, challenge cups, entrepreneurship lectures, and career planning?	1	5	2.79	1.128

From this, it can be seen that in terms of proactive behavior and organizational climate, the mean values of all items are above three point seven, indicating that students have a high recognition of proactive behavior and organizational climate. In terms of behavioral engagement, the highest is participating in internships, and the lowest is participating in summer social practice. This is somewhat related to the sample data of students. Under normal circumstances, the group of student cadres participating in social practice is relatively large, and the proportion of ordinary students is relatively small, further verifying the reliability of the sample

3. Research Findings and Discussion

3.1. Reliability and Validity Analysis

3.1.1 Confirmatory Factor Analysis (CFA)

This study employs Mplus to conduct confirmatory factor analysis (CFA) to measure the discriminant validity among variables. According to the analysis conducted through the three-factor model, two-factor model, and one-factor model respectively, as shown in table 5, the fitting indexes of the three-factor model, namely, $\chi 2/df = 1.782$, TLI = 0.056, CFI = 0.982, and RMSEA = 0.056, are significantly better than those of other models, indicating that the discriminant validity among the main variables in this study is good.

Table 5. Model Fit Test

Fitting Indices	c2	df	c2/df	RMSEA	SRMR	CFI	TLI	Model Comparison			
								Model Comparison	Dc2	Ddf	P
1.Baseline Model (three-factor)	90.84	51	1.782	0.056	0.042	0.982	0.977				
2.Two-Factor Model	476.719	53	8.995	0.18	0.091	0.811	0.765	2vs.1	385.879	2	0.000
3.One-Factor Model	822.682	54	15.235	0.241	0.141	0.658	0.582	3vs.1	731.842	3	0.000

Note: Baseline Model: Proactive Behavior, Organizational Climate, Behavioral Engagement; Two-factor model: Based on the benchmark model, taking proactive behavior as one factor and combining organizational climate and behavioral engagement into one factor.

3.1.2 Reliability and Validity Tests

Initially, the data were imported into SPSS 23.0 software, and a factor rotation analysis was conducted on the indicators using the varimax method. Three indicators (EU1, FU4, and HU2) with factor loading coefficients below 0.5 were excluded, leaving nine remaining indicators, as presented in table 6: Dimension, Items, Unstandardized Coefficients (Unstd.), Standard Error (S.E.), Z, P-Value, Standardized Coefficients (Std.), Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE).

Table 6. Results of Reliability and Validity Tests of the Scale

Dimension	Items	Unstd. Coefficient	S.E.	Z	P-Value	Std. Coefficient	Reliability (Cronbach's α)	CR	AVE
Peer Initiative	EU2	1.000				0.751	0.922	0.847	0.651
	EU3	0.954	0.085	11.222	***	0.721			
	EU4	1.266	0.108	11.760	***	0.932			
Organizational Climate	FU1	1.000				0.938	0.855	0.908	0.768
	FU2	1.062	0.055	19.301	***	0.879			
	FU3	0.885	0.052	16.859	***	0.808			
Behavioral Engagement	HU1	1.000				0.644	0.823	0.842	0.651
	HU3	1.754	0.194	9.057	***	0.868			
	HU4	1.933	0.224	8.632	***	0.950			

The reliability and validity of the scale were tested using confirmatory factor analysis. Reliability was tested using Cronbach's alpha coefficient and Composite Reliability (C.R.). It is generally believed that when both coefficients are greater than 0.7, it indicates good internal consistency. Validity (AVE) is generally considered to be greater than 0.5, indicating good convergent validity of each dimension of the measurement model.[9] In summary, it further demonstrates that the scale data have high reliability and validity, and the latent variables such as peer initiative, organizational climate, and behavioral engagement can be well interpreted by their corresponding observed variables.

Differential validity tests were conducted on the model, and the square roots of AVE for each latent variable were greater than the correlation coefficients between the latent variable and other latent variables. The factor loadings for the measurement items of each variable in this project were greater than 0.7, and the average variance extraction (AVE) was greater than 0.5, as shown in table 7, indicating good differential validity.

Table 7. Latent Variable Differential Validity Test

dimension	Peer initiative	Organizational climate	Behavioral investment
Peer initiative	**0.807**		
Organizational climate	0.587	**0.876**	
Behavioral investment	0.258	0.331	**0.807**

Note: The bold diagonal represents the root of *AVE*, while the lower triangle represents the Pearson correlation of dimensions

3.2. Model Hypothesis Testing

Regarding commonly used fit indices CFI, TLI, RMSEA, and SRMR, it is generally accepted that a model can be considered acceptable when CFI and TLI are no lower than 0.9, and RMSEA and SRMR are no higher than 0.08[10]. This study employed structural equation modeling (SEM) to fit and conduct path analysis on the hypothetical model, and the final model demonstrated good fitness. The specific indices are presented in Table 8, all of which meet the criteria for assessing the goodness of fit of the model.

Table 8. Model Fit Test

Fitting Indices	χ^2	df	χ^2/df	RMSEA	SRMR	CFI	TLI
Reference Value	134.616	48	2.8045	0.061	0.032	0.976	0.967
Test Value	-	-	≤ 3	<0.08	<0.08	>0.900	>0.900

Table 9. Estimation of Model Path Coefficients

Hypothesis	Path Coefficient	Unstd. Coefficient	S.E.	Z	P-Value	Std. Coefficient	Result
H1	Peer Initiative → Organizational Climate	0.715	0.047	15.340	0.000	0.733	YES
H2	Peer Initiative → Behavioral Engagement	0.219	0.065	3.338	0.000	0.214	YES
H3	Organizational Climate → Behavioral Engagement	0.687	0.072	9.561	0.000	0.643	YES

The path analysis conducted on the model yielded the standardized path coefficients and their significance levels among the latent variables, as presented in Table 9. When the P-value is less than 0.05, the result is deemed statistically significant. The hypotheses were verified based on the results of the path coefficients, which indicated that the hypothetical paths H1, H2, and H3 were valid. Specifically, in terms of peer proactive behavior, proactive behavior significantly and positively impacted both organizational climate and behavioral engagement, and organizational climate also had a significant positive effect on behavioral engagement.

3.3. Mediation Effect Test

The resulting mediation path is proactive behavior → organizational climate → behavioral engagement. This study employs the Bootstrap method to test the significance of the mediating effect, with the number of resamples set to 2000 and the confidence level set at 95%. The confidence intervals of the Bootstrap mediation effect test results all exclude zero, indicating that the mediation effect is established, namely, organizational climate mediates the relationship between peer initiative and students' behavioral engagement.

4. Research Conclusion

Peer initiative has a significant positive influence on college students' behavioral engagement, and organizational climate plays a mediating role in the relationship between peer initiative and students' behavioral engagement. This indicates that peer initiative not only directly promotes students' behavioral engagement, but also further enhances this positive effect by shaping a positive organizational climate. This finding is not only of great significance to the research on college students' behavioral engagement, but also provides practical guidance for colleges and universities to create a positive organizational climate.

Firstly, it highlights the vital role of peer groups in college students' behavioral engagement, emphasizing the importance of fostering a positive atmosphere in daily college and university organization and management. When peers actively take the initiative to create a supportive and encouraging organizational climate, students are more likely to actively engage in campus activities. Secondly, in college and university organizational management, it is crucial to encourage peers to help and support each other while simultaneously fostering a positive organizational culture, which can further stimulate students' behavioral engagement.

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Perceptions Towards the Design of Mood-Based Recommendations, Challenges and Gamification in *ARthibitX* on User Experience and Satisfaction

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Abstract: The Semantic Web has improved ontological representations, information retrieval, logic, and trust. Due to the lack of a hybrid crowdsourced co-inventive design workspace in Malaysia, this study has aimed to investigate perceptions towards *ARthibitX*, our markerless AR-enhanced Digital Art virtual museum-hybrid design workspace application. With the Semantic Web as future work and adopting Baidu's success factors, we have applied Liu, van Essen and Eggen's information flow into awareness as framework; the Technology Acceptance Model, User Experience Questionnaire and Computer System Usability Questionnaire as models. Multi-modality involves factoring in semiotics, Augmented Reality (AR), and mood-based personalization. To further enhance the genetic pool, theme-based curation-crowdsourcing and discussive-reflective forums for co-discovering/co-learning/co-designing creativity are developed. A/B user testing reveals a bigger picture from the mapping of models, and a taxonomical hierarchy for more prioritized/agile personalization. Findings also confirm the complementarity between the models and the Kano. *ARthibitX* can be repurposed for UN SDG themes and location-based contexts.

Keywords: Metaverse, museums, digital Art, gig economy, co-pivot, information flow, Augmented Reality, mood-based personalized user engagement, stacks, 2-layered methodology, technology acceptance-usability-user experience, Kano, repurposing

1. Introduction

The metaverse has broadened avenues for diverse networked design potentials along Berners-Lee's [1] Semantic Web roadmap, and Li's [2] components for successful Baidu, i.e., design frameworks and models, for scalability, transformability/transfer, and deep learning to maximize multi-modal channels. Both point us to conditional interdependence in representation, computation, and transformation.

We are interested in a subset of this bigger picture, i.e., in virtual museums and hybrid design workspaces. We have chosen the virtual museum and hybrid design workspaces as the context for this study, as many museums have revolutionized Art exhibitions, due

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to the COVID-19 pandemic. Hence, it is a dynamic experimental playground. For instance, in 2009, Georgia Tech, has transformed music into abstract Art. Tate's Virtual Wing [3] has utilized Meta's Spark AR to experiment and surprise in Instagram, Singapore's Art Science Museum has enabled visitors to color pictures, scan, and see their pictures in a huge digital wall, emulating a Smart City; and China's Power Station of Art has repurposed an old power station into an Art Museum; living out Art in essence. These echo Resnick's [4] creative society framework (imagine, create, play, share, reflect, imagine) and Goel's [5] design analogy and creativity.

1.1 Problems, objectives, hypotheses and research questions

This study continues from the Creativity and Cognition Conference in 2011. Both the virtual museum and hybrid design workspaces highlight the spectrum in user experience design, in terms of repurposing and extending to suit local and global contexts, audiences/communities and cultures, via diverse hybrid communicative spaces, technology and channels (Norman [6], Kwan [7]). They also provide many opportunities to investigate Liang and Kleeman's [8] information flow between dynamical systems.

For instance, for hybrid design workspaces, Liu, van Essen, and Eggen [9] find that social cues, processing of ambiguous information, and delivery of information in ambient design (context-aware) and built-in lightweight interactions best form the design space schema. These point to Art (semiotics/ambiguity) and AR (lightweight). Meng, Liu, Huang and Wang's [10] inclusion of perceived contextual offer (PCO) and implementation intention to the Unified Theory of Acceptance 2 (UTAUT2) for their mobile visual search (MVS) study further reveal that users' perceptions towards contextual offer, performance expectancy, hedonic motivation and habit, significantly affect MVS usage intention. Also, social factors and effort do not significantly predict MVS implementation intention and usage behavior. Hence, gamification is important.

As of July 2023, there is: a) no known virtual Augmented Reality (AR)-enhanced mood-based crowdsourced digital Art Museum; b) no hybrid design workspaces, which encourage discovery/development of new networked socio-technical-economic design potentials; and c) no investigation into whether users may feel lost in a virtual museum-hybrid design workspace platform. We thus aim to design and develop:

a) a virtual museum co-pivoting with hybrid design workspaces, where each is scalable/transformable/transferable, and maximizes multi-modal channels (AR with mood-based recommendations). AR provides another layer of networked design potential, between/among embedded, embodied (generative processing) and distributed cognition (offload cognitive load).
b) two design-"compression"-prioritization layers in developing a customer journey/ product roadmap, where each layer can be used by different stakeholders (by itself or in combination), as each stakeholder would have different needs, objectives, foci, and priorities, and each instrument has its own strengths. The first layer should provide richer insights, due to mapping/triangulation/prioritization of constructs. Findings will map to the second layer (the Kano model). This would lead to a complementary (UX-UI-TAM)-Kano model methodology.

The system objectives and hypotheses are presented in Table 1.

Table 1. System objectives and hypotheses

System objectives	Hypotheses
Obj. 1: Develop a markerless AR-enhanced personalized mood-based digital Art story-telling ecosystem, *ARthibitX.*	Hypothesis 1: Mood-theme-based "Storytelling personalized recommendations will create a more immersive, tailored experience; improving Art appreciation and satisfaction
Obj. 2: Encourage creativity, community engagement and friendly competition via digital theme-based artistic challenges	Hypothesis 2: Theme-based and time-limited Artistic Challenges in *ARthibitX* will encourage artistic exploration, deeper appreciation and satisfaction.
Obj. 3: Integrate gamification elements to enhance user participation and education.	Hypothesis 3: Gamification will enhance user participation, incentivize sustained engagement and satisfaction.
Obj. 4: Assess usability, user experience and technology acceptance	Hypothesis 4: AR in *ARthibitX* will enhance exploration and higher Art appreciation, compared to systems sans AR.
Obj. 5: Gain broader insights, by mapping and triangulating models	Hypothesis 5: CSUQ-TAM-UEQ-mapped findings are complementary to the Kano model.

Our research questions (RQ) are:

1) What are respondents' perceptions towards the interactive AR Art user experience?
2) Given Liang and Kleeman's [8] information flow between dynamical systems, which criteria should be given higher priority [11] in loosely coupled ecosystems?

1.2 Scope

This study is scoped only to the AR-enhanced digital Art platform. Art is chosen due to semiotics, where different Art can create different user experiences. Curation and derivation of criteria and weights from the 2 layers for dynamic personalization have not been implemented as there is no continuation beyond the capstone. Hence, the deep learning aspects are not explored, but some algorithms are briefly reviewed.

2. Related work

2.1 Socio-cultural-technology-frameworks, user experience

Li, Liew, and Su [12] highlight that success involves not only sophisticated technology, data management and tracking, but more importantly, the augmentation/balancing of cultural-heritage-sharing elements. Coulton, Murphy, Pucihar, Smith, and Lochrie [13] also emphasize the crucial role of representation and diverse perspectives in Art curation. As such, many artists and researchers, e.g. Walmsley [14], and Dawson and Chinma [15], have highlighted the importance of artistic contextualization to facilitate cognitive decoding and more meaningful appreciation during the exhibition/performance. Else, Hurst, Spyrou, Tekinerdogan, and Krampe [16] point out that visitors may feel detached.

Technologies e.g. the *Taking the Artwork Home* app has thus enabled users to curate crowdsourced Art exhibitions at home by selecting artworks, defining AR markers, and choosing display options. Other successful examples include *Artivive* (artists create digital artworks with AR elements), and *The Virtual ARt Exhibition* by the Metropolitan Museum of Art (which invites artists to submit Met-themed Artworks for assessment).

2.2 Interaction design and technological innovation in maximizing artistic reach and audience engagement in digital Art Exhibitions

Transformation develops novelty and surprise, which in turn increases audience engagement. For instance, Brown, and Alter's [17] study highlights how Art exhibitions, enhanced by digital tools, can help at-risk youths, to make sense of their world. Furthermore, through technology, the 2011 Creativity & Cognition computational Art exhibition has modelled and transformed pre/user-selected sound into AI-generated Art. In addition, the Canada Science and Technology Museum's 'Sound by Design' (Megson [18]) has utilized presence/movement to trigger soundscapes ('Horizons'). To encourage more advanced audience explorations, Pauls and Karsakov's [19] personalized recommendations have aided discovery of a broader range of Artworks; and Kljun, Coulton and Pucihar [20] have extended Art exploration to a remixing culture via AR.

At a more personal level, Peng, Desmet, and Xue [21] emphasize that understanding the user's mood is crucial to personalizing experiences. Thus, they suggest self-reported surveys/questionnaires as explicit feedback mechanisms. Conversely, Yang, Wei, and Pu [22] have proposed implicit feedback (user interactions with the exhibits, e.g. time on a certain page, navigation patterns). The former is more subjective and usually depends on averages. The latter is more objective but is computationally more expensive.

2.3 Crowdsourced curation, artistic diversity in digital Art exhibitions

Crowdsourcing promotes dialogue, fosters inclusivity, and challenges conventional practices in digital Art curation (Murawski [23], Carletti, Giannachi, Price, McAuley, and Benford [24]). By curating a diverse range of artistic styles, themes, and perspectives, digital exhibitions can actively involve users, expanding their appreciation of the digital Art world (Giannini & Bowen [25]). For instance, a digital Art exhibit in a Cdrama, highlights three parts of a Chinese tea set, but with no title. One of the visitors titled it "The Only One," as each evolves/innovates individually (loosely coupled) to the taste, texture, and culture and synergistic with the trending tea culture.

2.4 Kano model

For open innovation e.g. Starbucks' IdeaStorm, there would be many requirements. The Kano model (Kano, Seraku, Takahashi, & Tsuji [26]) measures success and likelihood of success for new requirements, by mapping functionalities (x-axis) to customer satisfaction (CS) (y-axis). Where weighted criteria analyses are usually at the system level, the Kano model improves agility in design and development, more specifically, at the functional level. Five qualities are referred to: indifferent (no impact), must-have (basic), performance (efficient/productive/learnable), attractive (delightful), and the opposite, reverse (dissatisfied). The Kano model is chosen due to its CS-functional mapping, critical to requirements engineering, and its inherent Gaussian graphical modelling (Miyamura, & Kano [27]), which is likely to maintain Gausianness within 1-2 standard deviations, given heterogeneous sampling.

3. Methodology, system design and development

3.1 System Design

Design and development correspond with the above objectives, research questions, hypotheses, and the iterative incremental prototyping methodology. Our framework (Figure 1) and research model (Figure 2) are in line with the International Requirements Engineering Board's (IREB) [28] Requirements Engineering framework (Figure 3).

ARthibitX's proposed stakeholders are the emerging and established Artists (primary actor), admin, and curator. From Figure 4, visitors first start choosing their moods, followed by their choice of genre. Attractions from the chosen genre will then line the walls of the virtual tour's hallway. Visitors can also participate in quizzes, to increase their knowledge and appreciation of artefacts and their history. Transferring from IdeaStorm, novice artists can post their Art piece corresponding to the curator's themes to be evaluated, exhibited and if possible, monetized. Art as NFT is however, beyond us.

With regards to user experience design and evaluation, Technology Acceptance Model (TAM) 1 highlights Venkatesh and Bala's [29] Perceived Usefulness and Perceived Ease of Use, TAM 2 extrinsic motivation factors influencing Perceived Usefulness, and TAM 3, human factors influencing Perceived Ease of Use. Schrepp, Hinderks, and Thomaschewski's [30] User Experience Questionnaire (UEQ) and Lewis's [31] Computer System Usability Questionnaire (CSUQ) are applied to gain preliminary insights to pragmatic and hedonistic qualities.

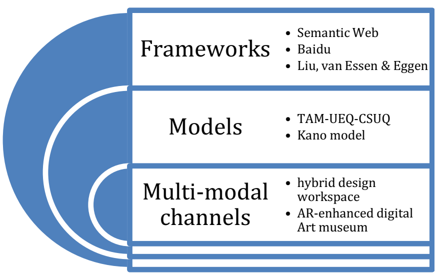

Figure 1. Overall picture

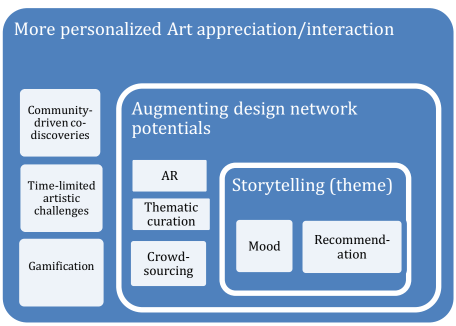

Figure 2. Research model@metaverse

Pragmatic qualities are quantified by perspicuity (ease of use), efficiency (clarity) and dependability (supportiveness). Hedonistic qualities are characterized by stimulation (interesting, exciting) and novelty (inventive, leading edge). This triangulated TAM-UEQ-CSUQ approach has gained meaningful insights in Lee's [32] prior study.

3.2 System Development

For *ARthibitX's* confirmation of user and system requirements and alpha testing, Figma is used to design, to test usability, visual aesthetics/experience. For beta testing, the Model-View-Controller (MVC) architecture handles data management, business logic, and database interaction, to ensure integrity and security. The MVC interaction flow in *ARthibitX* is coordinated, starting with user interaction in the view, triggering JS-handled events. CSS, HTML and JavaScript, with Vue.js are utilised for data binding, Three.js for immersive 3D models. phpMyAdmin handles database connections. Unity3D boosts AR experiences, and XAMPP ensures secure database interactions.

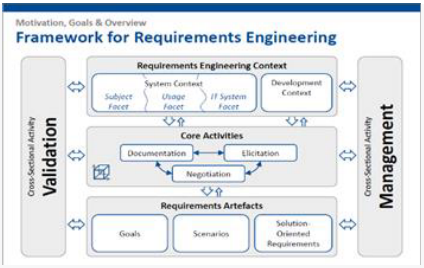

Figure 3. IREB's Requirements Engineering framework

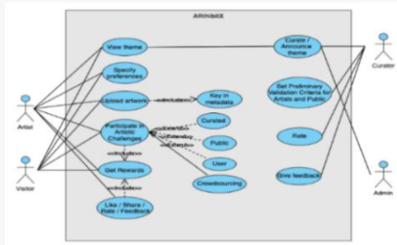

Figure 4. Use case diagram for *ARthibitX*

4. Findings

Research question 1: What are respondents' perceptions towards the interactive AR-enhanced user experience?

Alpha testing involves 30 participants, beta testing 37 participants. Both surveys are via Google Forms and distributed via the second authors' various social media groups. Hence, though convenience sampling, most of the respondents are undergraduate university students. In terms of questionnaire development, we have customized the generic UEQ, TAM, and CSUQ questionnaires to suit our objectives and hypotheses.

4.1 Alpha user testing

Sample screenshots are presented in Figures 5a, b, c, d below.

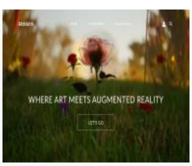

Figure. 5a. Homepage

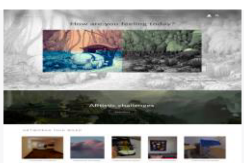

Figure. 5b. Mood-based questions, artistic challenges, weekly-featured Artworks

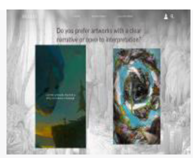

Figure. 5c. Mood-based storytelling – quiz-gamification

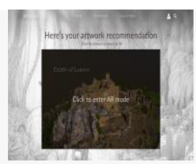

Figure 5d. Artwork recommendation with AR

4.1.1 Alpha testing demographics

There are 30 respondents for alpha testing. The majority (86.7%) are 16-30 years old, 10% are 31-45 years old. Furthermore, 50% are male and 46.7% are female. All do not have much prior experience with AR and Web-based Art platforms (Table 2).

Table 2. Demographics for alpha user testing (Likert scale 1 to 7, figures in percentage)

	1	2	3	4	5	6	7
Have you used AR applications before? If yes, rate your proficiency in using Web-Art platforms.	26.7	10.0	16.7	13.3	13.3	16.7	3.3

4.1.2 General UEQ-CSUQ-TAM alpha testing results

Table 3 presents the UEQ results first. Pragmatic (P) factors are mapped to TAM's ease of use and usefulness, hedonistic (H) factors to TAM's anchor and adjustment. There are no counts for Likert scales 1 and 2. For Likert scale 3, the result is 10%. To be consistent with CSUQ and TAM, the average over 7 in Table 2 is converted to over 5.

Table 3. Alpha user testing's UEQ-CSUQ-TAM results (Likert scale 1 to 7, in percentages)

Question	4	5	6	7	Avg. (/7)	Avg. (/7)	Avg. (/5)
UEQ							
Navigating through the exhibits was **intuitive** (P)	10.0	13.3	43.3	26.7	5.70		
The information and details by the Artwork are **clear and informative**. (P)	10.0	13.3	43.3	20.0	5.40	5.55	3.96
The recommendation in ARthibitX provided **relevant and interesting** Artworks. (P, H)	10.0	26.7	23.3	36.7	5.73	5.73	4.09
The visuals and presentation of the Artworks were **appealing and engaging** (H)	3.3	6.7	33.3	50.0	6.07		
The interaction with 3D models and exhibits was **enjoyable, immersive**. (H)	3.3	20.0	30.0	40.0	5.87	5.97	4.26
How **unique and innovative** is ARthibitX as a digital Art exhibition platform? (H)	3.3	10.0	36.7	46.7	6.13	6.13	4.38
Overall Average						5.82	**4.15**

CSUQ is decomposed into 4 categories (row headings in bold). Results for each category are presented in Table 4 below. The user testing results remain very promising.

Table 4. Alpha testing's CSUQ categorical decompositions and overall project performance (% in brackets)

Satisfaction, information quality, productivity (CSUQ)	**3**	**4**	**5**	**Avg.**
Usability and user experience				
How would you rate the overall **usability** of *ARthibitX?*	10 (33.3)	13 (43.3)	6 (20)	4.07
How easy was it to **navigate** *ARthibitX's* different sections*?*	10 (33.3)	10 (33.3)	9 (30)	4.05
How easy was it to **access/use** *ARthibitX* on your device*?*	8 (26.7)	9 (30.0)	12 (40)	4.17
Average				**4.10**
Information quality, learnability and recovery	**3**	**4**	**5**	**Avg.**
Did you encounter any difficulties while interacting with the 3D models in the exhibition? (I feel comfortable using this system/It was easy to learn to use this system)	11 (36.7)	4 (13.3)	4 (13.3)	2.74
How satisfied are you with the level of support and guidance provided throughout your experience with *ARthibitX*? (Whenever I make a mistake with the system, I recover easily and quickly/The information provided with this system, including introduction, user guides, is clear, organized, effective and easy to understand).	11 (36.7)	10 (33.3)	8 (26.7)	3.98
Average				**3.36**
Interface design and satisfaction	**3**	**4**	**5**	**Avg.**
How satisfied are you with the performance and responsiveness of *ARthibitX*? (The interface is pleasant. I like using it).	8 (26.7)	11 (36.7)	10 (33.3)	4.14
How would you rate the clarity and intuitiveness of the user interface in *ARthibitX*? (The interface is pleasant. I like using it).	10 (5.4)	10 (33.3)	9 (30.0)	4.10
How well did *ARthibitX* meet your expectations as a digital Art platform? (This system has all the functions/capabilities I expect).	9 (30.0)	10 (33.3)	10 (33.3)	4.05
Overall, how satisfied are you with the for showcasing/exploring experience of digital Art? (Overall, I am satisfied with the system).	6 (20.0)	10 (33.3)	13 (43.3)	4.31
Average				**4.10**
Overall project objective performance evaluation	**3**	**4**	**5**	**Avg.**
How satisfied are you with *ARthibitX's* level of interactivity?	6 (20.0)	12 (40.0)	11(36.7)	4.29
How likely will you recommend *ARthibitX* to other digital enthusiasts?	8 (26.7)	13 (43.3)	8 (26.7)	4.07
How satisfied are you with *ARthibitX*'s personalized recommendations?	7 (23.3)	13 (43.3)	9 (30.0)	4.19
Did *ARthibitX's* artistic challenges inspire creativity/participation?	7 (23.3)	13 (43.3)	11(36.7)	4.26
Were the curated artworks well-organized and presented coherently?	10 (33.3)	12 (40.0)	8 (26.7)	4.07

How likely are you to use *ARthibitX* to exhibit your digital Artworks?	8 (26.7)	11 (36.7)	11(36.7)	4.21
How innovative do you find ARthibitX as a digital Art platform?	4 (13.3)	10 (33.3)	14(46.7)	4.38
Average				**4.21**

4.2 Beta prototype improvements based on alpha testing insights

The alpha testing has revealed challenges in 3D model interaction in *ARthibitX's* exhibition hall, leading to changes in the beta prototype. To address unfamiliarity, a user guide is introduced. Familiar navigation, e.g. placing key features in the top menu bar, incorporating a home and a progress button, have enabled the user to quickly revert back to the top of the respective page. Optimizations, including a 'light mode,' have improved loading times; enhancing the overall 3D model interactions, and user experience for a seamless digital Art interactive journey.

4.3 Beta testing results

For beta user testing, questions are more concerned with value proposition. These are: channel preference, frequency in contributing to crowdsourcing, degree to which *ARthibitX* creates a dynamic inclusive space for developing perspectives and artefacts, degree that gamification engages, degree to which personalized digital Art storytelling outcomes meet preferences and mood, and the degree to which *ARthibitX* transforms interaction to become more innovative/immersive.

The corresponding CSUQ categories and the overall project performance evaluation are presented in Table 5. Only frequency and percentages above Likert scale 3 are shown. The overall objective performance's average is highest, followed by interface design and satisfaction, information quality, learnability and recovery, usability and user experience.

Table 5. Beta user testing CSUQ categories and the overall project performance evaluation (% in brackets)

Satisfaction, information quality, productivity (CSUQ)	**4**	**5**	**Avg,**
Usability and user experience			
Overall, my experience with *ARthibitX* was satisfactory.	19 (51.4)	18 (48.6)	4.49
I can efficiently navigate and engage with the features in *ARthibitX*.	19 (51.4)	18 (48.6)	4.49
I can swiftly interact with *ARthibitX's* functionalities.	18 (48.6)	16 (43.2)	4.35
I can effectively utilize *ARthibitX* for the intended activities.	21 (56.8)	15 (40.5)	4.38
Average			**4.43**
Information quality, learnability and recovery			
I feel comfortable using this system.	15 (40.5)	22 (59.5)	4.59
It was easy to learn to use this system.	17 (45.9)	20 (54.1)	4.54
When I make a mistake with the system, I recover easily, quickly	21 (56.8)	15 (40.5)	4.38
The information provided with this system, including introduction, user guides, is clear, organized, effective and easy to understand.	22 (59.5)	15 (40.5)	4.41
Average			**4.48**
Interface design and satisfaction			
The interface is pleasant. I like using it.	8 (21.6)	29 (78.4)	4.78
This system has all the functions and capabilities I expect it to have.	23 (62.2)	12 (32.4)	4.27
Overall, I am satisfied with this system.	**15 (40.5)**	**22 (59.5)**	**4.59**
Average			**4.55**
Overall project objective performance evaluation	**4**	**5**	**Avg,**
Q1: To what extent do you feel the platform fosters a dynamic and inclusive space for diverse digital artworks and perspectives?	10	**27** (72.9)	4.73
Q2: How engaging are gamification elements in the digital artistic challenges?	**20** (54.1)	17 (45.9)	4.46

Q3: Did you find the personalised digital art storytelling feature aligning well with your unique preferences and emotional disposition?	13 (35.1)	**23** (62.2)	4.59
Q4: Has *ARthibitX* transformed the way you interact with digital art, making it more immersive and innovative?	16 (43.2)	**21** (56.8)	4.57
Average			**4.59**

4.3.1 CSUQ-TAM-UEQ alpha-beta testing comparisons

Research question 2: Which criteria should be given higher relative importance in loosely coupled interconnected ecosystems?

Table 6 presents the mapping/triangulation between CSUQ-UEQ-TAM and differences between alpha-beta testing outcomes (from left to right). The foundation is taxonomical, parallel to the Open Systems Integration (OSI) model, providing an instantiation to Liang and Kleeman's [8] information transfer between dynamical system components. The taxonomy involves information quality, learning and recovery (contributing to usability in terms of well-structured coherence, clarity, ease of use) at the base. This is followed by user experience (interactivity). Interface (contextual offer e.g. aesthetics, theme-based curation, mood-based storytelling/personalized recommendations, artistic challenges, and gamification) contributes to attractiveness/satisfaction.

The overall objective system performance suggests that users are likely to recommend and use *ARthibitX*, due to the inclusive dynamic/personalized multi-perspective design space, discussive/evaluative/reflective forum (and possible monetization). Moreover, the two top AB testing differences (CSUQ's interface and satisfaction at 1.59 and usability and user experience at 1.12), point to the navigation menu. Its importance is confirmed in Table 7 and supports Lee and Yeap's [33] findings.

In terms of averages, the highest is usability, user experience (interactive, immersive, innovative) at 87%; followed by interface (and corresponding contextual offer) and satisfaction at 85%; overall objective system performance and key value proposition at 83%. The foundation (information, learnability (structure, clarity and ease of use) and recovery) at 81% average would require more improvements.

Table 6. CSUQ alpha and beta testing results mapped to/triangulated with TAM-UEQ

	Avg. (α)	**Avg. (β)**	**Diff**	**Alpha**	**Beta**	**Diff.**	**UEQ**
Overall objective system performance **(UEQ/TAM)**	4.21	4.59	0.34	Will personally use for future exhibitions? 4.21 Will recommend? 4.07 **Average = 4.14 (83%)**	Dynamic & inclusive space for diverse digital artworks/perspectives? **4.73 (95%)**	0.59	Supportive, efficient
CSUQ							
CSUQ: Interface & satisfaction	4.10	4.55	1.59	Artistic challenges 4.26 Personalized recommendation 4.19 **Average = 4.23 (85%)**	Gamification 4.46 Personalised mood-based digital Art storytelling 4.59 **Average = 4.50 (90%)**	0.27	Easy, efficient, interesting, exciting
CSUQ: Usability, user experience	4.10	4.43	1.12	Interactivity 4.29 Unique, innovative 4.38 **Average = 4.34 (87%)**	Immersive, innovative **4.57 (91%)**	0.23	Inventive
CSUQ: Info. Q, learnability, recovery	3.36	4.48	0.46	Curated work well-organized, coherent Average = 4.07 (81%)			Clear, easy

Figure 6a presents the corresponding matrix view, Figure 6b the "decision tree" view.

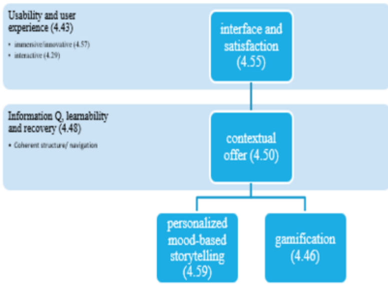

Figure 6a. Matrix view

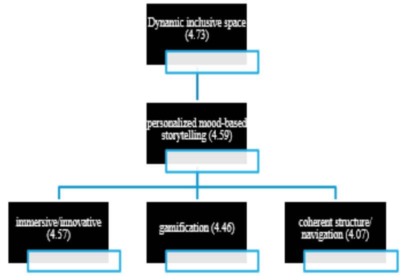

Figure 6b. Decision tree view

In addition, to determine the beta assignments, an interview is carried out with a focus group of 25 people, via Zoom. Participants are requested to specify 5 positive aspects, 5 negative aspects, and 5 desired features during the virtual session. Responses to Kano model's five qualities (attractive, performance, must-have, indifferent, and reverse) range from a Likert scale of 1 to 5.

The Kano model analysis considers the highest counts for an intersecting column/quadrant, as belonging to that respective column/quadrant. Findings are presented in Table 7. Table 7 confirms findings from Tables 5 (averages) and 6, that the biggest attraction is possible monetization within a dynamic, inclusive, personalized design workspace. Hence, hypotheses 1-4 are supported. (CSUQ-TAM-UEQ)-Kano mapped findings also confirm hypothesis 5, i.e., being complementary in gaining broader insights, similar to Oracle's cube aka Rubic's cube.

Table 7. Derived beta testing assignment of functionalities to qualities

Must-have
Easy Navigation (81%), Weekly Top Picks (78%), Clear User Guide (78%), Responsive Design (69%)
Performance
Immersive Features (92%), Artwork Curation (85%), Artistic Challenges (83%), Personalised Storytelling (79%), and a Nice UI/UX (79%)
Attractive
Uniqueness and innovativeness (94%), colour tone (92%), functional forms and buttons (89%)
Reverse
Lag and Performance Issues (45%), Absence of a Settings Page (28%) and the Lack of Social Features (19%)

5. Conclusions

We have framed our study within Berners-Lee's [1] Semantic Web roadmap, Li's [2] successful Baidu components, instantiated and attempted to optimize Liang and Kleeman's [8] information flow between dynamical systems to the virtual museum-hybrid design workspace context, and developed a modular/stack-based ontological system to structure, populate content, increase agility, scalability, transfer/ transformability. Findings have elicited users' preferences, led to the matrix, decision tree and Kano views, and extend prior studies on creativity, design thinking, Computational Thinking (CT)-Human-Computer Interaction (HCI) scaffolds [34-36].

An example of a metaheuristic is [37]'s exponential counterfactual regret minimization (ECFR). It traverses all nodes, then matches the next best strategy in the subsequent iteration with the current/local alternatives and redistributes the weight of the regret factor (risk). Due to diversity in contexts, we regard [11]'s weighted criteria analysis as generic method. Baseline research, e.g. in SMC 2024, is critical to assess the model's representativeness, reference, validation, incremental evolution, and stability.

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Current Situation and Progress of Green Electronic Supply Chain Management

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Abstract. With the increasingly serious global environmental problems, green supply chain management has gradually become an important strategy for enterprise sustainable development and environmental protection. Especially in the electronic information manufacturing industry, the implementation of green electronic supply chain management is of great significance to reducing resource consumption, reducing environmental pollution and enhancing the competitiveness of enterprises. This paper aims to analyze the current situation of green electronic supply chain management, discuss its development trend, and put forward the optimization path and strategy of green electronic supply chain management in the future through typical cases at home and abroad. It is concluded that although some achievements have been made in green electronic supply chain management, it still faces many challenges. Enterprises should take the initiative to assume the corresponding social responsibilities. In the future, with the further improvement of regulations and standards, and the continuous improvement of the information and intelligence level, the green electronic supply chain management will bring a broader development prospect.

Keywords. Green; electronic information manufacturing; supply chain management

1. Introduction

1.1 Research background

Our life has gradually entered the era of intelligent big data. [1] With the improvement of environmental awareness, enterprises also pay more and more attention to green supply chain management, that is, taking environmental protection measures in every link of the supply chain, including raw material procurement, manufacturing, logistics and transportation, to reduce the negative impact of enterprises on the environment. Green supply chain management can significantly improve the environmental performance of enterprises, reduce production costs and enhance market competitiveness by optimizing resource allocation, reducing pollution and resource waste.

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1.2 Research meaning

With the rapid development of science and technology, the electronic information manufacturing industry has become one of the pillar industries of the global economy. [2] However, the problems of energy consumption, waste discharge and the use of harmful substances generated in the production process of the electronic information manufacturing industry have become increasingly prominent, which have caused a serious impact on the environment. Zhang Peiyu, Sun Tingting and Li Haiyi pointed out that " green manufacturing is the fundamental way to solve the problems of resource and energy consumption, ecological environment and health and safety of the manufacturing industry."[3] Therefore, the introduction and practice of green electronic supply chain management has become an effective way to solve these problems.

1.3 Research method

1) **Case analysis method:** Through an in-depth analysis of the green supply chain management practices of typical enterprises at home and abroad, such as Lenovo Group, Huawei, Apple and HP, we summarize their successful experience and challenges. These companies have a large business scale and market share worldwide and come from different regions and industry backgrounds, with diversified business models and market positioning. Lenovo Group and Huawei are leaders in China's technology industry, while Apple and HP are world-renowned electronics manufacturers who have achieved some successful experience and innovations in green supply chain management.
2) **Regulations and standards comparison method:** Compared with the domestic and foreign policies, regulations and standards of green supply chain management, and analyzed its promoting role of green electronic supply chain management.
3) **Trend-based forecasting:** Based on the current situation and development trend of green electronic supply chain management, the development direction of green electronic supply chain management in the future.

1.4 Theoretical principle

1) **The concept of green Development:** The core theoretical basis of green electronic supply chain management is the concept of green development, that is, in the process of economic development, environmental protection and rational utilization of resources should be fully considered, to achieve a win-win situation of economic benefits and environmental benefits. This concept runs through the whole life cycle of electronic products, including procurement, production, transportation, use and recycling links.
2) **Sustainable development theory:** Sustainable theory emphasizes meeting current needs without compromising the ability of future generations to meet their needs.
3) **Supply Chain management theory:** Supply chain management theory involves the integration and coordination of internal and external resources to ensure the production, delivery and service of products to meet customer needs. On this basis, the green electronic supply chain management has increased the consideration of environmental protection.

2. Current status of green electronic supply chain management

2.1 Status quo of domestic research

1) **Policy environment:** In recent years, the Chinese government attaches great importance to the development of green supply chain management, and has introduced a series of policies, regulations and standard systems. For example, the Law on the Promotion of Circular Economy of the Peoples Republic of China, the Measures for the Pollution Control and Management of Electronic Information Products and other laws and regulations have put forward clear requirements for the design, production, sales and recovery of electronic products. In addition, China also actively promotes the formulation and implementation of national standards for green supply chain, such as the release of the "Green Supply Chain Management Standards for Electronic Information Manufacturing Enterprises".
2) **Enterprise practice:** The concept of green supply chain is still relatively unfamiliar to Chinese enterprises and all sectors of society, [2] with insufficient understanding of green supply chain among all parties. However, some leading companies in China's electronic information manufacturing industry, such as Lenovo Group and Huawei, have already achieved significant results in green supply chain management.
3) **Technical support:** Domestic research also focuses on the application of technical support in green electronic supply chain management, such as the application of advanced technologies such as the Internet of Things, big data, and artificial intelligence, which provides strong support for the transparent management, precise decision-making and intelligent control of the supply chain. Yang Chaojun et al. (2015) believe that the green supply chain management of enterprises will have a negative impact on enterprise value in the short term, but under the long-term management, improving the competitive advantage of enterprises will have a positive impact on enterprise value. [4]

2.2 Current situation of overseas research

1) **Policy environment:** Internationally, European and American countries and Japan and other developed countries have established a relatively perfect green supply chain management system. The EU has promoted the construction of a green supply chain system in the electronic and electrical industry by implementing the Scrapped Electronic and Electrical Equipment directive (WEEE) and the directive on the Prohibition of Certain Hazardous Substances in Electronic and Electrical Equipment (RoHS). In the United States, enterprises are encouraged to carry out green supply chain management practices through the EPAs environmental design projects and green supply chain goals.
2) **Corporate practice:** Liu Bochao pointed out that " green supply chain management requires enterprises to pay attention to environmental protection, energy saving and emission reduction in the closed loop of the whole life cycle.[5] International electronics giants such as Apple and HP have also made active exploration in green supply chain management. By implementing the "Green Manufacturing Plan", Apple requires its suppliers to comply with strict environmental protection standards to promote the overall green transformation of its supply chain. HP has continuously improved the greening degree of its supply chain by introducing the goal of green supply chain and establishing a green supplier evaluation system. Some factors were

also found to adopt green supply chain management practices, such as stakeholder pressure, customer-related issues, corporate environmental issues, the impact of environmental regulations and standards, and cost reduction.[6]

3) **Research focus:** Foreign scholars first began to study green supply chain management in 1994. At first, Webb (1994) proposed the concept of "green procurement", and green electronic supply chain management originated from green procurement [7]. Foreign research pays more attention to the theoretical framework construction and empirical research of green electronic supply chain management. Through case analysis, model establishment and other methods, the mechanism, effect and influencing factors of green supply chain management are deeply discussed.

4) **Technology and innovation:** Foreign research also focuses on the application of technological innovation in green electronic supply chain management, such as the research and development and application of new materials, new processes and new energy technologies, as well as the development of intelligent equipment and systems, which provides more efficient solutions for green supply chain management.

3. The development trend of green electronic supply chain management

3.1 Regulations and standards have been further improved

With the increasingly severe global environmental problems, governments will increase their policy support for green supply chain management, and further improve the relevant regulations and standard system. This will provide a clearer direction and basis for the implementation of green electronic supply chain management and promote its development to standardization and standardization.

3.2 The level of information technology and intelligence has been continuously improved

With the rapid development and application of information technology, the information and intelligence level of green electronic supply chain management will continue to improve. Using advanced technologies such as the Internet of Things, big data and artificial intelligence, the transparent management, precise decision-making and intelligent control of the supply chain are realized, and the efficiency and effect of green supply chain management are further improved.

3.3 Green supply chain management extends to the whole life cycle

In the future, the green electronic supply chain management will pay more attention to the green management of the whole life cycle of products. From product design, raw material procurement, manufacturing, logistics and transportation, use and maintenance, recycling and other links, will be included in the scope of green supply chain management.

3.4 The synergistic role of industrial chains was strengthened

The implementation of green electronic supply chain management requires the joint participation and cooperation of upstream and downstream enterprises in the industrial chain. In the future, the synergy of the industrial chain will be further enhanced, and enterprises will establish closer cooperative relations to jointly promote the implementation and development of green supply chain management.

4. Case analysis

4.1 State Grids green supply chain practices

In recent years, people's concept of green development is gradually enhanced, many companies take the initiative to take active green measures, to improve the green competitiveness of enterprises.[8] As a leading enterprise in Chinas energy and power industry, State Grid Co., Ltd. has made active exploration and practice in green supply chain management. The company promotes a series of measures, such as building the state grid green chain construction, leading the supply chain ecology, leading the standard system construction, and providing the digital intelligence of the supply chain. By 2025, State Grid plans to basically build a supply chain leading enterprise with market competitiveness, industry leading power and reaching the international leading level.

4.2 Green supply chain management of Lenovo Group

As one of the leading enterprises in Chinas electronic information manufacturing industry, Lenovo Group has made remarkable achievements in green supply chain management. By building a green supply chain management system, promoting green design, optimizing the production process, and adopting clean energy, the group has achieved the green management of the whole life cycle of its products. In addition, Lenovo Group also actively participates in the formulation and implementation of green standards at home and abroad and promotes the standardized development of green supply chain management in the industry. Its successful practice of green supply chain management has set a benchmark for the green development of Chinas electronic information manufacturing industry.

5. Existing problems and countermeasures

5.1 Open question

1) **Large energy consumption and waste emissions:** Electronic information manufacturing industry needs a lot of energy and raw materials, and at the same time produces a lot of waste and pollutants, which has a serious impact on the environment. The supply chain is complex, and it is difficult to comprehensively supervise the source and production process of raw materials, and there are certain transparency problems.

2) **Supply-chain partnerships are unstable:** Partnerships between supply chain member enterprises are prone to become unstable by conflicts of interest. Especially in the sharing of the implementation of green supply chain cost issues, easy to conflict.
3) **Insufficient technology and management level:** Green supply chain management needs the strong support of science and technology, but Chinas talent reserve in this aspect is relatively scarce, and the level of technology and information level is not high.
4) **The performance evaluation system is not perfect:** The current enterprise performance evaluation indicators often ignore the measurement of environmental pollution and resource use, and it is difficult to accurately reflect the effect of green supply chain management.
5) **Capital pressure of small and medium-sized enterprises:** Due to limited funds, small and medium-sized enterprises cannot bear high environmental protection costs, which limits their development in green supply chain management.

5.2 Countermeasures and suggestions

1) **Strengthen energy management and waste disposal:** Electronic information manufacturing enterprises should strengthen energy management and reduce energy consumption and waste emissions through technical improvement and management measures. Introduce advanced waste treatment technology to improve the recycling rate of waste and reduce environmental pollution.
2) **Establish a stable supply chain partnership:** By establishing long-term partnerships, the member companies in the supply chain can work together for the same profit and environmental goals. Strengthen communication and coordination, share the costs of implementing the green supply chain, and avoid conflicts of interest.
3) **Improve the technology and management level:** Increase the investment in the research and development of green supply chain management technology, train relevant talents, and improve the level of technology and information technology. Introduce advanced green supply chain management concepts and methods, establish scientific measurement standards, and improve the management effect.
4) **We will improve the performance evaluation system:** Establish a sound performance evaluation system, including environmental pollution and resource use into the evaluation indicators, to fully reflect the effect of green supply chain management.

6. Research Contribution and Limitations

6.1 Research contributions and innovation points

1) **Comprehensive analysis of the current situation:** This paper makes a comprehensive analysis of the current situation of green electronic supply chain management at home and abroad, covering the policy environment, enterprise practice and technical support. Through specific cases, such as the green supply chain management practices of enterprises such as Lenovo Group, Huawei, Apple and HP, the successful experience and achievements of these enterprises in reducing resource consumption, reducing environmental pollution and improving their competitiveness are demonstrated.

2) **Trend forecast is accurate:** The paper accurately predicts the development trend of green electronic supply chain management, including the further improvement of regulations and standards, the continuous improvement of the information and intelligence level, the extension of green supply chain management to the whole life cycle, and the enhancement of the synergy of the industrial chain. These predictions provide an important reference for enterprises and governments to promote green electronic supply chain management in the future.
3) **Countermeasures and suggestions are practical:** In view of the current challenges faced by green electronic supply chain management, such as inadequate understanding, imperfect system and mechanism and technical bottleneck, the paper puts forward feasible countermeasures and suggestions, which provide an effective path for enterprises to improve the level of green supply chain management.
4) **Combining theory with practice:** This paper not only analyzes the theoretical framework of the management of green electronic supply chain, but also shows the application of theory in practice through specific cases. This combination of theory and practice enables readers to have a deeper understanding of the connotation and importance of green electronic supply chain management.

6.2 Study limitations

1) **Data update lag:** Although the paper provides rich background information and case analysis, there may be some lag in the update of some data and policy information. With the continuous development of global green supply chain management, new policies, regulations and technology applications are constantly emerging, and relevant data and cases need to be updated regularly to maintain the timeliness of research.
2) **Regional limitations:** The paper mainly focuses on some typical electronic information manufacturing enterprises and policy environment at home and abroad, but the green electronic supply chain management practices in other regions and industries may involve less. Therefore, regional and industry differences should be considered when promoting and applying relevant experiences and results.
3) **Insufficient technical details:** Although the paper mentions the application of information technology, Internet of Things technology and big data technology in green electronic supply chain management, the specific implementation details and effect evaluation of these technologies may be less involved. Future studies could further explore the application details and practical effects of these techniques.

7. Conclusion

Green electronic supply chain management is an important way for the electronic information manufacturing industry to achieve sustainable development and environmental protection. Zhu Hongbin pointed out that "in order to help achieve the goal of" double carbon ", energy enterprises should take the initiative to assume corresponding social responsibilities and actively carry out and apply green supply chain management."[2]Zhang Shengmei also reached the conclusion through case analysis that the implementation of green supply chain management mode can promote the improvement of economic benefits of enterprises.[9]Many senior managers were interviewed in the plant E article, and although not all respondents really understand green supply chain management, they all believe it will be a necessary part of the future of electronics manufacturing.[10]In the future, with the further improvement of regulations and standards, the continuous improvement of information and intelligence level, and the enhancement of the synergy of the industrial chain, green electronic supply chain management will usher in a broader development prospect. For managers, the paper reveals the necessity and urgency of implementing green supply chain management. Through the successful cases of typical enterprises at home and abroad, managers can learn advanced green supply chain management strategies and best practices. The experiences and practices help managers to promote the implementation of green supply chain management within their enterprises. For policy makers, the research results of this paper provide an important reference for them to formulate and improve the relevant policies and regulations of green supply chain management. The paper also emphasizes the importance of information technology and intelligence level in green supply chain management, which provides useful ideas and inspiration for policy makers to promote the deep integration of information technology and green supply chain management.

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Assessing the Impact of Sustainable Practices on Green Supply Chain Management: Study on Organizational Environmental Management

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Abstract. In the contemporary business environment, the integration of sustainable practices is pivotal for enhancing the environmental performance and operational efficiency of supply chains. This study investigates the influence of Organizational Environmental Management (OEM) on the implementation and effectiveness of Green Supply Chain Management (GSCM). The proposed model identifies four critical sustainable practices Investment Recovery, Sustainable Distribution, Sustainable Design, and Sustainable Procurement and examines their impacts on green supply chain management performance. Using "Partial Least Squares Structural Equation Modeling (PLS-SEM)" software, this research analyzes data from a sample size of 365 individuals. The study posits that sustainable practice significantly contributes to green supply chain management. Additionally, the model evaluates the role of organizational environmental management in fostering these sustainable practices, emphasizing the importance of organizational commitment to environmental management. The study further explores the overarching influence of organizational environmental management on the holistic implementation of "green supply chain management", proposing a comprehensive approach to embedding sustainability within supply chain operations. The findings offer valuable insights for organizations and supply chain managers seeking to enhance their "green supply chain management" strategies through effective sustainable practices. Through clarifying the links between green supply chain management and organizational environmental management, this study offers a strong foundation for creating more sustainable and effective supply chain operations. This study contributes to the subject of sustainable supply chain management by underlining the crucial role of organizational environmental management in fostering environmental sustainability across the supply chain.

Keywords. Organizational Environmental Management, Investment Recovery, Sustainable Distribution, Sustainable Design, Sustainable Procurement, and Green Supply Chain Management

1. Introduction

In the quickly changing corporate environment of today, integrating sustainable practices within supply chains has become crucial for organizations aiming to enhance

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environmental performance and operational efficiency. The urgency of global challenges such as “climate change, resource depletion, and biodiversity loss” has led stakeholders including customers, investors, and regulatory bodies to demand greater corporate accountability regarding environmental impact [1]. In response, businesses are compelled to incorporate sustainability into their core operations, particularly within supply chain management (SCM). This shift not only meets external demands but also offers opportunities for cost savings, improved brand reputation, and innovation [2].

This study focuses on the role of Organizational Environmental Management (OEM) as a key factor in shaping Green Supply Chain Management (GSCM). OEM includes strategies and practices aimed at improving environmental performance, such as ISO 14001 certification, compliance with environmental regulations, and promotion of sustainable operations [1]. While research has highlighted OEM's importance in driving sustainable practices, a notable gap remains in understanding how OEM specifically influences GSCM's implementation and effectiveness.

External pressures, such as regulatory demands and market expectations, are often seen as key drivers for adopting sustainable practices in supply chains [3, 4]. However, these alone may be insufficient to ensure sustainability is integrated into organizational practices. Additionally, previous studies have identified critical sustainable practices including Investment Recovery (IR), Sustainable Distribution (SD), Sustainable Design (SDI), and Sustainable Procurement (SP) as essential components of GSCM [3] . These practices align with sustainability goals and reflect an organization's commitment to sustainable operations. However, the relationships between these practices and their collective impact on GSCM performance are underexplored, and their role as mediators in the OEM-GSCM link remains unclear [5] [2].

To address these gaps, this study aims to explore:

1. How does Organizational Environmental Management influence the adoption of sustainable practices within supply chains? 2. What are the direct and indirect impacts of IR, SD, SDI, and SP on GSCM performance? 3. How do these sustainable practices mediate the relationship between OEM and GSCM?

2. Background

Managers play a crucial role in advancing organizational environmental theory, implementing green practices, and steering companies toward sustainability. The growing demand for management strategies that prioritize sustainability is highlighted by [1] who emphasize the positive impact of green innovation on organizational satisfaction and corporate identity. Green identity and creativity are key drivers of green innovation, and organizational identity mediates the relationship between innovation policy, green identity, and green [6] Embracing green innovation not only supports sustainable growth but also enhances market competitiveness, as green-focused businesses often outperform less sustainable counterparts [7]. Additionally, green innovation has been linked to improved labor productivity and business performance, particularly in companies oriented towards customer needs [8] [7].

Globalization has driven intense competition and a focus on sustainable supply chains. Many businesses now adopt risk management, supply chain integration, adaptability, and agility to gain a sustainable advantage in a volatile environment [6]. Sustainable supply chains require continuous learning and improvement in core competencies, both within companies and across strategic partnerships [9]. Current research emphasizes the importance of acquiring, integrating, and utilizing knowledge to enhance dynamic capabilities in supply chain management [10].

Organizational Environmental Management (OEM) involves implementing environmentally sustainable practices supported by senior management, such as ISO 14001 certification and environmental auditing [6]. Both internal motivations and external pressures, such as regulatory demands, are essential in driving the adoption of GSCM strategies [9]. Sustainable procurement, a key component of GSCM, benefits from OEM by optimizing benefits while minimizing negative impacts on the economy, society, and environment [2].

3. Method

Employees from various small- and medium-sized and multinational manufacturing companies in Dhaka, Bangladesh, are the study's target demographic. For this study, we focused on 350 manufacturing industries, and between February and May of 2024, we gathered data. First, we intended to collect information from 529 workers to obtain a greater amount of data. Nonetheless, we were able to gather replies from 378 participants across a range of businesses. This accomplishment corresponds to a 69% response rate. It should be mentioned that missing values caused 13 replies to be disqualified throughout the data screening procedure. Consequently, there are 365 people in our final sample. This sample size is in line with the conclusions of other studies, who state that when each variable includes three or more items, a sample size of 100 or more is sufficient for convergence. Moreover, they are used for further analysis in this study. The sample size selected for our study adheres to the guidelines suggested by various scholars. Research indicates that a sample of 100 or more is adequate for achieving convergence when each variable includes three or more items[11]. Specifically, [12] recommend a sample size of 150 as suitable for obtaining a convergent and reliable solution. Similarly, [13] [14] advocate for a sample size between 50 and 100 when employing structural equation modeling (SEM). With Smart PLS software, data analysis has been conducted. The study employed a quantitative research design methodology, and every item on the questionnaire was taken from an earlier investigation.

Hypothesis 1$_a$: “Organizational environmental management” has positive effect on “investment recovery”.

Hypothesis 1$_b$: “Organizational environmental management” has positive effect on “sustainable distribution”.

Hypothesis 1$_c$: “Organizational environmental management” has positive effect on “sustainable design”.

Hypothesis 1$_d$: “Organizational environmental management” has positive effect on “sustainable procurement”.

Hypothesis 2$_a$: Investment recovery has a positive effect on “green supply chain management”.

Hypothesis 2$_b$: Sustainable distribution has a positive effect on “green supply chain management”.

Hypothesis 2$_c$: Sustainable design has a positive effect on “green supply chain management”.

Hypothesis 2$_d$: Sustainable procurement has a positive effect on “green supply chain management”.

Hypothesis 3: "Organizational environmental management" has a significant effect on "green supply chain management".

Hypothesis 4a: Investment recovery mediates the relationship between "organizational environmental management" and "green supply chain management".

Hypothesis 4b: Sustainable distribution mediates the relationship between "organizational environmental management" and "green supply chain management".

Hypothesis 4c: Sustainable design mediates the relationship between "organizational environmental management" and "green supply chain management".

Hypothesis 4d: Sustainable procurement mediates the relationship between "organizational environmental management" and "green supply chain management".

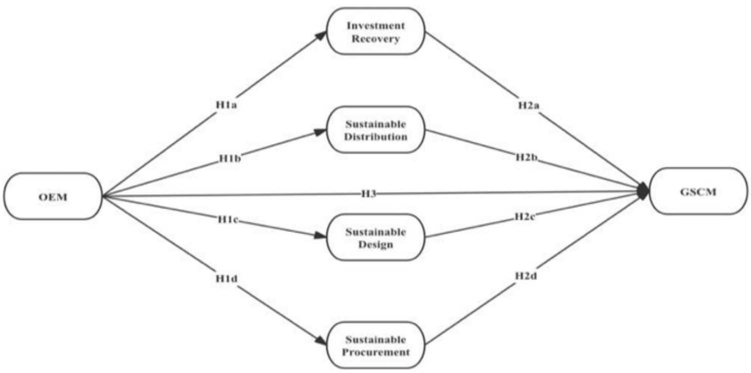

Figure 1: Theoretical Framework

4. Result

H1a (OEM -> IR) the path coefficient (STD Beta) is 0.232, with a t-value of 2.655 and a p-value of 0.008, showing a significant positive connection. Consistent with earlier research by [3], this validates the notion that Organizational Environmental Management favorably promotes Investment Recovery. H1b (OEM -> SD) the path coefficient is 0.026, with a t-value of 0.41 and a p-value of 0.682, indicating no significant relationship. This suggests that OEM does not significantly impact Sustainable Distribution directly. H1c (OEM -> SDI) the path coefficient is 0.467, with a t-value of 6.808 and a p-value of 0, showing a significant positive relationship. This confirms that OEM positively influences Sustainable Design, aligning with previous research by [2]. H1d (OEM -> SP) the path coefficient is 0.629, with a t-value of 10.493 and a p-value of 0, indicating a strong positive relationship. This supports the hypothesis that OEM significantly impacts Sustainable Procurement, echoing findings from studies by [15].

H2a (IR -> GSCM) the path coefficient is 0.645, with a t-value of 11.039 and a p-value of 0, demonstrating a significant positive relationship. This supports the hypothesis that Investment Recovery positively affects GSCM. H2b (SD -> GSCM) the path coefficient is 0.464, with a t-value of 6.39 and a p-value of 0, showing a significant positive relationship. This confirms that Sustainable Distribution positively impacts GSCM. H2c (SDI -> GSCM) the path coefficient is 0.35, with a t-value of 4.109 and a p-value of 0, indicating a significant positive relationship. This supports the hypothesis that Sustainable Design influences GSCM positively. H2d (SP -> GSCM) the path coefficient is -0.047, with a t-value of 0.514 and a p-value of 0.607, indicating no significant relationship. This suggests that Sustainable Procurement does not directly impact GSCM. H3 (OEM -> GSCM) the path coefficient is -0.097, with a t-value of 1.708 and a p-value of 0.088, showing no significant direct relationship between Organizational Environmental Management and GSCM.

First for H4a, organizational environmental management have a significant mediation impact on GSCM performance through investment recovery (β = 0.108, t = 2.282, $p < 0.05$). Second, for the H4b relation the study finds a mediation between OEM on GSCM through SD (β = 0.22, t = 3.822, $p < 0.05$). Third, for the H4c relation the study finds a no effect between OEM on GSCM through sustainable design (β = -0.03, t = 0.506, 0.613). Regarding the H4d, there also no significant relationship between OME and GSCM through sustainable procurement, (β = -0.045, t = 1.641, $p < 0.101$). However, there is no evidence of a direct relationship between OEM and GSCM (β = -0.097, t = 1.708, $p < 0.088$).

Table 1. Direct and Mediation Relationship

Hypothesis	Regression Path	STD Beta	TValue	P values	Decision
H1a	OEM -> IR	0.232	2.655	0.008	Supported
H1b	OEM -> SD	0.026	0.41	0.682	Not Supported
H1c	OEM -> SDI	0.467	6.808	0	Supported
H1d	OEM -> SP	0.629	10.493	0	Supported
H2a	IR -> GSCM	0.645	11.039	0	Supported
H2b	SD -> GSCM	0.464	6.39	0	Supported
H2c	SDI -> GSCM	0.35	4.109	0	Supported
H2d	SP -> GSCM	-0.047	0.514	0.607	Not Supported
H3	OEM -> GSCM	-0.097	1.708	0.088	Not Supported
Hypothesis	**Regression Path**	**STD Beta**	**TValue**	**P values**	**Decision**
H4a	OEM -> IR -> GSCM	0.108	2.282	0.023	Mediation Relation
H4b	OEM -> SD -> GSCM	0.22	3.822	0	Mediation Relation
H4c	OEM -> SDI -> GSCM	-0.03	0.506	0.613	No Relation
H4d	OEM -> SP -> GSCM	-0.045	1.641	0.101	No Relation

5. Discussion

The study provides valuable insights into the influence of Organizational Environmental Management on Green Supply Chain Management, particularly through various sustainable practices such as Investment Recovery, Sustainable Distribution, Sustainable Design, and Sustainable Procurement. However, as highlighted in the table and previous discussions, several hypotheses were not supported or yielded non-significant results. These non-significant findings suggest that while OEM positively affects several sustainable practices, its direct impact on Sustainable Distribution and overall GSCM performance might be influenced by other factors not captured directly in this study, such as market dynamics, infrastructural challenges, or regulatory frameworks.

The non-significant relationships observed in the study, specifically for H1b (OEM -> SD), H2d (SP -> GSCM), H3 (OEM -> GSCM), H4c (OEM -> SDI -> GSCM), and H4d (OEM -> SP -> GSCM), suggest that certain sustainable practices and OEM's direct influence on GSCM may require more nuanced consideration. For example, the lack of significant impact between OEM and Sustainable Distribution (H1b) could be attributed to external logistical challenges or limitations in the distribution infrastructure that OEM alone may not address. Similarly, the non-significant relationship between Sustainable Procurement and GSCM (H2d) implies that procurement strategies, while critical for sourcing environmentally friendly materials, may need to be paired with other operational adjustments to truly impact GSCM performance. The non-significance of the direct link between OEM and GSCM (H3) suggests that OEM's effectiveness in enhancing GSCM may be mediated by specific sustainable practices, rather than having a direct effect. These findings highlight the complexity of integrating sustainability across supply chain functions and suggest that additional factors, such as market pressures, resource availability, or regulatory support, may be necessary for these practices to have a significant impact on GSCM outcomes.

The non-significant mediation relationships found in this study, particularly in H4c (OEM -> SDI -> GSCM) and H4d (OEM -> SP -> GSCM), indicate that Sustainable Design Innovation (SDI) and Sustainable Procurement (SP) do not mediate the relationship between Organizational Environmental Management (OEM) and Green Supply Chain Management (GSCM) in a meaningful way. This suggests that while both SDI and SP are critical sustainable practices, their roles in bridging the effect of OEM on GSCM may be limited or require additional factors to be impactful. In the case of SDI, it's possible that design innovations alone may not directly influence broader supply chain sustainability unless they are fully integrated into operational or distribution processes. For Sustainable Procurement, the results suggest that merely adopting green sourcing practices may not be enough to enhance GSCM performance without being supported by other practices, such as supplier collaboration or effective resource management. These non-significant mediation results point to the need for a more comprehensive approach where these sustainable practices are synergistically aligned with OEM strategies and supported by broader organizational initiatives.

6. Conclusion, Limitations and Future Work

This study provides valuable insights into the relationship between Organizational Environmental Management (OEM) and Green Supply Chain Management (GSCM), revealing how various sustainable practices influence this connection. The findings confirm that OEM positively affects Investment Recovery (IR), Sustainable Design (SDI), and Sustainable Procurement (SP), highlighting the role of committed environmental management in fostering sustainable practices within organizations. Notably, the study underscores the critical mediating roles of Investment Recovery and Sustainable Distribution in enhancing GSCM outcomes. These insights are significant for organizations aiming to implement effective sustainability strategies, as they emphasize the need for a holistic approach that integrates multiple sustainable practices. By identifying the pathways through which OEM impacts GSCM, this research contributes to both theoretical understanding and practical applications in sustainable supply chain management. Organizations can leverage these findings to develop robust OEM strategies that prioritize investment recovery and sustainable distribution, ultimately leading to improved environmental performance and economic sustainability. This study has several limitations that should be noted. The research primarily examines direct relationships and mediation effects among selected sustainable practices, potentially overlooking other contextual factors that may influence the OEM-GSCM relationship. Secondly, the non-significant findings should be discussed further. The study could explore why Sustainable Distribution and Sustainable Procurement did not significantly contribute to GSCM performance and whether external factors, such as logistical capabilities or policy regulations, play a role. Finally, the study does not address potential barriers organizations face in implementing these practices, which could provide valuable insights for enhancing sustainability initiatives.

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Blockchain Traceability and Customer Premium Willingness to Pay for Geographic Indication Agricultural Products

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Abstract. With the application of blockchain traceability in the supply chain of geographic indication agricultural products, the price of them has increased annually, and whether customers are willing to pay higher prices for the sake of the new digital technology raises concerns. The results of this study demonstrate that: blockchain traceability of geographic indication agricultural products positively affects customer self-expansion, perceived quality, and premium willingness to pay; customer self-expansion positively affects perceived quality and customer premium willingness to pay; customer perceived quality positively affects customer premium willingness to pay; and customer self-expansion and perceived quality play the role of parallel mediators and chained mediators between blockchain traceability and customer premium willingness to pay of geographic indication agricultural products. Therefore, enterprises of geographic indication agricultural products can reduce market uncertainty by applying blockchain traceability technology and increase the price of products to compensate for the input cost of the new technology.

Keywords. blockchain traceability; self-expansion; perceived quality; customer premium willingness to pay

1. Introduction

Geographical indication (GI) agricultural products refer to agricultural products named after their places of origin, such as Yangcheng Lake Hairy Crabs and Dandong Strawberries. However, because of the asymmetry of market information, fake goods of fictional origin such as “bathing crabs” have appeared. Blockchain technology is currently being used progressively in agricultural product tracking and tracing (Zhang Shengping & Du Bisheng, 2023) [1].

Academics have conducted a large number of studies on GI agricultural products in recent years, and the dependent variables are mainly focused on the variables of

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willingness to buy, brand trust, brand value, and willingness to pay, etc. From the existing studies, few scholars have explored customers premium payment willingness for blockchain-traceable GI agricultural products from the perspective of customers' self-perception. Customers purchase blockchain-traceable GI agricultural products, on the one hand, to ensure the credibility of the authentication of the origin, and on the other hand, they can trace the entire production, distribution and sales process of agricultural products throughout space, time, and the region by simply scanning the code for traceability, which empowers the customers with new capabilities and resources, and enables them to obtain the perception of self-expansion.

2. Theoretical Background

2.1 Blockchain Traceability for Agricultural Products

In the traditional traceability method, the information is easily modified, and the responsibility is difficult to be traced, which makes this method difficult to meet the customer's requirements for food safety (Yuan et al., 2020) [2]. Blockchain traceability system has high transparency and strong traceability, and the information basically cannot be modified once it enters the blockchain, guaranteeing its security and reliability, and thus can solve the above problems (Tan and Saraniemi, 2023) [3].

In the study of the impact of new technologies on customers, some scholars found that, according to the socio-technical theory, the introduction of blockchain traceability, as an emerging technology, can create a new process of social interaction, and this process will have a positive impact on the customers' willingness to buy and re-purchase (Zhang et al., 2012) [4].

2.2 Customer Willingness to Pay a Premium

Customers are prepared to pay more for a product that meets their expectations in terms of quality (Wang, 2016) [5] and certification (Liu and Sam, 2022) [6]. The majority of academics concur that trust is the primary driver of the premium (Li, 2022) [7]. When customers have to make decisions about products, trust plays a significant role in lowering their perception of risk (Hou et al., 2019) [8]. It has been demonstrated that customers' willingness to pay more for organic and traceable food can be positively influenced by trust (Liu and Sam, 2022) [6].

2.3 Customer Self-Expansion Theory

Self-Expansion Theory (Belk, 1988) [9] suggests that customers categorise closely related to others, intangible or tangible objects as part of themselves. Customers are able to expand their self-perception through this process and this perception could extend beyond the limits of the body itself (Belk, 2013) [10]. This discourse opens up a new direction in the study of person-product relationships.

By the age of artificial intelligence, related studies have found that customers are able to achieve self-expansion in their interactions with smart products, a process that empowers individuals with new capabilities and resources (Nie et al., 2023) [11], which benefits the business or brands (Gorlier and Michel, 2020) [12].

2.4 Perceived Quality

Perceived quality is an important basis for influencing customers' product evaluation and value assessment. Some studies have shown that customers' judgement of product quality is slower and more complex compared to customer attitudes, so the process requires more information and is made after customers have thought deeply about it. In contrast, customers' access to information during the purchase process is limited, so the perception of product quality carries more subjective implications (McGoldrick, 1984) [13].

2.5 Hypothetical derivation

This study proposes the following hypothesis:
H2: GI agricultural products blockchain traceability positively affects customer self-expansion.
H3: Customer self-expansion positively affects customer premium willingness to pay.
H4: Customer self-expansion plays a mediating role in the relationship between blockchain traceability of GI agricultural products and customers' premium willingness to pay.
H5: GI agricultural products blockchain traceability positively affects customer perceived quality.
H6: Customer perceived quality positively affects customer premium willingness to pay.
H7: Customer perceived quality plays a mediating role in the relationship between blockchain traceability of GI agricultural products and customer premium willingness to pay.
H8: Customer self-expansion positively affects customer perceived quality.
H9: Self-expansion and perceived quality play a chain mediating role in the relationship between blockchain traceability of GI agricultural products and customers' premium willingness to pay.

3. Study Design

3.1 Questionnaire Design and Measurement of Variables

Based on the research hypotheses presented in the previous section, the variables to be measured in this study include blockchain traceability of GI agricultural products, self-expansion, perceived quality, and customers' premium willingness to pay. Self-expansion is referred to the study of De Kerviler and Rodriguez (2019) [14]. Perceived quality is referred to the study of Kou and Powpaka (2017) [15]. And customer's premium willingness to pay is referred to the study of Netemeyer (2004) [16] et al. In this study all variables question items were used on a 5-point Likert scale and gender, age, education and monthly salary were added to the questionnaire as control variables.

3.2 Data Collection and Sample Characteristics

In this study, we conducted a questionnaire survey through the Internet, created a questionnaire on the platform of “Credamo” and released a paid questionnaire through “Data Bazaar”. Ultimately, 400 questionnaires were collected, 283 valid questionnaires were obtained, with an effective recovery rate of 70.75%.

After analyzing the demographic characteristics of the 283 respondents, it was found that, the sample characteristics largely align with the overall customer profile of GI agricultural products, which is composed primarily of young and middle-aged individuals who have a certain level of consumption ability and are interested about the products' place of origin.

3.3 Reliability and validity analysis

Internal consistency and reliability were the two selected validation indicators. It was found that this questionnaire performs well in terms of portfolio reliability and internal consistency.

Table 1. Results of reliability and convergent validity tests

Question Items	**Standardised factor loading**
Self-expansion Cronbach’s α=0.826 CR=0.86 AVE=0.673	
I am able to improve my ability after purchasing this product.	0.849
I am able to increase my knowledge after purchasing this product.	0.809
I become a better person after purchasing this product.	0.802
Perceived Quality Cronbach’s α=0.827 CR=0.861 AVE=0.608	
The product looks appetising.	0.804
The product is healthy.	0.753
The product is tasty.	0.771
The product is fresh.	0.790
customer premium willingness to pay Cronbach’s α=0.798 CR=0.851 AVE=0.655	
I am willing to pay a higher price for GI products for the same type of products.	0.829
I prefer to buy GI product even if it is more expensive.	0.796
I am willing to continue to buy the product even if the price of the product is slight higher.	0.803

After that, the questionnaire is assessed for validity. In Table 1, it was discovered that all of the study's variable standard factor loadings were greater than 0.7 and that the average variance extracted (AVE) were greater than 0.5, demonstrating that the convergent validity satisfied the necessary conditions. The discriminant validity of this scale is good, as demonstrated in Table 2, where the square root of AVE for each variable is greater than the correlation coefficient of that variable with other variables. The aforementioned analyses are adequate to demonstrate the high reliability and validity of this questionnaire.

Table 2. Results of validation of differentiated validity

Variables	Self-Expansion	Perceived Quality	Customer Premium Willingness to Pay
Self-Expansion	0.82		
Perceived Quality	0.468**	0.78	
Customer Premium Willingness to Pay	0.43**	0.402**	0.81
Average Value	3.1743	3.795	3.575
Standard Deviation	0.94	0.733	0.84

Note: ** indicates that p<0.01 (two-tailed test). Values below the diagonal are the correlation coefficients between the variables, and values above the diagonal are the square root of the AVE.

4. Data Analysis and Results

SPSS software was selected for research hypothesis validation. Hypothesis 1, Hypothesis 2, Hypothesis 3, Hypothesis 5, Hypothesis 6 and Hypothesis 8 were validated using multiple regression analysis and Hypothesis 4, Hypothesis 7 and Hypothesis 9 were selected for validation using the PROCESS add-in for SPSS.

Table 3 displays the analysis findings for the multiple regression analysis model that was constructed for the verification of the following hypotheses: 1, 2, 3, 5, 6, and 8. Results show that hypothesis 1,2,3,5,6 and 8 are confirmed.

Table 3. Results of multiple regression analysis

Variables	Self-Expansion		Perceived Quality			Customer Premium Willingness to Pay			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Sex	-0.276*	-0.252*	0.183*	0.200*	0.285**	0.003	0.021	0.104	-0.075
Age	0.098	0.065	0.121	0.098	0.085	0.146*	0.121*	0.110	0.095
Job	0.030	-0.017	-0.039	-0.030	-0.028	-0.048	-0.038	-0.037	-0.031
Education	0.031	-0.006	0.045	0.017	0.033	-0.008	-0.037	-0.020	-0.027
Monthly Salary	0.059	0.016	0.104	0.072	0.082	0.175**	0.141*	0.153**	0.131*
Blockchain Traceability		0.679***		0.498***			0.525***		
Self-Expansion					0.369***			0.367***	
Perceived Quality									0.422***

Note: *** indicates that p<0.001 , ** p<0.01, and * p<0.05.

Then, the PROCESS plug-in was applied to verify hypotheses 4, 7 and 9 and the results of the analysis are shown in Table 4.

Table 4. Results of the analysis of mediation effects

Type of Effect	Effect	Standard Deviation	BootLLCI	BootULCI
Blockchain Traceability→ Self-Expansion→Customer Premium Willingness to Pay	0.164	0.097	0.160	0.395
Blockchain Traceability→ Perceived Quality→Customer Premium Willingness to Pay	0.060	0.053	0.004	0.134
Blockchain Traceability→ Self-Expansion→Perceived Quality→Customer Premium Willingness to Pay	0.046	0.033	0.003	0.097
Blockchain Traceability→ Customer Premium Willingness to Pay	0.525	0.024	0.335	0.715

Table 4 shows hypotheses 4, 7 and 9 are confirmed.

5 Conclusions and Implications

5.1 Conclusions and Theoretical Contributions

This study examines how customers' premium willingness to payment is affected by the blockchain traceability of GI agricultural products, as well as the parallel and chain mediating roles that self-expansion and perceived quality play in this process. The theoretical contributions of this study are mainly as follows: firstly, this study enriches the research related to GI agricultural products. Secondly, the results of this investigation broaden the marketing domain's self-expansion theory's explanatory reach. Ultimately, this study contributes to the body of knowledge on consumers' premium willingness to pay for GI agricultural products.

5.2 Management Insights

This paper adopts an enterprise management perspective, addresses the issue of customer premium payment decision-making posed by the blockchain traceability of GI agricultural products, and offers some guidance on the practice of enterprise management, namely the following three main points:

First, developing towards high-end development, integrating the supply chain, and utilizing blockchain traceability technology are favorable routes for capable GI agricultural goods firms that have reached a certain size. Second, in order to encourage consumers' perceptions of their own self-expansion, the information provided to them by the traceability of GI agricultural products should be as recognizable and clear as feasible. Third, indicators connected to product quality should be the focal point of traceability data.

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Investigating Impact of Chasing Productivity Demand on Workplace Cheating Behavior and Mental Health of Employees: Empirical Evidence from Pakistan

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Abstract. This research examines how pursuing productivity targets affects workplace cheating behavior and mental well-being among manufacturing companies in Pakistan. Human resources support acts as a moderator to alleviate the negative effects of chasing productivity demands. The relationship is also analyzed with focus on the mediating role of performance pressure. A survey technique was utilized, involving a questionnaire that was modified from prior research. 301 respondents who were employees from various manufacturing companies in major cities of Pakistan made up the sample. Smart PLS is used for data analysis, and PLS-structural equation modeling is used to evaluate measurement and structural models. The results indicate that the pressure to increase productivity significantly impacts employees' decision to engage in cheating behavior and has negative effects on employees' mental well-being through performance pressure. This study also indicate that support provided by HR would mitigate the Harmful consequences caused by chasing productivity demands on employees' cheating behavior and mental health issues. The research holds significant importance for the organizations to understand the cause of high demand jobs and overcoming the adverse effects along with achieving the organizational goals by controlling and supporting employees' regarding their pressures.

Keywords. Chasing Productivity Demands (CPD), Work Intensification, Performance Pressure (PP), Workplace Cheating Behavior (WCB), Mental Health (MH), HR Support (HS)

1. Introduction

Manufacturing firms depend on the supply and demand of their goods. Production targets are allotted to laborers to accomplish under fixed timeline. Employees in manufacturing companies work long hours with a heavy workload, putting in extra time on weekends,

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overtime, and different shifts to meet the organization's productivity goals[1]. Workers working hundred hours per week report significant level of work strain as compared to those working less hours per week Employees working longer hours to meet the demanded targets give hesitating reactions which reflects the hazards of work intensification such as cheating behavior [2]. Cheating/dishonest behavior is characterized as behavior in which an employee disregards norms or rules of the organization for personal advantage according to literature. Falsifying can be used at work to influence others to view us the way we view ourselves, such as pretending to have read a book related to one's field that they haven't actually read[3]. Manufacturing plants utilize developed technology that is huge in size for the proficient production of goods. Laborers deal with these huge machines to deliver an enormous number of outputs in a fixed time. They face immense pressure to meet their set targets which is the productivity demands [4]. Prolonged pressure can lead to both physical and mental repercussions This study focus on Chasing productivity demand as key factor in highly the adhere affects of it on employees.Considering the gap in the literature that our paper focuses on, this is one significant perspective from which no exploration has been directed with regard to Pakistan. This indicates that further investigation is required in the field of literature with respect to the adverse effects of chasing productivity demands worldwide. The study contributed to existing knowledge and filled the gap by presenting a specific pathway guided by HR support in a developing country. The relationship of Chasing productivity demand with workplace cheating behavior and mental health, moderating role of HR support hasn't been studied especially in a developing country.

To address the gaps, this study aims to explore the following questions: How performance pressure mediates between chasing productivity demand, workplace cheating behavior, and mental health? How chasing productivity demand affects the workplace cheating behavior of employees? How chasing productivity demand affects the mental health of employees? How HR supports influence the relationship of chasing productivity demand and performance pressure? By answering these questions, the study aims to achieve the objective to analyze the mediating role of performance pressure between chasing productivity demand and workplace cheating behavior, To investigate the relationship between chasing productivity demand and workplace cheating behavior, To investigate association between chasing productivity demand and employee's mental health, To investigate how HR support influences the association between chasing productivity demands and performance pressure, resulting in a decreased impact of productivity demands on workplace dishonesty and mental health problems when HR support is stronger.

2. Background

Chasing productivity demand refers to employees dashing with time as the opponent, to execute difficult job demands to accomplish the standard and amount of yields in the predefined time. Work productivity expansion prompted work intensification. The issues related to heavy workload is rising each day [5]. All the employees appeared to be involved in workload issue as they have to fulfill the productivity demands, no matter what background they belong. These high demands cause pressure which leads to workplace cheating behavior at times as well as there mental health. The job demand–job command model suggested that in circumstances of high job demand, environment laborer has. A work plan is promoted by this model, proposing high demand and control, cultivates a climate that supports learning and independence. Job strain model: Karasek's work strain model expresses that the most danger to physical and emotional wellness from pressure happens to laborers confronting high work demand or choice scope in gathering those requests Employees in manufacturing companies for the most part work under close time limits and ominous workplaces[5]. The increasing demands of the firm make workers understanding tough and influence the mental health. Depression and anxiety are the most common mental disorders, and the prevalence of these disorders appears to be rising, at least in Western countries. In manufacturing firms, laborers face immense pressure to meet their targets[1] . The quantity of hour's workers working to meet the demands or targets has an unavoidable impact on physical health as well as mental health. An increase in weekly working hours has adverse effects on their wellbeing. High job demands have consistently been associated with psychological distress and depression .The impacts of the pressures on people to apply more effort from the presentation of automated advancements, might be alleviated partly, only if people are shielded from such pressures[6]. Based on these groumds the following hypothesis are given:

H1: chasing productivity demand has a significant relationship with performance pressure.

H2: chasing productivity demand plays positive relation with workplace cheating behavior.

H3: Chasing productivity demand has a significant relationship with mental health.

In this paper, it was investigated how chasing productivity demand and performance pressure interact with workplace cheating. Past investigations likewise found that ten to twenty-nine percent of practicing purchasing agents admit to deception [7]. Individuals lie as a reaction to pressures under which they get themselves. Counterproductive workplace behavior or dishonest behavior is demonstrated activities that compromise the wellbeing of an association and it's individual .Workers cheating behavior and crime is a gigantic and inescapable issue for firms and the economy[8]. Immense performance pressure triggers sensations of unfairness which affect their mental health, increase in absenteeism in fast-food restaurants, unpunctuality by employees in hospitals and bank, robbery in production line representatives. Similarly, casual gathering standards tolerating exploitative conduct have been appeared to identify with burglary by cafe laborers and medical caretakers. Many researchers have declared the significance of worker prosperity as a mechanism to accomplish better and more performance[9]. Based on these arguments following hypothesis are proposed:

H4a: Performance pressure have a significant relation with workplace cheating behavior

H4b: Performance pressure have a significant relation with mental health.

H5a: Performance pressure mediates chasing productivity demand and workplace cheating behavior.

H5b: performance pressure plays a mediating role between chasing productivity demand and mental health.

It usually presumes a test-taker who needs to progress nicely however falls under pressure[4]. Human resource management, also known as HR, a department within a company that aims to amplify employee productivity to support the goals of their supervisors. HR is primarily concerned with the management of individuals within organizations; all the importance is placed on policies and procedures[3]. The HR department in manufacturing firms offers limited help to workers, particularly production laborers, afar fundamental legitimate. Based on these ground the following hypothesis ig given:

H6: HR assistance reduces the impact of chasing productivity demands on work misconduct and employee well-being by moderating the association with performance pressure.

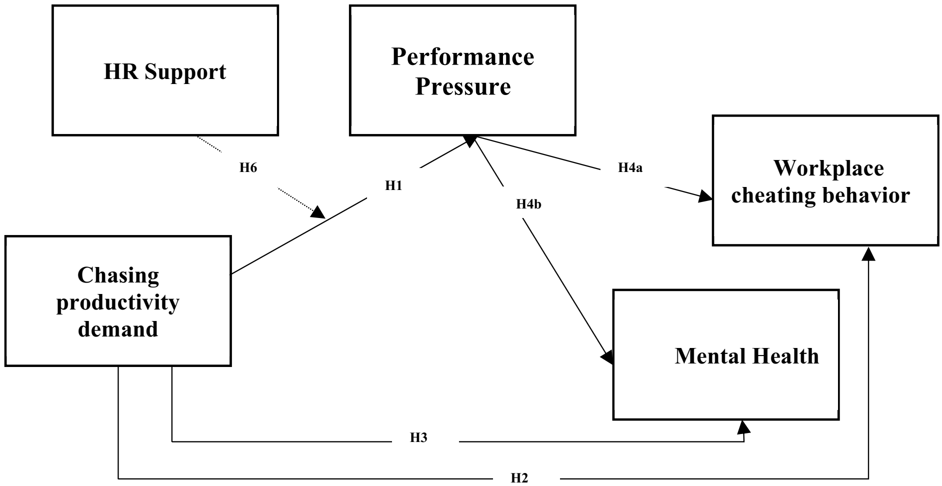

Figure 1. Research Framework

3. Methodology

The target population for this study is includes white and blue collar employees from various Electrical and Automotive and related equipment industries in Lahore, Islamabad, Multan, and Faisalabad, Pakistan based on stratified sampling technique. This method is useful, as it allows the researcher to make more reliable and informed conclusions by confirming that each representative subclass has been adequately represented in the selected sample. 60 manufacturing industries were identified for this study and collected data from March 2024 to June 2024 from blue collar employees. The research followed a quantitative research design method, and all questionnaire items were adopted from previous studies. Our survey tool includes a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5) for each question. Surveys are randomly given to employees in manufacturing companies through their representatives and email. The questionnaire in Urdu was distributed to facilitate blue-collar workers in completing the survey. Initially, our goal was to gather data from a larger number of employees, targeting 450 individuals. However, successfully obtained responses from 330 participants across various industries. This achievement translates to a response rate of 69%. It should be noted that 29 responses were excluded during the data screening process due to missing values. Consequently, our final sample consists of 301 participants. This sample size aligns with the findings of several researchers who suggest that a sample of 100 or more is sufficient for convergence when each variable has three or more items. The sample size selected for our study adheres to the guidelines suggested by various scholars. Specifically, [8, 10] recommend a sample size of 150 as suitable for obtaining a convergent and reliable solution. Similarly, [11] advocate for a sample size between 50 and 100 when employing structural equation modeling (SEM). Data analysis was performed using Smart PLS software. PLS-SEM is a current method that provides for precise estimate and is especially useful in behavioral research aimed at analyzing individual perceptions or actions.

4. Result

H1 (CPD-> PP) with a p-value of 0.000, indicating a significant positive relationship. This supports the hypothesis that employees Chasing productivity demand gets under Performance Pressure, consistent with previous studies by [2]. H2 (CPD-> WCB) with a a p-value of 0.000, indicating highly significant relationship. This suggests that employees chasing productivity demands gets involved into workplace cheating behaviors. H3 (CPD-> MH) with a p-value of 0.000, showing a significant positive relationship. This confirms that chasing productivity demand influences negatively on their mental health, aligning with previous research by [9]. H4a (PP -> WCB) with a p-value of 0.000, indicating a strong positive relationship. This supports the hypothesis that Performance pressure on employees lead them towards workplace cheating behavior echoing findings from studies by [7]. H4b (PP -> MH) with a p-value of 0.000, indicating a strong positive relationship too. This supports the hypothesis that Performance pressure on employees directly affect their mental health negatively echoing findings from studies by [11].

H5a (CPD -> PP -> WCB) with a p-value of 0, demonstrating a significant positive relationship. This supports the hypothesis that Performance pressure on employees mediates between chasing productivity demands and workplace cheating behavior, similar to R. H5b (CPD→ PP→ MH) with a p-value of 0, indicating a significant positive relationship. This supports the hypothesis that Performance pressure mediates between chasing productivity demands on employee's and their mental health. H6 (CPD ->HR* -> PP) with a p-value 0.001, indicating high level of moderation. This suggests that Human resource support positively moderates the relationship of chasing productivity demand and performance pressure of employees, similar to [11].

Table 1. Direct, Mediation and Moderation Relationship

Hypothesis	Regression Path	Effect type	P values	Decision
H1	CPD →PP	Direct effect	0.000	ACCEPTED
H2	CPD→ WCB	Direct effect	0.000	ACCEPTED
H3	CPD→ MH	Direct effect	0.000	ACCEPTED
H4a	PP→ WCB	Direct effect	0.000	ACCEPTED
H4b	PP→ MH	Direct effect	0.000	ACCEPTED
Hypothesis	**Regression Path**	**Effect type**	**P values**	**Decision**
H5a	CPD -> PP -> WCB	Direct effect	0.000	Partial MEDIATION
H5b	CPD→ PP→ MH	Direct effect	0.000	Partial MEDIATION
H6	CPD ->HR* -> PP	Direct effect	0.001	SUPPORTED

5. Discussion

This study centered on investigating the influence of chasing productivity demand and performance pressure on workplace cheating behavior and mental health of employees.

The specific objective was to explain the link of chasing productivity demand , an independent variable, with two dependent variables i.e., workplace cheating behavior and mental health through a mediator i.e., performance pressure and a mediating moderator, HR support. The model proposed in this study was confirmed, offering proof that Performance pressure caused in chasing productivity demand impulses to perform at a particular level similar to [9], and at not meeting this level, it conveys a dispute among execution similar to [8] and what one is required to do. The study's findings suggested the following: performance pressure in a working environment has negative effects similar to [1]; Workload and performance pressure effect physiological health of employees and decision-making ability. Performance pressure caused by chasing productivity demand plays a role in provoking lying behavior, which is a workplace cheating behavior; and The chasing productivity demand can be achieved within the time limit and with optimization if performance pressure is controlled or even minimized that will help the employees to work with well.In line with these research findings, the results confirm the anticipated positive correlation between CPD and employee workplace cheating behavior, as well as mental health. The importance of HR assistance for manufacturing companies in Pakistan was highlighted, as it allows them to boost their competitive edge through bettering their employees' performance. The study findings also emphasized the significant and immediate impact of performance pressure on employees' workplace cheating behavior and mental well-being. Moreover, the research showed the significant and immediate influence of CPD on workplace cheating behavior and mental health. By providing assistance from the human resource department to workers, companies can effectively address the challenges faced by employees and greatly improve the organization's performance by mitigating the negative impacts of performance pressure on employees.

Apart from the significance of this study there is always room for improvement..This study was specifically based in Pakistan therefore, this study has some geographical limitations. So it is recommended in future the research can be conducted from different countries. Caution should be used when generalising the findings of the study. The data for this study was only collected from manufacturing firms so it cannot be generalized for other industries. Leaving a gap for future research to conduct the research on this model in different sectors. it is recommended for further research in industries like banking or construction industry and any other sector.

6. Conclusion

With the recognition of the issues faced my individuals, the concept of chasing productivity demand is given significant attention. However, there is lack of research investigating how chasing productivity demand impacts employee's behavior on the work place and how to overcome it in Pakistan. This research shows the relevance of these factors. It was seen in previous studies that majority discussion was based on home and work conflict and also work demands with burnout and organization based issue.

This study has filled the gap by giving a framework showing how employees who are chasing the work demands given to them are exposed to mental health issues and how they get into deviant behavior in manufacturing firms in Pakistan. Results of this study demonstrates that positive association exists between chasing productivity demand, workplace cheating behavior and mental health of employees mediated by performance pressure. HR support given to employees can help in reducing the performance pressure that ultimately reduces the workplace cheating behavior and improves the mental health of the employees. It is concluded from this study HR support plays a major role in creating mental connections among the organization targets with employees. It shapes the behavior and attitude of the employees.

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The Impact of Market Green Pressure on Green Performance of Chinese Manufacturing Companies: The Mediating Role of Green Organizational Capability

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Abstract. In the context of innovation-driven development and green low-carbon development, it has be-come an important research topic to help traditional manufacturing industries cope with green pressure and improve green performance by optimizing organizational capabilities. This study investigates the mediating role of the three dimensions of green organizational capabilities when firms face the impact of market green pressures on green performance, and the technological innovation's moderating role. The researcher obtained 307 valid data through questionnaires from top managers in manufacturing companies and processed the data using SPSS 26.0 and MPLUS 3.8. The findings suggest that green organizational capability positively mediates market green pressure and corporate green performance; technological innovation plays a positive role as a moderator in the process of the market green pressure to enhance green organizational capability. This research offers valuable insights for the green transformation of manufacturing firms.

Keywords. market green pressures, green organizational capacities, green performance, technological innovation

1. Introduction

Traditional manufacturing industry as the foundation of modern industrial system, its sustainable development has a profound impact on China's economic growth [1]. According to the stakeholder theory, the ability of suppliers to provide environmentally friendly raw materials and the environmental demand of customers for products will exert green market pressure on the firm, which will further influence the firm's green performance. In addition, effective reduction of pollution and waste, management of products and services, and the creation of a green corporate image are also important internal organizational capabilities for companies to achieve their green goals, and the capability view of the business sees such green organizational capabilities as necessary for companies to cope with green pressures and to improve their green performance.

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In the field of green performance research, external green pressure [2] has been the focus of many researchers. From a supply chain perspective [3], this paper focuses on two aspects of market green pressure faced by manufacturing firms: supplier green pressure [4] and customer green pressure [5]. Second, the internal organizational capability of enterprises is, on the one hand, the key to effectively cope with green pressure, and on the other hand, it is an important factor to achieve green innovation and [6]. Meanwhile, technological innovation is conducive to improving organizational capability and enhancing understanding of stakeholders, including customers, to help enterprises cope with external pressures [7].

In conclusion, this paper aims to help manufacturing enterprises to improve their internal organizational capability, enhance their green performance and achieve green transformation.

2. Theoretical basis and research hypothesis

2.1. Market Green Pressure and Green Performance

The green market pressure faced by manufacturing enterprises has a profound impact on the direction, structure and quality of the development of internal organizations [8]. From the perspective of the supply chain, existing studies believe that customers' environmental demand for products, suppliers' ability to provide green raw materials, and competitors' ability to provide green products and services will exert pressure on enterprises, which constitutes market green pressure [9]. In this study, market green pressure is divided into supplier green pressure and customer green pressure, in order to study the influence mechanism among market green pressure, enterprise green organizational capability, and green performance from the supply chain perspective more deeply. The essence of enterprises responding to market green pressure and adopting green production activities to achieve environmental benefits is to maintain competitive advantage and maximize profits. The existing studies believe that green performance is the evaluation of economic and environmental benefits obtained by enterprises in the process of green development by comprehensively considering resource inputs and environmental costs [1]. According to stakeholder theory, companies will pay attention to the environmental pressure from suppliers and customers, and make efforts to alleviate the pressure and improve environmental performance. This paper argues that green pressure from stakeholders is an external driver of corporate greening. Therefore the hypothesis is proposed:

H1: Market Green Pressure positively affect Green Performance.

2.2. Market Green Pressure and Green Organizational Capability

The enterprise capability view holds that green organizational capability as a capability system becomes a unique heterogeneous resource of enterprises, which is of great significance for enterprises to cope with green pressure and improve green performance [10]. In this paper, green operational capability, green dynamic capability and green creativity are summarized as green organizational capability of enterprises [11]. Among them, operational capability refers to the ability of enterprises to skillfully carry out various functional activities in products, services, processes, supply chains and other links; Green dynamic capabilities are the ability of an enterprise to analyze and optimize its existing resources in order to adapt to dynamic market changes; Green creativity is the concept of the innovative value of a company's operations [12].

Firstly, when responding to the green pressure from external stakeholders, enterprises will develop green innovation strategies that affect all aspects of enterprise operations such as products, services, processes and supply chains [13]. Second, companies will respond to stakeholder green pressures by integrating and reconfiguring resource allocation capabilities, developing green dynamic capabilities in the process to maintain competitive advantage and achieve sustainable development [14]. In addition, in the face of green pressures from the market, companies will be targeted to enhance green creativity based on the pressure-oriented [15]. Therefore, the hypothesis is proposed:

H1a. Market Green Pressure positively affect Operational Capabilities.

H1b. Market Green Pressure positively affect Green Dynamic Capabilities.

H1c. Market Green Pressure positively affect Green Creativity.

2.3. Green Organizational Capability and Green Performance

It has been shown that companies that pay attention to green performance have the characteristics of proactive awareness, innovative thinking and risk taking [16,17]. When these characteristics are abstracted from specific capabilities, they correspond to the three dimensions of green organizational capabilities. It can be seen that existing research has not examined what organizational capabilities firms should have in place to improve green performance in a systematic way [18]. Combined with the above analysis, this paper argues that the green organizational capability, which consists of operational capability, green power capability and green creativity, will serve as a heterogeneous resource of the enterprise and help it to form a competitive advantage, and the competitive advantage of the green organizational capability will be the intrinsic driving force for the improvement of the enterprise's performance [19]. Therefore, the hypothesis is proposed:

H2a. Operational Capabilities positively affect Green Performance.

H2b. Green Dynamic Capabilities positively affect Green Performance.

H2c. Green Creativity positively affect Green Performance.

2.4. The Mediating role of Green Organizational Capability

To meet stakeholder interests in the face of external pressures, companies will improve their day-to-day operational capabilities to achieve expected performance [20]. Second, the market is in a state of fluctuation and change, which requires companies to have the green dynamic capability to take appropriate green actions to achieve green performance. In addition, external pressure will continue to stimulate enterprises to generate innovative ideas and practices, achieve sustainability performance by enhancing organizational green creativity and innovation-driven development [21]. Therefore, the hypothesis is proposed:

H3a. Operational Capabilities positively mediates the relationship between Market Green Pressure and Green Performance.

H3b. Green Dynamic Capabilities positively mediates the relationship between Market Green Pressure and Green Performance.

H3c. Green Creativity positively mediates the relationship between Market Green Pressure and Green Performance.

2.5. The Moderating role of Technological Innovation

Only by alleviating market pressure through technological innovation and rationally allocating resources can enterprises build their core competitiveness [22], thereby improving their green organizational capabilities. This study believes that technological innovation can not only help manufacturing enterprises better cope with green pressure, but also push enterprises to accelerate the improvement of green organizational capabilities, including operational capability, green dynamic capability and green creativity. Following the theory of technological innovation and using technological innovation as a moderating variable, this paper examines whether technological innovation can help firms to reduce market pressure.

H4a. The relationship between Market Green Pressure and Operational Capabilities is positively mediated by Technological Innovation.

H4b. The relationship between Market Green Pressure and Green Dynamic Capabilities is positively mediated by Technological Innovation.

H4c. The relationship between Market Green Pressure and Green Creativity is positively mediated by Technological Innovation.

Figure 1 shows the conceptual framework of this paper.

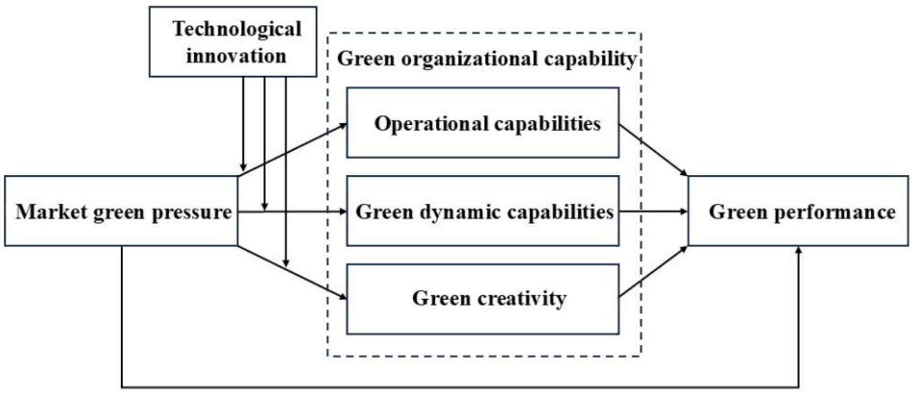

Figure 1: conceptual framework

3. Methodology

This study takes the middle and senior managers of manufacturing enterprises as the survey sample and adopts the questionnaire survey method, which mainly collects data by distributing questionnaires on site and posting links on questionnaire star. The research period of this study is from September 2023 to February 2024, and 307 valid questionnaires were obtained. In terms of firm size (number of employees), 201–500 account for 140 (45.6%), 501–1000 for 85 (27.7%). In terms of firm age (establishment period), 3–5 account for 106 (34.5%), 6–10 for 92 (30.0%). In terms of nature of the firm, private company account for 171 (55.7%), nationalized company for 109 (35.5%). In terms of firm revenue (RMB), 5 - 50 million account for 129 (42.0%), <5 million for 103 (33.6%). In terms of business type, assembly manufacturing account for 109 (35.5%), metal processing for 76 (24.86%). In terms of years of service of respondents, 4–6 years account for 138 (44.95%), 7–9 years for 85 (27.6%). This diverse respondent profile forms the foundation for the research and allowed for a representative structure of the questionnaire. Table 1 shows the questionnaire questions and references.

Table 1. Question items and references

		Item Codes
Market Green Pressure *(referred from Zhi et al. (2012) [19] with adjustments)*		MGP1: Most of our suppliers have high green standards.
		MGP2: An important indicator of the corporate reputation of most of our suppliers is green innovation.
		MGP3: Most of our suppliers guarantee environmentally friendly materials.
		MGP4: Most of our suppliers are environmentally conscious.
		MGP5: High level of demand for green products by the majority of our customers.
		MGP6: Our customers value our company's green and innovative behavior.
		MGP7: Our customers need products that meet environmental regulations.
		MGP8: Our customers value products with green concepts.
Green Performance *(referred from Zhu et al. (2004) [15] with adjustments)*		GP1: Our products are more profitable compared to other firms in the same industry.
		GP2: Our products are produced in a more resource-efficient manner than other companies in the same industry.
		GP3: Compared with other companies in the same industry, our company creates less pollution in the process of producing products.
		GP4: Easier recycling of our products than other companies in the industry.
Technological Innovation *(referred from Xie et al. (2010) [23] with adjustments)*		TI1: Our new products have created many new business opportunities in the marketplace.
		TI2: Our new products have won numerous awards for innovation.
		TI3: Our company owns more patents than most of our counterparts.
		TI4: Companies continue to introduce new technologies that can improve processes or workflows
		TI5: Our company can conceptualize many new ways to improve product processes or workflows.
		TI6: The process design of our products is developed faster than our counterparts.
Green Organizational Capabilities	**Operational Capabilities** *(referred from Wu et al. (2010) [21] with adjustments)*	OC1: Have information systems that provide efficiency in cooperation across functions.
		OC2: Have a regularized process to promote cooperation between different sectors.
		OC3: Continuous improvement of our production and work flows.
		OC4: We have great control and flexibility over the inputs and outputs of our products.
		OC5: We are continuing to reduce waste and pollution in our manufacturing operations.
		OC6: We can ensure that we deliver products to our customers as per the agreement.
	Green Dynamic Capabilities *(referred from Lu et al. (2019) [22] with adjustments)*	GDC1: We value and regulate the environmental impact of our suppliers' knowledge and capabilities.
		GDC2: The products we manufacture accept a green assessment by environmental experts prior to delivery.
		GDC3: We attach great importance to environmental sustainability and optimize our internal structures
		GDC4: We will adjust our relationship with suppliers in order to reduce the environmental pollution caused by our products.
		GDC5: We will keep abreast of and understand the enabling policies related to sustainable production.
		GDC6: We are able to keep up to date with and respond to changes in green technology in the industry.
		GDC7: We are able to adapt to market changes and understand our customers' sustainability-related requirements.
	Green Creativity *(referred from Chen et al. (2012) [20] with adjustments)*	GC1: Our company's employees can come up with new approaches to achieving green targets.
		GC2: Our company's employees are able to come up with new green solutions to improve environmental behavior.
		GC3: Our company encourages new green philosophies to our employees.
		GC4: Our company's employees can put green ideas into practice.
		GC5: Our company's employees can find creative approaches to solving environmental challenges.

4. Analysis and results

The study used SPSS 26.0 software and cascade regression to analyze statistical significance tests. The results of model 1 show that market green pressure significantly benefits firms' operational capacity (β=0.346), and H1a is verified; the results of model 2 show that market green pressure significantly benefits firms' green dynamic capacity (β=0.490), and H1b is verified; the results of model 3 show that market green pressure significantly benefits firms' green creativity (β=0.454), and H1c is verified. The results of Model 7 indicate that market green pressure significantly benefits green performance (β=0.383) and H1 is verified. The results of model 4 indicate that firm operational capability significantly benefits green performance (β=0.387), and H2a is verified; the results of model 5 indicate that firm green dynamic capability significantly benefits green performance (β=0.393), and H2b is verified; the results of model 6 indicate that firm green creativity significantly benefits green performance (β=0.494), and H2c is verified. From model 8, market greening pressures and operational capabilities significantly affect corporate green performance (β = 0.281; β = 0.293) and hypothesis H3a is verified. From model 9, Market greening pressures and green dynamic capabilities significantly affect firms' green performance (β = 0.239; β = 0.294), and hypothesis H3b is verified. From model 10, Market green pressure and green creativity significantly affect firms' green performance (β = 0.242; β = 0.311), and hypothesis H3c is verified.

For testing the moderating effect of technological innovation, the interaction term ‘market green pressure× technological innovation’ is included to construct model 11, and found that technological innovation has a strong beneficial moderating effect on market green pressure to promote the enhancement of operational capacity (β = 0.130), and hypothesis H4a is verified; The interaction term ‘market green pressure× technological innovation’ was included to construct model 12, and from the test results, technological innovation has a significant positive moderating effect on market green pressure to promote the enhancement of green dynamic capacity (β = 0.169), and hypothesis H4b was verified; The interaction term ‘market green pressure× technological innovation’ was included to construct model 13, and from the test results, the positive moderating effect of technological innovation on market green pressure to promote green creativity was significant (β = 0.183), and hypothesis H4c was verified. The results are shown in Table 2.

Table 2. Regression analysis results

	Operational capabilities		Green dynamic capabilities		Green creativity		Green performance						
Varibles	Model 1	Model 11	Model 2	Model 12	Model 3	Model 13	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Firm size	0.002	-0.004	0.084	0.081	0.055	0.056	-0.062	-0.097	-0.085	-0.069	-0.069	-0.094	-0.086
Firm age	0.035	0.036	0.028	0.028	-0.064	-0.067	0.022	0.035	0.070	0.081	0.071	0.073	0.101
Nature of the firm	-0.266***	-0.182	-0.144	-0.052	-0.183**	-0.096	-0.024	-0.076	-0.058	-0.152	-0.074	-0.110	-0.096
Firm revenue	-0.006	0.020	-.092	-0.061	-0.049	-0.017	0.090	0.109	0.095	0.025	0.026	0.052	0.040
Business type	-0.062	-0.060	-0.026	-0.023	-0.032	-0.027	0.044	0.030	0.033	0.018	0.036	0.026	0.028
Years of service of respondents	-0.156	-0.150	-0.067	-0.063	-0.095	-0.094	-0.093	-0.124	-0.112	-0.142	-0.096	-0.122	-0.112
Market green pressure	0.346***	0.217***	0.490***	0.353***	0.454***	0.331***				0.383***	0.281***	0.239***	0.242***
Operational capabilities							0.387***				0.293***		
Green dynamic capabilities								0.393***				0.294***	
Green creativity									0.494***				0.311***
Technological innovation		0.321***		0.332***		0.289***							
Market green pressure * Technological innovation		0.130**		0.169***		0.183***							
R2	0.161		0.212		0.206		0.166	0.192	0.201	0.159	0.232	0.234	0.246
Adj_R2	0.142		0.194		0.187		0.147	0.173	0.182	0.139	0.211	0.214	0.225
F	39.260***		76.601***		63.951***		51.597***	62.660***	66.601***	48.503***	25.305***	16.464***	17.717***

Note: N=307, *** P value <0.001, ** P value <0.01, * P value <0.05.

5. Discussion

5.1. Theoretical contributions

Currently, most of the research related to green performance focuses on one-dimensional internal factors, and there is no research that systematically and comprehensively explores the influence of internal capabilities on the green performance. Based on the previous research, systematically explore the factor of organizational capacity within the enterprise, which further opens the "black box" of the role of market green pressure on enterprise green performance and extends the relevant theoretical research on green performance.

5.2. Management inspiration

Firstly, manufacturing companies should be sensitive to changes in external pressures and respond to these green pressures in a timely and effective manner to achieve green performance with both economic and environmental benefits. Second, manufacturing companies should be able to adapt to changing market dynamics and progressively build their own competitive advantage by analyzing, integrating and optimizing existing resources in products, services, processes and supply chains. Finally, as the added value of technology helps to reduce costs and improve quality, the manufacturing industry must pay attention to technological innovation in practice and cultivate the concept of technological innovation among its employees, so as to respond more effectively to the green pressures of the market, improve green organizational capabilities, and ultimately realize a significant increase in the green performance of the enterprise.

6. Conclusion and Limitations and Prospects

6.1. Research conclusion

The conclusion is as follows: The market pressure promotes the green organization ability of enterprises from three aspects: enterprise operation ability, green dynamic ability and green creativity. Among them, the beneficial influence of market green pressure on green dynamic ability is the strongest, followed by green creativity. Green organization capability significantly affects enterprise green performance from three aspects: operation capability, green dynamic capability and green creativity. Market green pressure significantly affects corporate green performance, and the mediating role of green organization capability in this process has been confirmed. This study also confirmed that technological innovation positively moderates the influence of green market pressure on green organizational capability, and the path of technological innovation on the influence of green market pressure on green creativity is the strongest.

6.2. Limitations and Prospects

This paper is still limited and needs further research. First of all, considering the time cost limitation, the cross-sectional data of a single time point is used in this study, and more objective longitudinal data can be considered in future studies. Secondly, the results of this study are aimed at Chinese manufacturing enterprises. Considering the cultural attributes of the samples, similar studies can be conducted in different countries in the future. Finally, follow-up studies can further explore the interaction between the three factors within green organizational capacity.

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Decision-Making and Coordination of Closed-Loop Supply Chains for Power Batteries Considering Recycling Services

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Abstract. For a closed-loop power battery supply chain composed of a power battery manufacturer and a complete vehicle enterprise, considering that the level of recycling service will affect the demand of the recycling market, this paper analyzes the impact of factors such as recycling cost coefficient on the optimal decision by constructing a centralized and decentralized closed-loop supply chain decision model, and examines the optimal choices within both centralized and decentralized decision-making frameworks. On this basis, a "revenue sharing" contract is designed. Finally, a numerical example is used to investigate and verify. It is found that the increase of recycling service cost will affect the earnings of manufacturers and vehicle companies, and then affect their decisions. The coordination and Pareto improvement of power battery closed-loop supply chain can be achieved by reasonably designing the range of revenue sharing contract parameters.

Keywords. Power battery, Closed-loop Supply Chain, Recycling Services, Coordination contract

1. Introduction

In recent years, the environmental issues resulting from global warming have intensified significantly. Controlling carbon emissions and signing relevant emission reduction treaties have become the consensus of all countries in the world. Therefore, new energy vehicles are rapidly gaining popularity in the market due to their eco-friendly features, low-carbon, energy-saving and convenient characteristics. According to the statistics of China Automobile Association, in 2023, the production and sales of new energy vehicles in China totaled 9.587 million and 9.495 million, with year-on-year growth of 35.8% and 37.9% respectively, and the market share reached 31.6%, which is expected to exceed 50% in 2026, occupying a dominant position in the automotive market [1]. The most critical component of new energy vehicles is the power battery. The rapid development of new energy vehicles has brought many retired old batteries. Failure to handle retired power batteries correctly may result in severe safety accidents, including combustion and explosions. Simultaneously, the leakage of hazardous electrolytes in power batteries can lead to severe environmental contamination. In addition, power batteries contain precious nickel, lithium, cobalt and

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other materials, which will cause a lot of waste of resources and economic losses if not effectively recycled. To cope with the large-scale trend of power battery retirement, how to efficiently recycle power batteries is a problem worth discussing. Among the factors that consumers actively participate in during the waste product recycling phase, economic factors and service factors account for a large proportion [2]. Improving the service level is one of the common ways to attract consumers. For the closed-loop supply chain of power batteries, the use of high-quality service is a feasible solution to deal with the large-scale trend of power battery retirement and improve the recycling amount of waste batteries.

2. Literature Review

A growing number of researchers are concentrating on the recycling challenges associated with power batteries in the new energy vehicle sector. The closed-loop supply chain, acknowledged for its strengths in promoting environmental protection and conserving resources, has been widely studied, making the investigation of power battery recycling from this perspective a popular topic. Gu et al. [3] constructed a three-stage closed-loop supply chain for electric vehicle battery recycling and reuse, discussing the relationships between return rates, sorting rates, and recycling rates to optimize total profits over different periods. Lou Gaoxiang et al. [4] compared the effectiveness of government subsidies based on recycling volume versus battery capacity on improving the recycling rate. Sun et al. [5] considered the cascading utilization and material recovery of power batteries from the closed-loop supply chain perspective in the context of carbon reduction, establishing three recycling models to study the optimal recovery decisions and low-carbon strategies for electric vehicle manufacturers. Jiao Jianling et al. [6] explored the impact of regenerated material revenues on carbon emissions within the closed-loop supply chain. Zhang Chuan et al. [7] studied the selection of recovery modes and carbon reduction strategies for electric vehicle power battery manufacturers under carbon quota trading policies. Currently, research on power battery recycling mainly focuses on government policy impacts, different recycling models, and carbon policy influences, while studies considering the impact of service factors remain relatively scarce.

When companies in a closed-loop supply chain participate in both sales and recycling, they tend to focus solely on their own interests, leading to double marginalization effects that reduce the overall profit of the supply chain. Thus, contracts are needed for internal coordination to enhance the profits of participating companies. Currently, there is a wealth of research in academia on supply chain contract coordination. Lariviere et al. [8] discovered that increasing sales through wholesale price contracts can enhance supply chain efficiency. Kunter et al. [9] studied a supply chain model considering marketing efforts and coordinated it using revenue-sharing and cost-sharing contracts. Fang Jian et al. [10] researched how manufacturers can use revenue-sharing contracts to encourage suppliers to invest more in carbon reduction, thereby lowering the carbon emissions of the supply chain. As research on closed-loop supply chains has grown, many scholars have begun to consider contract coordination within them. Zhou Weilang et al. [11] studied pricing and service level decisions in two closed-loop supply chains led by different dominant players, designing revenue-sharing contracts and two-part tariff contracts to improve system performance and company profits. Xie et al. [12] explored contract coordination issues in dual-channel closed-loop supply chains and derived optimal decisions through revenue-sharing mechanisms. Liu Shan et al. [13] addressed pricing decisions and coordination issues in closed-loop supply chains with corporate social responsibility, establishing a "revenue-sharing and recycling cost-sharing" contract to coordinate the closed-loop supply chain. However, research on the coordination of power battery closed-loop supply chains is relatively limited.

So far, research on closed-loop supply chains for power batteries has primarily focused on government policies and different recycling models, with little consideration given to coordination strategies for these supply chains. Additionally, the impact of service levels on the recycling of power battery closed-loop supply chains has not been addressed. Based on this, this paper will incorporate recycling service levels into the closed-loop supply chain model, broadening the research field of power battery closed-loop supply chains. The research will explore the best decision-making strategies in this scenario and investigate the impact of service levels on the recycling processes of power battery closed-loop supply chains. Finally, it will discuss how to achieve coordination within the power battery closed-loop supply chain.

To address the aforementioned issues, this paper studies a closed-loop supply chain for power batteries involving a power battery manufacturer and a new energy vehicle manufacturer (hereafter referred to as the vehicle manufacturer), which is tasked with recycling used power batteries. A corresponding Stackelberg game model is established to determine the optimal decisions of supply chain members in the sales and recycling processes under two decision-making scenarios. The paper will conduct a comparative analysis of the changes in decisions and profits and formulate a 'revenue-sharing' contract to promote coordination within the closed-loop supply chain for power batteries, providing insights for the operation of the power battery closed-loop supply chain.

3.Research Assumptions and Basic Model

In our study, a closed-loop supply chain is composed of a power battery manufacturer and a new energy vehicle enterprise, and the whole vehicle enterprise recycles the power batteries. Assuming that the power batteries sold and recycled in this paper are the same model, there is no difference between remanufactured power batteries and new batteries. In order to simplify the calculation, this paper regards the wholesale price of power batteries as the manufacturing cost of new energy vehicles. For the convenience of subsequent research, we suggest the following hypotheses:

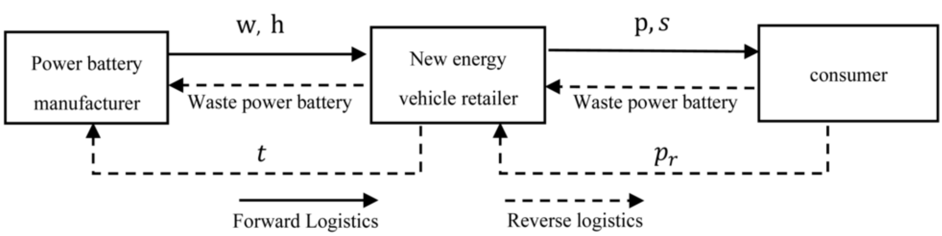

Figure 1. Closed loop supply chain model of power battery for new energy vehicles

(1) Suppose that the demand of consumers in the new energy vehicle market for new energy vehicles is equivalent to the demand for power batteries: $D = \alpha - \beta p + \delta h$, and $\alpha - \beta p > 0$.
(2) Revenue from recycling power batteries: $\Delta = c_n - c_r$, and $c_n > c_r$, In other words, utilizing recycled materials in the production of power batteries can reduce production costs.
(3) The recycling amount of power batteries in this model is $Q = A + kp_r + \gamma s$, A refers to the number of used batteries voluntarily returned by consumers. To simplify the calculation, assume that a is 0, so, $Q = kp_r + \gamma s$, and $0 < \gamma < k$.

Table 1. Parameters and decision variables

Decision variables	Definition
w	Wholesale price of unit power battery
h	Energy density per unit power battery
t	Unit waste power battery recycling transfer price
p	Unit power battery sales price
p_r	Recycling price of waste power batteries per unit
s	Recycling service level
Parameters	**Definition**
α	Total market size
β	Retail price sensitivity coefficient of new energy vehicles
δ	Power battery energy density sensitivity coefficient
c_n	Production cost of power battery
c_r	Cost of waste power battery reproduction
k	Price sensitivity coefficient of waste power battery recycling
γ	Recovery service level sensitivity coefficient
μ	Power battery energy density R&D cost coefficient
φ	Elasticity coefficient of service cost recovery
I_r	Average input recovery cost per battery
π_m, π_r, π	Manufacturer profit, vehicle enterprise profit and total profit of closed-loop supply chain
c, d, sr	Centralized decision model, decentralized decision model and contract coordination model

4. The Optimal Decisions

In this section, we will consider three models: centralized decision-making scenario, decentralized decision-making scenario and coordination scenario under decentralized decision-making.

4.1 Centralized Decision-Making Scenario

Under centralized decision-making, the power battery closed-loop supply chain is regarded as a whole, and the goal is to maximize the profits of the supply chain. Thus, the total profit represents the combined earnings of power battery manufacturers and vehicle companies. Expressed as:

$$\pi^c(p, p_r, h, s) = (p - c_n)(\alpha - \beta p + \delta h) + (\Delta - p_r - I_r)(kp_r + \gamma s) - \frac{1}{2}\mu h^2 - \frac{1}{2}\varphi s^2 \tag{1}$$

Proposition 1:The optimal decision of power battery closed-loop supply chain under centralized decision is as follows: $p^{c*} = \frac{(\alpha-\beta c_n)\mu}{-\delta^2+2\beta\mu} + c_n$, $p_r^{c*} = \frac{(I_r-\Delta)(\gamma^2-k\varphi)}{-\gamma^2+2k\varphi}$, $h^{c*} = \frac{(\alpha-\beta c_n)\delta}{-\delta^2+2\beta\mu}$, $s^{c*} = \frac{k\gamma(\Delta-I_r)}{-\gamma^2+2k\varphi}$, $Q^{c*} = \frac{k^2\varphi(\Delta-I_r)}{-\gamma^2+2k\varphi}$, $D^{c*} = \frac{\beta\mu(\alpha-\beta c_n)}{-\delta^2+2\beta\mu}$, $\pi^{c*} = \frac{1}{2}(\frac{(\alpha-\beta c_n)^2\mu}{-\delta^2+2\beta\mu} +$

$\frac{k^2\varphi(\Delta-I_r)^2}{-\gamma^2+2k\varphi}$) . In order to make the conclusion effective, it is necessary to meet:$2k(\delta^2-2\beta\mu)<0, (\delta^2-2\beta\mu)(\gamma^2-2k\varphi)>0$.

4.2 Decentralized Decision-Making Scenario

Under decentralized decision-making, a Stackelberg game relationship is formed with power battery manufacturers as the main and vehicle enterprises as the subordinate. They make decisions aimed at maximizing their individual profits. Consequently, the manufacturer takes the initiative in determining the wholesale price, energy density, and recycling transfer price, while the vehicle enterprise subsequently sets the retail price, recycling price and recycling service level of new energy vehicles. The profit functions of manufacturers and vehicle enterprises are as follows:

$$\pi_m^d(w,h,t)=(w-c_n)(\alpha-\beta p+\delta h)+(\Delta-t)(kp_r+\gamma s)-\frac{1}{2}\mu h^2 \quad (2)$$

$$\pi_r^d(p,p_r,s)=(p-w)(\alpha-\beta p+\delta h)+(t-p_r-I_r)(kp_r+\gamma s)-\frac{1}{2}\varphi s^2 \quad (3)$$

Proposition 2: In the closed-loop supply chain model under decentralized decision-making, in order to maximize their profits, the optimal decisions of manufacturers and vehicle enterprises are as follows: $w^{d*}=\frac{2\mu(\alpha-\beta c_n)}{-\delta^2+4\beta\mu}+c_n$, $h^{d*}=\frac{(\alpha-\beta c_n)\delta}{-\delta^2+4\beta\mu}$, $t^{d*}=\frac{I_r+\Delta}{2}$, $p^{d*}=\frac{3\mu(\alpha-\beta c_n)}{-\delta^2+4\beta\mu}+c_n$, $p_r^{d*}=\frac{(I_r-\Delta)(\gamma^2-k\varphi)}{-2\gamma^2+4k\varphi}$, $s^{d*}=\frac{k\gamma(\Delta-I_r)}{-2\gamma^2+4k\varphi}$,:$Q^{d*}=\frac{k^2\varphi(\Delta-I_r)}{-2\gamma^2+4k\varphi}$, $D^{d*}=\frac{\beta\mu(\alpha-\beta c_n)}{-\delta^2+4\beta\mu}$.
The optimal profit functions of power battery manufacturers, vehicle enterprises and total profit of supply chain are as follows:

$$\pi_m^{d*}=\frac{k^2\varphi(\Delta-I_r)^2}{4(-\gamma^2+2k\varphi)}+\frac{(\alpha-\beta c_n)^2\mu}{2(-\delta^2+4\beta\mu)}$$

$$\pi_r^{d*}=\frac{\beta(\alpha-\beta c_n)^2\mu^2}{(-\delta^2+4\beta\mu)^2}+\frac{k^2\varphi(\Delta-I_r)^2}{8(-\gamma^2+2k\varphi)}$$

$$\pi^{d*}=\frac{\mu(\alpha-\beta c_n)^2(-\delta^2+6\beta\mu)}{2(\delta^2-4\beta\mu)^2}+\frac{3k^2\varphi(\Delta-I_r)^2}{8(-\gamma^2+2k\varphi)}$$

Corollary 1: $s^{d*}, Q^{d*}, \pi_m{}^{d*}$ and $\pi_r{}^{d*}$ decreased with the increase of φ, p_r^{d*} increased with the increase of φ, $w^{d*}, h^{d*}, p^{d*}, D^{d*}$ are independent of φ.
This is because when the cost of recycling service level increases, vehicle enterprises will no longer provide relatively high recycling services, which will affect a group of customers who pay attention to recycling service experience. The recycling volume of waste power battery market is determined by the recycling price and recycling service level. To improve the recycling volume, the whole vehicle enterprises can only increase the recycling price to attract customers, which will impact their own profits. Meanwhile, the recycling volume will continue to decline, and the profits of both sides will also be reduced due to the reduction of recycling volume. The provision of recycling services by vehicle enterprises only affects the reverse recycling supply chain but fails to affect the decision-making in the forward sales supply chain.

Corollary 2: $s^{d*}, Q^{d*}, \pi_m{}^{d*}$ and $\pi_r{}^{d*}$ increased with the increase of γ, while p_r^{d*} decreased with the increase of γ. The proof process is consistent with corollary 1.

This is because when consumers pay attention to the recycling service level, vehicle enterprises are willing to improve the recycling service level to attract consumers, and the recycling volume also increases, so the earnings of manufacturers and vehicle enterprises also increase, while vehicle enterprises also bear the cost of more recycling service level. In order to improve their profits, they choose to lower the recycling price.

Proposition 3:(1)$p^{c*} < p^{d*}, h^{c*} > h^{d*}, p_r^{c*} > p_r^{d*}, s^{c*} > s^{d*}, Q^{c*} > Q^{d*}$;(2) $\pi^{c*} > \pi^{d*}$. This is because centralized decision-making is the most efficient approach, treating manufacturers and vehicle enterprises as a unified entity to make decisions aimed at maximizing system-wide interests. Under decentralized decision-making, manufacturers, as leading enterprises, in order to maximize their own revenue, reduce the input cost of power battery energy density, increase the wholesale price, leading vehicle enterprises to raise retail prices to improve their profits; In the process of reverse recycling, manufacturers depress the transfer price of recycling, and vehicle enterprises are forced to reduce the recycling price together and reduce the cost of recycling services, resulting in the reduction of recycling volume. Under decentralized decision-making, the effect of double marginal effect is obvious, while centralized decision-making can eliminate the double marginal effect, improve environmental benefits, and realize the optimization of strategic decisions and profitability maximization of the whole supply chain system.

4.3 Contract coordination scenario

Through the comparative analysis in the previous section, the supply chain under centralized decision-making has the highest revenue and the best effect. To improve the system revenue of the closed-loop supply chain and realize the Pareto optimization of the benefits of manufacturers and vehicle enterprises, this section designs a coordination mechanism to realize the coordination of the closed-loop supply chain.

The "revenue sharing" contract is used to coordinate the decision-making behavior of both parties, to realize the optimization of the overall profit of the power battery closed-loop supply chain. When the members reach a revenue sharing contract, the manufacturer will offer the power battery to the vehicle company at a reduced wholesale price, and the vehicle enterprise will sell it to the consumer at the price. After the sale, the vehicle enterprise will share the sales revenue between the two parties to make up for the loss of the manufacturer. The manufacturer will get σ of the sales revenue, and the vehicle enterprise will get σ of the sales revenue $1-\sigma$,and $\sigma \in [0,1]$. The optimal profit functions of power battery manufacturers and vehicle enterprises are as follows:

$$\pi_m^{sr} = (\sigma p + w - c_n)(\alpha - \beta p + \delta h) + (\Delta - t)(kp_r + \gamma s) - \frac{1}{2}\mu h^2 \quad (4)$$

$$\pi_r^{sr} = ((1-\sigma)p - w)(\alpha - \beta p + \delta h) + (t - p_r - I_r)(kp_r + \gamma s) - \frac{1}{2}\varphi s^2 \quad (5)$$

Proposition 4:when $w_r^{sr*} = (1-\sigma)c_n$, $\frac{2\beta\mu}{-\delta^2+4\beta\mu} \le \sigma \le -\frac{4\beta\mu(-\delta^2+3\beta\mu)}{(-\delta^2+4\beta\mu)^2}$,both manufacturers and vehicle enterprises can achieve Pareto improvement, in order to enable coordination across the closed-loop supply chain. The following are the optimal profit functions for power battery manufacturers and automotive companies

$$\pi_m^{sr*} = \frac{k^2\varphi(\Delta - I_r)^2}{4(-\gamma^2 + 2k\varphi)} + \frac{\mu(\alpha - \beta c_n)^2(-\delta^2 + 2\beta\mu\sigma)}{2(-\delta^2 + 2\beta\mu)^2}$$

$$\pi_r^{sr*} = \frac{k^2\varphi(\Delta - I_r)^2}{8(-\gamma^2 + 2k\varphi)} + \frac{\beta\mu^2(\alpha - \beta c_n)^2(1-\sigma)}{(-\delta^2 + 2\beta\mu)^2}$$

The necessary condition for effective contract coordination is that the profits of both manufacturers and vehicle enterprises are higher than those resulting from decentralized decision-making. Conditions to be met: $\pi_m^{sr*} \geq \pi_m^{d*}; \pi_r^{sr*} \geq \pi_r^{d*}$. The value range of profit sharing coefficient σ obtained jointly is: $\frac{2\beta\mu}{-\delta^2+4\beta\mu} \leq \sigma \leq -\frac{4\beta\mu(-\delta^2+3\beta\mu)}{(-\delta^2+4\beta\mu)^2}$.

Proposition 4 shows that the optimization of the system can be realized when the above parameters meet a certain relationship. It can be found that under this contract condition, the power battery manufacturer will give the vehicle enterprise a wholesale price lower than the production cost of the power battery, so that the vehicle enterprise can have the power to accept the contract mode; After the implementation of the coordination contract, the coordination of the supply chain can be achieved by adjusting the range of contract parameters, and the power battery manufacturers and vehicle enterprises can achieve Pareto improvement. As for the specific value of coordination parameters, it depends on the bargaining power between manufacturers and vehicle enterprises. Thus, the 'revenue-sharing' contract can achieve effective coordination within the closed-loop supply chain.

5. Numerical Analysis

To better verify the correctness of this conclusion, this section verifies the correctness of the previous conclusion through numerical simulation. Hypothesis $\alpha = 50, \delta = 0.8, \beta = 1, \mu = 5, c_n = 20, c_r = 5, I_r = 3, k = 0.8$.Next, we first investigate the impact of the sensitivity γ of recycling service level on the optimal decision.

After the analysis of corollary 1 and corollary 2, it is found that consumers' influence on γ on S is affected by φ, so φ=1,2,3,4 is set under the condition that the parameter conditions are met. Taking γ as the abscissa, the impact of the sensitivity of recycling service level on the optimal decision under decentralized decision-making is plotted, and Figure 2 is obtained; at the same time, to make it easier to see the change of γ's impact on profits, let φ=1,1.3,1.5 to get Figure 3.

By observing Fig. 2 and Fig. 3, it can be found that: (1)s, Q and π_m, π_ralways increase with the increase of γ,while $p_r$decreases with the increase of γ, which corresponds with the conclusion of inference 3. (2) With the increase of φ, the increasing trend of s, Q and π_m, π_r ,and the decreasing trend of p_r gradually slow down.

It can be concluded that consumers' attention to the recycling service level of recycling enterprises will affect the decision-making of vehicle enterprises. When the cost is appropriate, vehicle enterprises always choose to improve the recycling service level, and the recycling volume is also improved, which will bring environmental benefits and improve their own profits; However, when the recovery service cost coefficient gradually increases, the recovery service cost paid by vehicle enterprises will affect profits, and vehicle enterprises tend not to provide a relatively high level of recovery service.

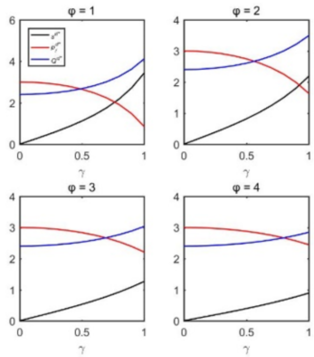

Figure 2. The influence of γ on decision variables

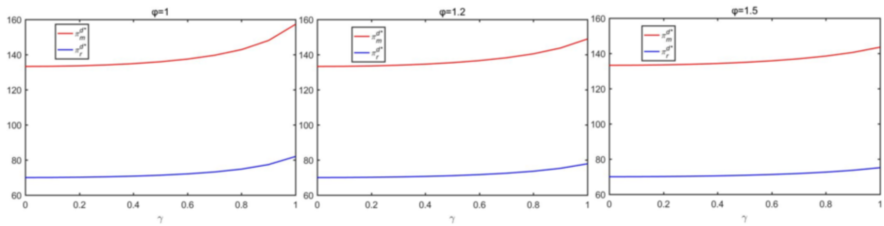

Figure 3. Impact of γ on profits

To verify the effectiveness of the "revenue sharing" contract, this section examines the profit changes of power battery manufacturers and vehicle enterprises after the implementation of the coordination contract. Hypothesis $\gamma = 0.6, \varphi = 3, \Delta\pi$ is the ordinate, Hypothesis $\Delta\pi = \pi^{sr*} - \pi^{d*}$,Taking the revenue sharing coefficient σ as the abscissa, the impact of coordination contract on the profits of closed-loop supply chain entities is plotted, and Figure 4 is obtained.

Looking at Figure 4, we can find that after the implementation of contract coordination, with the increase of σ, the profits of power battery manufacturers increase, and the profits of vehicle enterprises decrease. Because the contract needs to meet that the profit after coordination is greater than that before coordination, when σ is at a certain level, that is, $0.516 \leq \sigma \leq 0.766$, the profits of manufacturers and vehicle enterprises are higher than those before coordination, which achieves Pareto improvement for both parties in the supply chain and mitigates the impact of double marginalization, indicating the success of "revenue sharing" contract coordination.

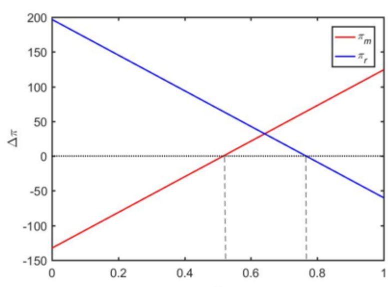

Figure 4. The influence of σ on the profit of closed loop supply chain

6. Conclusions and Limitations

This study focuses on the closed-loop power battery supply chain formed by one power battery manufacturer and one vehicle enterprise. Considering how recycling service levels impact the closed-loop power battery supply chain, this paper compares and analyzes the optimal decisions and profit fluctuations under centralized versus decentralized decision-making. In conclusion, the appropriate contract is developed to achieve coordination within the power battery closed-loop supply chain.

Through the research, we can get the following enlightenment: (1) with the improvement of consumers' quality of life, there has been a huge change in the concept of consumption. Consumers pay more and more attention to the service quality brought by consumption. For recycling enterprises, we should seize this trend and improve the level of recycling services, which not only meets the friendly change to the environment, but also can improve their own profits and obtain environmental benefits. (2) If the cost of providing recycling services remains high, enterprises in the closed-loop supply chain need to cooperate to improve the efficiency of recycling enterprises, so as to make both sides win-win; Or the government may intervene, consider that recycling enterprises bear the cost of recycling services, and provide subsidies to recycling enterprises to improve the efficiency of closed-loop supply chain.

In this paper, the power battery closed-loop supply chain is regarded as a two-level supply chain, but the power battery is only one part of the whole chain from production to sales, which involves multiple links and enterprises. If enterprises in other links are added to make decisions and coordination, more and more valuable conclusions can be obtained. In addition, we can also consider the decision-making of enterprises in closed-loop supply chain in the case of asymmetric information, which will also be the research direction in the future.

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Section 3

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Research on Influencing Factors of Chinese College Students' Rural Employment Intention Under the Background of Rural Revitalization

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Abstract. This empirical study integrates the push-pull theory and the theory of planned behaviour and uses optimal scale regression to explore and investigate the rural employment intentions and influencing factors of Chinese freshmen. This study indicates that 42.3% of university students express interest in working in rural regions. Various factors such as personal characteristics, human and social capital influence this inclination. Higher educational levels, agricultural specialization, leadership roles, lower socioeconomic background, and highly educated parents positively correlate with the willingness of graduates to work in rural areas. Factors boosting this inclination include personal perception of rural employment value, societal attitudes toward rural work, access to rural job information, urban employment pressures and costs, university promotion, and support from local governments. Conversely, obstacles include job quality, personal development, children's education, and rural welfare. To encourage rural employment among students, government entities should enhance policy development and promotion, fostering a positive attitude towards rural work. Educational institutions must provide adequate guidance, while students should proactively adjust their employment mindset.

Keywords. Rural revitalization; College student employment; Rural employment willingness

1. Introduction

Rural revitalization is an important part of the country's modernization drive. In order to better develop the countryside, the Twentieth Congress of the Communist Party of China (CPC) proposed that to rejuvenate the nation, the countryside must be revitalized. Due to the dual system of urban-rural division in China, a large number of rural labor forces flow to the cities, and the brain drain in the countryside is serious, which has become an important factor hindering the development of rural areas[1]. What is different from this situation is that college students with high human capital find it very difficult to find jobs

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in cities because of their large number and fierce competition[2]. According to statistics, the number of college graduates in China is on the rise, and the number of college graduates in 2023 is expected to reach 11.58 million. The employment competition for college graduates is becoming more and more fierce, and the employment rate of college graduates in some areas continues to decline, and even some of them are unemployed after graduation.

Encouraging college students to work in rural areas can not only solve the problem of scarce human capital in rural areas, but also better complete the work of rural revitalization, and effectively alleviate the problem of college students' employment difficulties[2]. The willingness of college students to work in rural areas determines whether they will stay in rural areas. "It is the starting point and driving force of rural employment behavior". To attract more college students to work in rural areas, it is necessary to improve college students' willingness to work in rural areas[4]. However, at present, most college students will not take rural areas as their first choice of employment, and rural employment of college students presents a certain degree of structural lack[5]. According to a survey, the proportion of Chinese university students who are willing to go to rural areas for employment is only about 30 per cent, which is much lower than that of other Asian countries (60 per cent in both Bangladesh and Thailand, 50 per cent in India, and 33 per cent in Vietnam)[6].

So, what is the current situation of college students' rural employment intention in China? Which college students are more willing to work in rural areas? What are the influencing factors of college students' willingness to work in rural areas? From the perspective of push and pull theory and planned behavior theory, this study constructs an analysis framework and conducting a questionnaire survey of recent college graduates, tries to understand the current situation of Chinese college students' willingness to work in the countryside, determines the types of college students who have strong willingness to work in the countryside, and probes into the factors influencing the willingness to work in the countryside to analyse them, so as to provide targeted ideas and references for the enhancement of college students' willingness to work in the countryside.

2. Theoretical Basis and Literature Review

2.1. Theoretical Basis

Push and pull theory is a classic theory to study the problem of population mobility, which has strong explanatory power on the factors influencing college students' willingness to take up employment in rural areas. In the late 1950s, D.J. Bogue systematically put forward the push and pull theory of labour migration, and the push and pull theory has been gradually matured and known in the academic world since then. According to D.J. Bogue, from the point of view of kinematics, the decision of urban-rural migration of labour force is the result of the interaction of two different The result of the interaction of forces in two different directions. One is the force that prompts the labour force to migrate between urban and rural areas, including the push force from rural areas and the pull force from cities; the other is the force that hinders the population to migrate between urban and rural areas, including the pull force from rural areas and the push force from cities[7]. According to the push and pull theory, college students' employment in rural areas is the result of the joint action of urban push, intermediate hindering factors, individual characteristics and rural pull. However, in the complex practice of college students' rural employment, the city is not the only push force and the rural area is not the only pull force, in fact, both the city and the rural area produce both push and pull forces for college students.

The Theory of Planned Behavior (TPB) was developed by psychologist Icek Ajzen in the 1980's.The theory is mainly used to explain and predict the behavioural intentions of individuals and the behaviour itself. The theory suggests that an actor's behavioural attitudes, subjective norms, and perceived behavioural control work together to influence his or her behavioural intentions[8]. College students going to rural areas for employment is also a deliberate and planned behaviour, whether college students choose to be employed in rural or urban areas is essentially a behavioural tendency presented by their choice of employment area. This means that the theory of planned behaviour can be used to explain college students' willingness to work in rural areas.

2.2. Literature Review

In order to promote rural revitalization and development and relieve the employment pressure of college students, the state encourages college students to return to their hometown for employment. The investigation and research on college students' returning to their hometown for employment have attracted the attention of many scholars. Yang Jing et al. took five colleges and universities in Jiangxi Province as examples to explore the factors influencing college students' willingness to return to their hometown for employment from the perspective of push-pull theory, and concluded that students whose parents are engaged in agriculture or who study in agricultural colleges and universities themselves are more inclined to return to their hometown for employment[8]. In practice, college students have a low intention to return to their hometowns for employment. Luo Zhangsong et al believe that the lack of local endogenous impetus, the influence of traditional values in rural areas, and the unsound policy system cause college students to be reluctant to return to their hometowns[10]. Xu Xiaoping conducted a survey on 12 colleges and universities in Shaoxing City, and combined with the cross-analysis results of employment intention, based on the social support theory, analyzed that national policy orientation, hometown employment environment, peer value orientation and family resource endowment were the main influencing factors for college students to return to their hometown for employment[11]. Ju Shaowei, Cai Meng. focused on the group of college students and found that the reason why college students returned home for a short period of employment and employers tended to prefer stable occupations was the uncertain employment prospects in their hometown[11]. Ling Jianzhong believe that the local government should timely issue supporting policies, strengthen cooperation with enterprises, cultivate good employment soil, strengthen infrastructure construction, and increase the propaganda of socialist core values[13]. Based on a micro perspective, Qi Yangyang proposed suggestions for college students majoring in physics to improve the employment guidance system, carry out special social practice activities, and rural governments to take the initiative to strengthen contact with students[14]. Gangwar believes that the reserve of employment knowledge and the ability to bear risks have an important impact on college students' employment intention in rural areas[15]. P.A.Baffour investigated the relationship between rural employment intention, occupational motivation, rural contact and parents' vocational education status (PPES) of 302 fourth-year medical college students in Ghana. The results showed that occupational motivation factors had no influence on rural employment intention of college students. While parents' education status hinders college students' rural employment intention[16]. A. Amalba found that community-oriented education model may help stimulate medical students' interest in rural areas and influence their career choice [17].

Existing studies indicate that college students generally exhibit low willingness to seek employment in rural areas, with influencing factors being numerous and intricate. Researchers have predominantly utilized theories such as the push and pull theory, AISA model, social support theory, planned behavior theory, and opportunity cost theory to explore various aspects affecting college students' employment willingness, encompassing individual, family, school, society, and policy perspectives. While valuable research results have been attained, there are notable limitations. Most prior research methods rely heavily on speculative and descriptive statistics, neglecting in-depth case interviews crucial for uncovering the underlying reasons behind college students' inclination towards rural employment. Consequently, the complete elucidation of the multifaceted influences on college students' employment intentions remains challenging. Moreover, existing studies overlook the interrelation among factors shaping college students' employment intentions in rural areas, erroneously assuming their independence despite the evident close connections between these factors[17].

3. Methodology

3.1. Research hypothesis

This study employs the push-and-pull theory and the theory of planned behaviour as theoretical frameworks. The push-and-pull theory examines the influence of external factors on rural willingness, whereas the theory of planned behaviour considers the impact of subjective consciousness on rural willingness. The push-and-pull theory is a traditional theory of population migration, and this study of college students' willingness to relocate to the countryside for employment is a migration from urban to rural areas[7]. This also applies to population mobility. The theory of planned behaviour was initially employed in the field of information systems to examine the user's willingness to continue using emerging technology. It has since been applied to a multitude of behavioural studies. College students' choice of urban or rural employment can be considered a behavioural decision, thus aligning with the Theory of Planned Behaviour model. The factors of urban push and rural pull are those that encourage college students to consider rural employment, while the factors of urban pull and rural push act as deterrents. When faced with these same push and pull factors, individual factors and individual perception in the push and pull theory can explain the employment intentions of college students. In addition, the willingness of college students to pursue employment in rural areas is influenced by their attitudes towards such opportunities, the subjective norms they perceive to be relevant to this decision, and their perceived behavioural control. A positive attitude towards rural employment, support from significant others, and a strong sense of behavioural control are all associated with a greater intention to pursue rural employment. Conversely, a negative attitude, lack of support, and weak perceived behavioural control are associated with a lower intention to pursue rural employment.

- Rural employment attitude, subjective norm, perceived behavior control and rural employment intention

The theory of planned behavior indicates that attitude, subjective norm, and perceived behavior control have an impact on intention. Behavioral attitude refers to the positive or negative evaluation and tendency towards behaviors based on individual values. If college students hold a positive attitude towards rural employment, they are more likely to choose to work in rural areas. Conversely, if they have a negative attitude, they are less inclined to seek employment in rural settings. Subjective norms reflect the influence of social environment and peer pressure on individual actions. The attitudes and opinions of those around individuals can sway their willingness to engage in certain behaviors. College students are more willing to pursue rural employment if they have support from family and friends. A welcoming social environment further encourages college students to consider rural employment as a viable option. Perceived behavioral control relates to the perceived difficulty in adopting a particular behavior. College students who believe they can easily adapt to rural employment are more confident in their abilities and readiness. Therefore, the study posits the following assumptions:

H1: The rural employment attitudes, subjective norms, and perceived behavioral control of college students are positively correlated with their intentions to seek rural employment.

- Urban thrust, rural pull and rural employment intention

The push and pull theory points out that the push of the outflow place and the pull of the inflow place are the two forces that promote the labor force to the outflow place [16]. In this study, urban as the outflow of labor force, rural as the outflow of labor force, urban employment pressure, employment policy, school publicity, urban living cost and major matching will make college students leave the city and choose the countryside when they choose the re-employment, while rural pull in personal emotion, rural development prospects and local government support will make people full of hope for rural employment. Thus, the rural employment will be generated. Therefore, the following assumptions are made in this study:

H2: Urban thrust (employment policy, school publicity, urban employment pressure, urban living cost, major matching) promotes college students' employment willingness to go to the countryside.

H3: Rural pull (personal emotion, rural development prospect, local government support) plays an important role in promoting college students' rural employment intention.

- Urban pull, rural push and rural employment intention

The pull of the outflow and the thrust of the inflow hinder the labor force from the inflow to the outflow. Because the urban economy is more developed, if you work in the city, you can get higher wages, personal development, and better development of children's education in the future, and it is more decent to work in the city, while the rural areas have poor infrastructure, different living habits, and lower welfare benefits than the urban treatment, so they will affect college students to work in the countryside. Therefore, the following assumptions are made in this study:

H4: Urban pull (high salary, respectability, personal development, children's education) will have a negative effect on college students' willingness to work in rural areas.

H5: Rural push (rural welfare, rural infrastructure, rural life) will hinder college students' willingness to work in rural areas.

- Individual characteristics and rural employment intention

Individual characteristics are the characteristics of individuals as research objects. When people make their willingness, they will measure it according to their own conditions and judge the direction of employment. When considering employment, college students will judge whether to go to rural areas for employment according to their basic information, human capital and family social capital. Different human capital, family housing and social capital will have an impact on college students' employment choice. Therefore, the following assumptions are made in this study:

H6: Individual characteristics, human capital and family social capital factors affect the generation of rural employment intention of college students.

3.2. Data collection

The data used in this study are from a questionnaire survey conducted between March and March 2023. The respondents were fresh college graduates in 2023, involving 27 universities in H province. The questionnaire adopts stratified sampling method, according to the school level, 123 students are selected from 2 "985 Project" colleges and universities, 125 students are selected from 4 "211 Project" colleges and universities, 217 students are selected from 5 ordinary colleges and universities, 411 students are selected from 12 ordinary colleges and universities, and 108 students are selected from 4 junior colleges and universities. A total of 984 questionnaires were distributed, 10 invalid questionnaires were excluded, and 974 valid questionnaires were obtained, with an effective rate of 98.98%. The information characteristics of the samples are shown in Table 1.

Table 1. Basic information

Name	sort	Frequency	Percentage
Gender	male	398	40.9%
	female	576	59.1%
Type of household registration	Agricultural household registration	540	55.4%
	Urban household registration	434	44.6%
Place of residence	Village	208	21.4%
	Market towns	188	19.3%
	County	268	27.5%
	Small and medium-sized cities	210	21.6%
	Provincial capital or municipality	100	10.3%
Political profile	Party members (including probationary members)	152	15.6%
	Communist Youth League members	664	68.2%
	The Masses	152	15.6%
	Other	6	0.6%
Monthly household income	Less than 2,000	55	5.6%
	2000-5000.	157	16.1%
	5001-9000.	319	32.8%
	9001-15000.	252	25.9%
	15,000 +	191	19.6%

3.3. Variable design and reliability and validity test

This study conducted a scale design for college students' rural employment influencing factors. Among them, the rural employment attitude, subjective norms, and perceived behavioural control scales were designed with reference to Ajzen's classic scales of the theory of planned behavior[18]; the urban push-pull, rural push-pull, and personal factors were designed with reference to the relevant scales of LEE[19]. Taking rural employment intention as the dependent variable, 35 independent variables were designed, as shown in Table 2. SPSS (21.0) was used to process the data. Cronbach Alpha=0.941 for the rural employment behavior perception scale and Cronbach Alpha=0.947 for the rural and urban push and pull factors scale, indicating high reliability of the questionnaire. Rural employment behavior perception scale KMO=0.941, rural and urban push and pull factor scale KMO=0.957, the questionnaire has good structural validity.

3.4. Data processing

This study mainly used SPSS 21.0 for descriptive statistics and correlation analysis of the data, and optimal scale regression hypothesis was used for testing.

4. Results

4.1. Regression model

According to the data type of this study, independent variables include disordered variables, categorical variables and other variable types. In this study, the optimal scale regression in statistical software SPSS (21.0) was adopted to analyze the factors affecting the rural employment intention of college students. This method is good at quantifying the different values of categorical variables and converting them into numerical variables for statistical analysis. Table 2 lists the definition and assignment of the dependent variables and their respective variables among the influencing factors of college students' rural employment intention. The results of optimal scale regression are shown in Table 2, where R2=0.413 and significance =0.000 < 0.05, indicating a good fit of the model.

Table 2. Optimal scale regression results of factors influencing rural employment intention of college students

Variable type	Variables	B values	Standard deviation	F-value	Sig value
Rural employment attitudes	Employment value	0.119	0.048	6.164	0.000
	Employment ideas	0.083	0.048	2.959	0.019
	Employment Exercise	0.029	0.065	0.195	0.941
	Employment Career Development	0.056	0.045	1.538	0.189
Subjective norms	Attitudes of those around you	0.097	0.043	4.993	0.001
	Understanding rural Degree	0.075	0.057	1.735	0.140
Perceptual Behavioral control	Wishes of people around you	0.135	0.070	3.668	0.006
	Job coping ability	0.065	0.056	1.378	0.240
	Ability to access information	0.095	0.060	2.562	0.037
	Rural employment difficulty	0.044	0.038	1.316	0.262
Urban thrust	Employment pressure	0.137	0.059	5.497	0.000
	Cost of living	0.116	0.052	4.901	0.001
	Employment policy	0.061	0.069	0.794	0.529
	Public opinion in favor	0.046	0.045	1.081	0.365
	School publicity	0.067	0.041	2.637	0.033
	Professional Matching	0.254	0.090	7.953	0.000

Country Rally		Rural development prospects	0.148	0.077	3.717	0.005
		Local government support	0.087	0.052	2.788	0.026
		Personal emotions	0.084	0.066	1.617	0.168
Urban pull		High pay	0.061	0.050	1.505	0.199
		respectability	0.108	0.053	4.244	0.002
		Personal development	0.128	0.077	2.729	0.028
		Children's education	0.103	0.050	4.297	0.002
Country push		Rural welfare	0.089	0.049	3.340	0.010
		Rural infrastructure	0.059	0.040	2.218	0.065
		Country living conditions	0.107	0.071	2.246	0.062
Individual Factors	Individual characteristics	Gender	0.044	0.028	2.500	0.114
		Siblings	0.019	0.034	0.333	0.564
	Human capital	University level	0.080	0.031	6.812	0.000
		Professional	0.061	0.027	5.084	0.000
		Student cadre or not	0.072	0.030	5.837	0.001
		Political affiliation	0.035	0.029	1.434	0.231
		Maximum scholarship	0.070	0.029	5.938	0.001
	Social capital	Parental education	0.104	0.034	9.210	0.000
		Monthly household income	0.049	0.052	0.902	0.001
	R2=0.413,ANOVA=0.000,N=964					

4.2. Result analysis

- Analysis of rural employment attitude

As shown in Table 2, the influence coefficients of employment value, employment correctness, employment exercise and employment and career development on rural employment intention are all positive. Among them, sig values of employment value and employment concept are all less than 0.05, which is statistically significant through significance test, indicating that college students who subjectively believe that rural employment is valuable are more willing to have rural employment. The sig values of employment exercise and employment career development were both greater than 0.05, which did not pass the significance test and did not have statistical significance.

- Analysis of Subjective norms

As shown in Table 2, the influence coefficients of attitude and willingness of people around them on rural employment willingness of college students are analyzed to be 0.097 and 0.135, and their sig values are both less than 0.05, with statistical significance. It indicates that the attitude and willingness of people around them have a very significant positive impact on college students' willingness to work in rural areas. The sig value of rural understanding degree is greater than 0.05, which has no statistical significance.

- Analysis of perceived behavior control

As shown in Table 2, the sig values of job coping ability and rural employment difficulty were both greater than 0.05, which did not have statistical significance. The coefficient of influence of easy access to rural employment information on college students' willingness to work in rural areas is 0.095, and its sig=0.037 is less than 0.05. After passing the significance test, it has statistical significance, indicating that the more access to rural employment information, the more willing to work in rural areas. At present, there are many preferential policies for rural college students at the national, provincial and municipal levels, and policy supports such as three support and one support, and village officials for college students all encourage college students to work in rural areas.

- Analysis of urban thrust

As shown in Table 2, the analysis of the influence coefficients of urban employment pressure, urban living cost, school publicity and major matching on college students' rural employment intention are 0.137, 0.116, 0.033 and 0.254, and the sig values of these four items are less than 0.05, all of which are statistically significant. It shows that the greater the urban employment pressure, the higher the urban living cost, the stronger the publicity of the school, the more matching between the major and the village, the stronger the employment intention of college students. The sig value of employment policy and public opinion support is greater than 0.05, which has no statistical significance.

- Analysis of country rally

As shown in Table 2, the analysis of the influence coefficients of rural development prospects and local government support on college students' rural employment intention are 0.148 and 0.087, and their sig values are both less than 0.05, which have significant statistical significance through significance test. It shows that the better the rural development prospect and the more rural employment support government issued by the local government, the stronger the rural employment intention of college students. The influence factor of personal emotion on rural employment intention of college students is 0.084, and its sig value is =0.168>0.05, which has no statistical significance on rural employment intention of college students.

- Analysis of urban pull

As shown in Table 2, the analysis of influence coefficients of respectability, personal development and children's education on rural employment intention of college students is 0.108, 0.128 and 0.103, and their sig values are all less than 0.05, with statistical significance. It shows that decent work degree, personal development and children's education have an obstacle effect on college students' willingness to find employment in rural areas. sig value =0.199>0.1 indicates that its impact on rural employment willingness of college students has not passed the significance test and is not statistically significant.

- Analysis of country push

As shown in Table 2, the influence coefficient of rural welfare on college students' rural employment intention is 0.089, sig value =0.01 < 0.05, and the significance test indicates that rural welfare has a hindrance effect on college students' rural employment intention. The sig values of rural infrastructure and rural living conditions were both greater than 0.05, which did not pass the significance test.

- Analysis of individual

As shown in Table 2, both sig values of the two factors of individual characteristics were greater than 0.01, which failed the significance test and did not have statistical significance. The analysis of the influence coefficients of human capital factors such as university level, major, whether or not student leader and award student on rural employment intention of college students are 0.080, 0.061, 0.072 and 0.070, and their sig values are all less than 0.05. It indicates that the higher the school level, the more agriculture-related the major, the worse the class leader and the worse the student achievement, the higher the rural employment intention of college students. The political status sig=0.231 was greater than 0.05, which did not pass the significance suggestion and did not have statistical significance. In social capital, the sig value of parental education =0.000 and sig value of family monthly income =0.001, both lower than 0.01, indicate that the higher the education level of parents and the family income below the middle level, the higher the college students will go to the countryside.

5. Conclusion and Discussion

5.1. Discussion

According to the optimal scale regression results can be seen in the design of the 35 variables in 20 variables is a significant effect on the college students rural employment intentions, based on this conclusion, college students rural employment intentions can be optimised from the following aspects.

- From the perspective of government

Firstly, it is essential to improve rural employment policies. The government should enhance rural employment policies by introducing support for rural scientific research projects, subsidies for college students' rural employment and entrepreneurship, improving salary benefits to meet the basic wage needs of college students, providing certain subsidies to college students employed in rural areas, establishing a sound security mechanism for college students' employment in rural areas, and encouraging college students to work in rural areas. Relying on grassroots governments, schools, and hospital staff dormitories, explore the construction of rural talent apartments to address the personal living and enterprise development challenges faced by college students in rural areas. Secondly, create a favorable rural employment environment. The government can support enterprises that help rural economic development, attract college students to work in rural areas with good working environments and attractive salaries, and improve rural infrastructure construction. Vigorously promote the "Connect Every Village" project to make rural transportation more convenient, create distinctive modern livable new rural areas, reduce college students' concerns about rural life and material conditions, and attract more outstanding college students to participate in rural employment. Thirdly, promote in-depth reforms in related majors. Promote close integration of relevant majors with rural industries, encourage numerous higher education institutions to cooperate with the government in offering majors, and train talents in areas such as rural social workers, medical and health care, early childhood education, and smart agriculture to address current shortages. Ensure that what is lacking in rural areas is what is being trained, and guarantee that college students returning to rural areas have work opportunities. Improve the university-rural employment service system to ensure that every college student fully grasps rural development opportunities.

- From the perspective of social

Fostering a positive rural employment narrative is essential. By dispelling stereotypes and biases related to rural employment through advocacy and information dissemination, perceptions regarding rural employment can be transformed. Promoting awareness of rural employment prospects and showcasing rural development achievements can alter mindsets and encourage college students to consider rural work as a fulfilling career path. Public opinion shaping plays a pivotal role in enhancing societal acceptance of rural employment, thereby enticing more college graduates to contribute to rural communities.

- From the perspective of the educational institution

First, we should strengthen ideological education. Among college students, undergraduate students (except 985 colleges) have a lower intention to find employment in rural areas, while 985 colleges and college students have a higher intention to find employment in rural areas. Colleges and universities should strengthen the ideological education of students and guide them to establish a correct employment concept, which is very necessary. According to the questionnaire, most college students do not want to stay in rural areas for employment because they think that rural areas are backward and not conducive to their own development. Second, rural employment-related courses should be offered. Colleges and universities can set up courses related to rural employment, systematically plan the courses of employment and entrepreneurship for college students, integrate rural employment into the courses of employment and entrepreneurship for college students, pay attention to classroom persuasion, change the teaching mode, invite local outstanding village officials and rural entrepreneurs to enter colleges and classrooms, and use their personal experiences to let college students learn from and serve as benchmarks. Take the initiative to explore employment practice courses, in the form of rural volunteer service, rural research and other good employment courses, so that college students fully understand the desire for talents in rural revitalization, eliminate the psychological resistance to rural employment from the heart, and more clearly understand the relevant policies and regulations, and maintain a good rural employment mentality. Third, make good use of campus media publicity.

Colleges and universities around the country should give full play to the impenetrable role of campus media in educating people, use various online platforms to show the changes in rural areas in recent years, give full play to the silent role of literary works in embellishing things, and organize various literary and artistic activities popular with college students to tell stories of rural development such as poverty alleviation and rural revitalization, so as to enhance students' confidence in rural employment. Pay attention to exploring and praising the advanced examples of rural employment and entrepreneurship college students, vigorously publicize outstanding students who have made certain achievements in rural revitalization and development and encourage more students to stay in the countryside for employment with the power of example by organizing large-scale commendation meetings, grassroots employment figures exhibition, employment figures story exhibition and other ways.

- From the perspective of the family unit

First, parents should change their outdated ideas and concepts. Families are willing to invest a lot of money and time to raise their children, most of them in order to change the fate of the family and hope that their children will have a better future. The parents of college students should actively change their ideas and set reasonable expectations. Parents' will determine whether their children can stay in rural employment, so parents should change their attitude toward rural employment, understand the current rural employment environment, to know that staying in rural employment can also have a good future, and the country urgently needs talents to join, to help rural development, through family education and parental ideological influence, parents should correct their views on rural employment, Help college students correctly understand rural employment and establish a good view of employment. Second, family members should respect each other. In Chinese society, what parents think often has a great influence on their children and can even play a decisive role. The employment willingness of college students is still largely influenced by family members, and it is common for college students to follow the arrangement of family members and fail to realize their dreams.

- From the perspective of the individual

First, abandon urban mindset. The results of the questionnaire show that 53% of college students choose to work in the "suburbs", and they also prefer politics in their choice of career type. Few are willing to go to the bottom, mainly because they think that urban work is more comfortable, and rural revitalization does not lack this person. Therefore, college students should abandon their bad employment psychology and correct their own employment concept. They should not only focus on employment location and salary, but also take into account personal ideals, life values and national needs. Second, consider employment according to their own situation. When looking for employment opportunities, college students should consider comprehensively based on their own ability, major and future prospects. At present, there is a serious phenomenon of college students' employment, some urban and institutional positions are difficult to find, while rural positions are not sought. College students should have a correct understanding of their own ability, have a correct cognition of staying in the countryside to work, and do not follow the crowd or look low.

5.2. Shortcomings and Prospects

Firstly, the data in this paper comes from universities in Hubei Province, and the study may be limited by sample selection and geographical restrictions, which may not be broadly representative of all college student groups. Second, the multidimensional analysis of rural employment intention needs to be deepened, especially the consideration of psychological dimension and cultural factors. Future research should expand the scope of the sample and adopt a mixed research method, combining quantitative and qualitative data, to explore in depth the intrinsic motivations and barriers of college students' rural employment intentions. At the same time, it should pay attention to the tracking study of the implementation effect of the policy and assess the actual impact of the proposed recommendations, so as to provide a basis for the continuous optimisation of the strategy of introducing talents to the countryside.

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Digital Inclusion in Ecuadorian Education Through Innovative Resources for Teaching Entrepreneurship

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Abstract. This study investigates the implementation of innovative resources for digital inclusion in entrepreneurship education in Ecuador. Using a mixed-methods approach (quantitative and qualitative), it examines the impact of these tools on secondary school students and teachers. The findings show that digital resources not only enhance technological skills but also increase student engagement in learning activities. This highlights the crucial role of integrating digital technologies into the educational system to promote more inclusive and effective learning experiences. The study concludes with recommendations for expanding the use of these tools to other areas of the curriculum.

Keywords. Learning, digital, entrepreneurship and management, environments.

1. Introduction

In Ecuador, the digital divide remains a significant challenge, particularly in the educational context [1]. The need to develop interactive resources that facilitate digital inclusion is critical for improving the quality of teaching and learning, especially in areas like entrepreneurship. This study aims to analyze how innovative resources, such as digital platforms and interactive applications, can contribute to greater inclusion and participation of students in the classroom [2]. By addressing this gap, the research seeks to enhance understanding of the role digital inclusion plays in educational development, particularly in under-researched settings like Ecuador.

The integration of interactive digital tools in Ecuadorian education is crucial for fostering inclusive educational environments. Students must develop participatory skills, but current traditionalist teaching methods, such as rote memorization and individualistic approaches, often lead to disengagement [3], [4].

Furthermore, many teachers still rely on outdated pedagogical strategies, failing to apply collaborative, interactive methods that encourage active student involvement and

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the practical application of acquired knowledge [5]. As a result, there is an urgent need to promote autonomous learning, where students experience transformative educational activities that connect them to their environments and improve classroom dynamics.

Education in Ecuador is recognized as a constitutional right, as outlined in Article 26, [6] which asserts that education is a lifelong right and an inescapable duty of the state [7]. Interactive learning, emphasized in various studies, supports socio-educational development by fostering responsibility among educational actors and creating pedagogical environments conducive to forming competent individuals equipped to face societal challenges [8].

Recent reviews and empirical research on digital technologies and self-directed learning have had a positive impact on the teaching-learning process. Digital environments have been shown to enable students to learn and improve their competences and performance levels. They also create a shift in pedagogy from a teacher-centred approach to a student-centred approach [9].

Students have been taking advantage of these digital environments to enhance their learning. Governments, organisations, private institutions and teachers are providing interactive digital educational materials (paid or free) that aim to offer students additional educational resources for their learning process. The new generation, born since the 1990s, has a different experience with digital environments because they use technology from a very young age [10]. Teaching activities need to be designed through creativity and interactive spaces. An emerging consensus suggests that engaged and active forms of learning with digital media take place in communities where students, through participation, learn to communicate, produce digital content, construct identities and share and distribute knowledge [11].

Students also need to develop skills that prepare them to innovate, lead, collaborate and persevere, taking into account that entrepreneurship and management is a very important subject for all students. The subject is focused on developing innovative thinking, given that the contents can be applied to any person from any social condition. In an evolving society, technological tools generate better capabilities in students, designing interactive activities based on teamwork, where they learn together, share what they learn and are able to develop their skills in the subject of entrepreneurship [12].

The subject of Entrepreneurship aims to develop specific skills in students. It is taught in the three years of the General Unified Baccalaureate (BGU). According to the [13] one of the main objectives is for students to "develop their entrepreneurial skills, with the daily application of these skills, to become a dynamic person in society as a whole, in their family, geographical area or city and, therefore, to generate sources of employment" [14].

The teachers apply digital strategies aimed at a good academic performance of their students, but these are insufficient in the development of interactive learning, coupled with limited existing resources for teaching the subject [15]. The entrepreneurship is designed to enhance their education and teach them the art of communication, time management, negotiation and collaboration. In fact, entrepreneurship is not just another content topic; it is a mindset that helps people develop agile thinking so that they can identify problems and find solutions that create value [16].

2. Methodology

This research employs a mixed-methods approach, integrating both quantitative and qualitative methods to offer a comprehensive analysis of the effects of digital resources on education, specifically within the context of Ecuadorian entrepreneurship education. The combination of these methods allows for a broader understanding of both measurable outcomes and the perceptions of the participants involved.

2.1 Research Design

The study follows an exploratory sequential mixed-methods design, where qualitative data was first collected to identify key themes and inform the quantitative phase. This design was chosen due to the limited existing research on digital inclusion in entrepreneurship education in Ecuador. The study aims to explore the uncharted area of how digital tools impact the teaching-learning process in this specific educational context.

2.2 Sampling and Participants

The sample was purposively selected, focusing on ensuring the representation of both students and teachers actively participating in entrepreneurship education. The participants included 150 secondary school students and 10 teachers from various educational institutions across Ecuador. This purposive sampling allowed the study to capture insights from those directly involved in the implementation of digital resources in classrooms.

2.3 Instruments

Quantitative Instruments

1) **Surveys:**
Surveys were administered to both students and teachers to collect quantitative data on key variables such as student engagement, access to technology, and self-assessed entrepreneurship skills. The surveys included Likert-scale questions and multiple-choice items to capture the extent of digital inclusion and the use of digital tools in classroom settings.

2) **Student Participation:**
Quantitative data on student participation was measured through class attendance and participation in interactive digital activities related to entrepreneurship education.

3) **Entrepreneurship Skills:**
To evaluate the development of entrepreneurship skills, students completed a self-evaluation using standardized rubrics, and their performance was assessed through standardized tests that measured entrepreneurial knowledge and competencies.

4) **Access to Technology:**
Data on technology access was gathered by measuring the availability of devices (e.g., computers, tablets) and internet connectivity in both home and school environments. This aimed to evaluate the impact of digital resource accessibility on the students' ability to engage with the curriculum.

Qualitative Instruments

Semi-structured Interviews:
Semi-structured interviews were employed as the primary qualitative data collection method. These interviews were conducted with teachers and students to gain in-depth insights into their experiences with digital tools in the classroom. The interviews explored topics such as:

- **Technological accessibility**
- **Impact on student engagement**
- **Perceptions of digital resources**
- **Challenges faced during digital integration**

These interviews allowed for flexibility in responses while maintaining a consistent structure to compare results across participants.

2.4 Data Analysis

- **Quantitative Data Analysis**

The quantitative data were analyzed using descriptive statistics (mean, standard deviation) to summarize the responses and inferential statistics to test the study's hypotheses. Additionally, correlation analysis was employed to examine the relationship between access to technology and student engagement.

- **Qualitative Data Analysis**

The qualitative data from the interviews were analyzed using a thematic analysis approach. This method enabled the identification and coding of recurring themes and patterns across the responses. The identified themes were then categorized and compared against the proposed study hypotheses to assess how digital resources influence student engagement and reduce socioeconomic disparities in education.

2.5 Study Hypotheses

The study is guided by two hypotheses, designed to test the impact of digital resources on educational outcomes:

- **H1:** The integration of digital technologies in the classroom improves student engagement in entrepreneurship learning.
- **H2:** Access to innovative digital resources reduces socioeconomic educational gaps in Ecuadorian educational institutions.

2.6 Ethical Considerations

All participants were informed about the purpose of the research, and informed consent was obtained prior to data collection. The anonymity of participants was maintained, and all data were stored securely in compliance with institutional ethical guidelines.

3. Results and Discussion

Table 1. Composition of high school students in Ecuador vs. in the canton of Ambato 2024

Quantity	2021	2022	2023	2024	2025
Bachelor's students in the country	902355	996488	1002397	1006510	1008345
Baccalaureate students in the Ambato-Tungurahua	21904	22621	22517	21106	22099
Frequency Overview	0.02%	0.02%	0.02%	0.02%	0.02%

Source. Ministerio de Educación 2024

In Ecuador, the number of high school students is shown in Table 1, where the canton of Ambato represents only 0.02% of the total population of the country.

Table 2. Student survey reliability statistics.2024

Reliability statistics	**Cronbach's alpha**	**N of elements**
Cronbach's alpha	0,861	28

Source. Authors' own elaboration.

Table 2 presents the reliability index of the student survey, which is highly reliable. Cronbach's Alpha obtains a value of 0.861, close to 1, indicating that it is an adequate instrument and aligns with the research variables. The minimum acceptable value for the Cronbach's Alpha coefficient is 0.70; below this value, the internal consistency of the scale used is low. On the other hand, the maximum expected value is 0.90; above this value, redundancy or duplication is considered. Therefore, the results are favorable with a result of 0.861.

Table 3. Reliability Statistics of the Teacher Survey

Reliability Statics	Cronbach´s alpha	N. elements
Cronbach's alpha	0,851	27

Source: Authors' own elaboration

Table 3 shows the reliability index of the teacher survey. It is reliable, as Cronbach's Alpha obtained a value of 0.851, close to 1, indicating that it is an adequate instrument and aligns with the research variables.

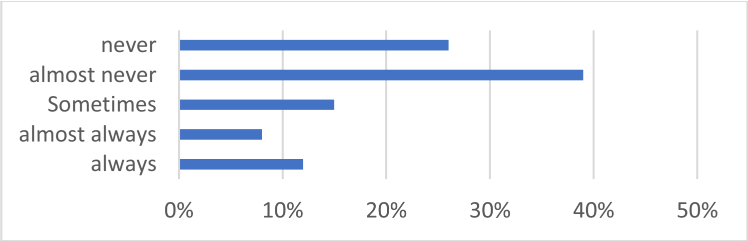

Fig. 1 Frequency of use of digital environments

The information this in the Fig.1, of the 100% of respondents, 48% of teachers answered that they almost never use interactive digital environments in the Entrepreneurship subject, 24% said sometimes, 16% said never, while "always" and "almost always" reflect 8% and 4% respectively.

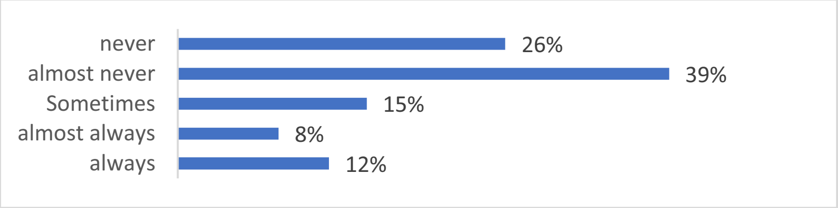

Fig. 2 Updating the teacher's knowledge of the use of interactive digital tools and environments.

In Fig. 2, the results show that 52% of teachers never update their knowledge about the use of interactive digital tools and environments, 16% do it sometimes, 12% almost never and 12% almost always, while only 8% always update their knowledge. These results highlight the need to strengthen teachers' technological competencies.

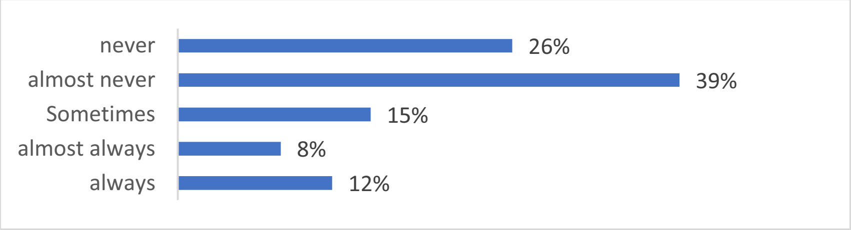

Fig. 3 Use of interactive digital environments and the teaching of the subject Entrepreneurship and Management

In Fig. 3, of the 100% of teachers surveyed regarding their interest in incorporating interactive digital environments to motivate students in the Entrepreneurship subject, the results reflect that 32% always show interest, 20% almost always, 16% sometimes, 20% never, and 12% almost never. These results suggest that older teachers may be resistant to using technology, despite the fact that the application of interactive digital environments helps provide meaningful teaching in the Entrepreneurship subject.

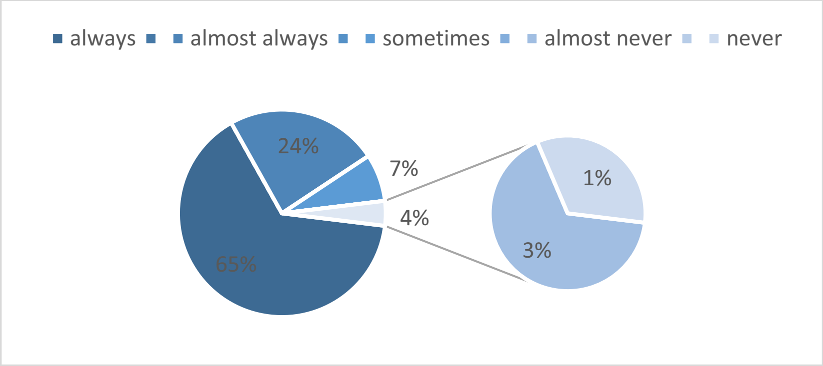

Fig. 4 Interactive digital environments are useful for learning new theoretical and practical content.

In Fig. 4, of the 100% of the students surveyed, 65% responded that they always consider interactive digital environments useful for learning new theoretical and practical content in the subject of Entrepreneurship, 24% consider them almost always, 7% sometimes, 4% almost never and 2% never. These results indicate that interactive tools are highly valued by students for acquiring new knowledge and specific competences in a subject that can provide them with skills to generate business ideas and projects.

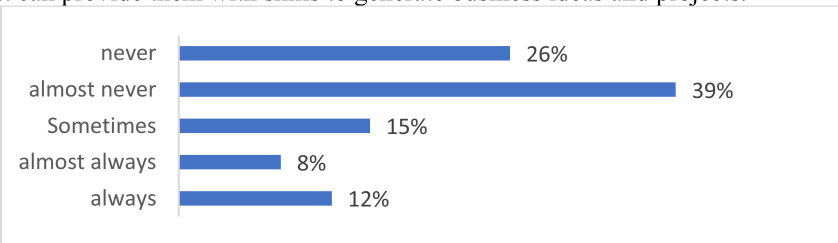

Fig. 5 Interactive digital environments are useful for learning new theoretical and practical content.

In Fig. 5, of the 100% of respondents, 45% indicated that they always find interactive digital environments useful for learning new theoretical and practical content, 32% said almost always, 18% sometimes, 3% almost never and 2% never. These resources, when implemented, help students acquire new knowledge and subject-specific competences that can provide them with the skills to generate business ideas and projects.

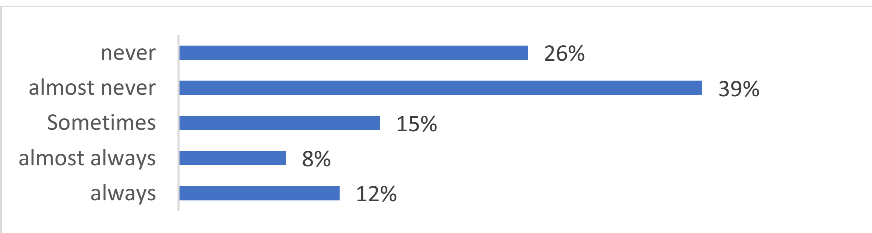

Fig. 6 Technological capacity of students at home and in schools to develop skills and abilities in the digital environment.

In Fig. 6, regarding the technological capacity of students at home and in schools to develop skills and abilities in the digital environment, the results show that 39% of students indicated that they almost never have this capacity, 26% never, 15% sometimes, 8% almost always, and 12% always. These results reflect that the lack of technological devices is one of the obstacles that impede the quality of teaching in the education system in Ecuador. The marked social differences also contribute to these undesirable results, as the ideas of the country's future entrepreneurs are born in these spaces.

4. Conclusions

The integration of innovative digital inclusion resources in Ecuadorian education, particularly in entrepreneurship education, offers a pivotal opportunity to enhance the accessibility, quality, and relevance of the learning experience. By effectively implementing interactive technologies and digital tools, it is possible to foster more dynamic and engaging learning environments that align with the evolving needs of 21st-century learners. This approach not only strengthens students' entrepreneurial competencies but also contributes to educational equity by providing equal opportunities for all, irrespective of geographical or socio-economic disparities.

To fully realize the benefits of digital inclusion in Ecuadorian education, it is crucial to address persistent challenges such as inadequate infrastructure, insufficient teacher training, and inequitable access to technology. A continued commitment from educational institutions, government bodies, and other stakeholders is essential in advancing towards a more inclusive and innovative educational system that is equipped to meet global challenges.

Finally, it is imperative to develop interactive designs that move beyond the traditional methods currently employed by teachers in Ecuadorian schools. New technological initiatives will not only inspire greater student motivation but also cultivate creativity and innovation. Such advancements will be instrumental in transforming entrepreneurship models and skill development, enabling Ecuador to meet its evolving national needs at any time and place.

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Methods for Enhancing Digital Scholarship Services in University Libraries

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Abstract. Digital scholarship services (DSS) are of great significance in promoting the prosperity and development of academic research, facilitating academic cooperation, and protecting academic heritage.Several methods for enhancing theDSS provided by university libraries are proposed by network research and literature research methods, including i) establishing a professional DSS team, ii) establishing digital scholarship research guides, iii) building digital scholarship space, iv) providing embedded course service in the center, v) promoting cooperation with other institutions to develop DSS, and vi) configuring digital scholarship resources.These methods were concluded from the present investigations in order to provide strong guarantees for the inheritance and development of academic research by researchers, promote the development of disciplines, and improve the quality of academic research.

Keywords. University libraries, Digital scholarship, Digital scholarship services

1. Introduction

As universities today have become increasingly connected and collaborative, libraries have become the engine and platform for knowledge creation, retention, sharing, and utilization [1]. With the rapid development of computer technology and information technology, digital learning is becoming a new service content for university libraries. The definition of digital scholarship (DS) is widely debated. On the basis of analyzing various interpretations of digital scholarship concepts abroad, Liu et al. summarized digital scholarship as "not only a digital technology, but also a new academic exchange model and teaching research paradigm, and also a digital scholarship product itself" [2].

DS is originated from the United Kingdom at the end of the 1990s and evolved on the basis of the concepts of electronic science, network infrastructure, and electronic learning. The Digital Scholarship Services (DSS) in university libraries in the United Kingdom and North America have developed for a long time and are relatively mature [3]. By establishing digital scholarship centers, assembling dedicated service teams, and constructing and planning digital research spaces equipped with software and hardware facilities, robust functionalities, and distinctive attributes, we empower faculty and students to overcome challenges encountered in academic pursuits within the current digital landscape. Gradually, these initiatives have cultivated distinct advantages and fostered DSS characteristics tailored to the university's developmental trajectory.

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Digitalization is the basic background of contemporary academic research, and improving the ability of DSS is an important issue faced by university libraries. Digital learning has triggered a revolution in the service mode of the library community, especially university libraries and research libraries. The advantages and significance of DSS in university libraries mainly lie in the following three aspects:

(1) Rich information resources

The library owns abundant and reliable documentary information resources. In particular, the digitalization and digitization of precious resources make exploring new forms, such as digital humanities research possible.

(2) Professional human resources

The library focuses on the organization, retrieval, and management of resources and can play a role in the collection, organization, publication, preservation, and reuse of digital resources, and can enable researchers to separate from the organization and storage of digital resources.

(3) Important infrastructure

The library owns a software and hardware environment for digital display, storage, publishing, open access, and data management, and provides all teachers and students with equal access to the library's software and hardware facilities, especially high-end hardware and professional software, to eliminate some inequalities caused by high prices or property ownership issues.

DS encompasses the entire process of knowledge production, knowledge organization, and knowledge exchange activities. It enables humanities research institutions and scholars to more conveniently collect, organize, analyze, and disseminate academic materials, thereby improving the efficiency and influence of academic research.

The provision of digital academic services by university libraries has profound significance in the modern academic environment, including promoting the sharing of academic resources, improving research efficiency, supporting open science, and driving changes in academic evaluation systems. These services not only adapt to the development of information technology, but also greatly promote the efficiency and quality of academic research.The purpose of this paper is to propose the methods for enhancing the DSS in university librariesto provide strong guarantees for the inheritance and development of academic research by researchers, promote the development of disciplines, and improve the quality of academic research.

2. Literature review

Digital Science refers to a series of academic activities that use digital technology and tools throughout the research process of data retrieval, statistics, analysis, modeling, preservation, and publication. Such as geographical information system (GIS) and digital mapping, digitization of analog media/imaging, digital collection, metadata creation, digital storage, data monitoring and management, 3D modeling and printing, statistical analysis, digital exhibition, research project planning, digital publishing, text calculation and analysis, interface usability design, visualization, database development, technical maintenance, digital scholarship software development, etc.[3].

Ocran*et al.* assessed the role of academic libraries in digital scholarship at the University of Cape Coast and revealed that digital scholarship contributes to faculty members'delivery through the provision of information literacy training for new students, provision of reference lists of materials available in the library and provision of lists of new materials [4]. Zhu focused on two particularly challenging issues facing Chinese academic libraries - space constraints and the trending of DSS and aimed to explore which spaces students and faculty wanted and how to leverage low-use spaces and growing DSS to build the Center for Digital Scholarship (CDS) to meet their demands [5].

Li *et al.*reported on a research study aiming to identify the user requirements of DSS in university libraries [1]. A set of strategic suggestions for DSS development were devised for library and information science researchers, library managers, and library manager professionals. Zhou *et al.*reported on a literature review that aimed to establish a guiding framework for the development of DSS in China's university libraries [6]. The framework was developed through systematically searching, screening, assessing, coding, and aggregating DSS.

Montoya *et al.*discussed the increased use of digital infrastructure in pedagogy by the Library Special Collections at UCLA [7]. The digital project collaboration approach can set the stage for more flexible and innovative digital instruction, building on the current skillsets of library staff to facilitate new modes of faculty and librarian partnerships.

Xu investigated the DSS of 36 foreign university libraries, including digital scholarship space, digital humanities services, scientific data services, academic exchanges and digital publishing, digital scholarship seminars and training, digital research tools, digital technology support services, etc. [8].

Liuinvestigated and analyzed 8 libraries as samples from five aspects: center overview, organizational structure, personnel allocation, space service, and academic support [9]. Deng analyzed the main practices of digital scholarship services in the American library community and gave some suggestions [10].

Er made an analysis of DS support in Canadian university libraries paying attention to the establishment of relevant departments, the history and current situation of their digital scholarship support,their teams of digital scholarship support, the publishing, and preservation of research results, the management of research data,support for teaching andcurriculum, support for digital research projects, digital scholarship education, space support for interdisciplinary cooperation, and so on [11].

Tu and Xu surveyed the library DSS mainly focused on physical space services, digital research tools services, researching data services, discussing and training services, digital scholarship technology support, and so on [12].Wang summarized the development history, development mode, and service guarantee of the digital scholarship service of the University of Illinois at Urbana-Champaign Library by case study and network survey and presented some suggestions to promote digital scholarship in China [13]. Er found that academic libraries in North America provide the DSS such as training courses, guidance, and education integrated into digital scholarship activities, cooperating with institutions and using a variety of ways for education [14].

Cox described the increase in different learning spaces as multi-sensory whereby users have the ability to shape their own learning space using a multitude of different tools provided by the library [15]. Ideally, the IT infrastructure requires minimal training for the users and no ongoing interventions from the service team. Examples include learning management systems, wikis, video streaming, individual and shared file storage, and virtual computer labs [16].

From the existing research mentioned above, these researches mainly focuses on summarizing and discussing the content and mode of DSS provided by many university libraries in Europe and America. However, there are relatively few studies that provide clear ideas and references for Chinese university library staff to try to form DS teams and determine the current service mode and content.

3. DSS in University Libraries

3.1. Establish a professional digital scholarship service team

Given the variations in disciplinary distributions, user needs, and the library's inherent strengths, resources, funding, and personnel capacities, there exists no one-size-fits-all model for establishing digital scholarship centers. Research university libraries can either independently select an appropriate service model to establish their digital scholarship centers and institutions, tailored to their unique circumstances, or collaborate with other university entities to jointly set up such centers and institutions.

University libraries should clarify the objectives of DSS, develop digital scholarship service systems and standards, build a digital scholarship service management mechanism, guarantee and evaluate mechanism to ensure the sustainability of DSS, and build a digital scholarship service model and implementation plan on the basis of the established mechanism. At the same time, university libraries can, on the basis of understanding their own university culture, determine the functions and service contents of their own university libraries' DSS by evaluating various factors, such as organization scale, organization type, capital source, staffing, physical spaces, etc., and will adjust the service contents in time according to the process of service development and the service experience gained, provide a digital scholarship exchange, exploration and cooperation environment for university researchers.

The service personnel of the DSS team needs to have professional knowledge and be able to skillfully operate various digital scholarship research tools, and perform their respective functions in project management and coordination, data management and analysis, digital resource production and editing, institutional knowledge base construction, embedded course teaching, software and hardware tool use, multimedia digitization, and project training. Therefore, research-oriented university libraries should set up positions with different disciplinary backgrounds and skills according to the users'needs to help faculty and students plan, analyze, visualize, store, share, and publish digital projects. At the same time, university libraries should also create good training and learning opportunities for digital scholarship service personnel, and constantly update the knowledge system for carrying out DSS professionally.

University libraries can build a sustainable, coordinated, and harmonious digital scholarship service ecological environment by restructuring or reallocating human resources and strengthening the construction ofservice capacity. For example, to increase the setting and training of university science librarians, digital technology librarians, programmers, resource construction librarians, and other types of professional librarians, to focus on improving the professional skills and awareness of collaborative work of professional librarians. Furthermore, it is crucial to enhance coordination and communication with the university's human resources department and devise a comprehensive plan to recruit new librarians with multidisciplinary professional backgrounds, aligning with the requirements of a specialized librarian workforce. Concurrently, emphasis must be placed on enhancing the professional competencies of librarians by facilitating opportunities for off-campus professional development training, as well as regularly organizing intra-library professional skill exchange sessions.

3.2. Establish digital scholarshipresearch guides

University libraries can provide some research guides for relevant information on the websites of their libraries for solving their problems. These research guidescould include the access to the audio and video resources, file conversion, poster design, configuration scope and instructions of software and hardware equipment, audio and video editing and digital teaching video, and charging standards of advanced digital services. These research guides can also be quickly positioned according to different needs. The librarian will also update the guides regularly or irregularly according to the needs.

In addition, university librariesshould build a multi-functional digital scholarship management and service platform, aggregate information knowledge, data resources, software tools, technical resources, etc. to increase the intelligent and one-stop search function, to improve the usability and visibility of the service platform, to create an interactive academic research space with digital storage, inquiry and answer, academic exchange, open access, display and demonstration, and online evaluation functions, and create activities such as finding, creating and sharing information through platform users, sharing knowledge and experience, knowledge dissemination, and academic publishing.

3.3. Builddigital scholarship space

The digital scholarship space is able to meet the complexity and diversity of users' needs and fulfill the mission of theuniversity in the context of insufficient funds, space, and specialists [2]. On the one hand, university libraries can organize and optimize their library spaces, make use of the characteristics to carry out space design and reconstruction planning, and integrate library technical facilities, resources, and services to create digital scholarship space. At the same time, it is also necessary to standardize the rules for the use of space, such as making clear provisions on the management and coordination of space, the purpose of using the space, and the reservation of space use the time for making good use of space orderly and effectively. On the other hand, digital scholarship space can also be actively promoted through various publicity media of the library, so that digital scholarship researchers can understand the tools, resources, facilities, and functions of digital scholarship space. At the same time, libraries should take various ways to explore users' needs, improve the utilization rate of digital scholarship space, promote the development of digital scholarship research, and stimulate the enthusiasm of using space.

University libraries should fortify their infrastructural development in accordance with the specific conditions of their facilities, thereby providing a foundational guarantee for the effective implementation of DSS. The construction of a digital scholarship center is the demand of university libraries to adapt to the environment and development trend and shall have the following functions:

· The visualization function can provide a high-resolution visualization wall and touch screen interactive whiteboard for research data visualization and facilitate digital scholarship research.

· The discussion function can be equipped with high-performance computers, installed with digital scholarship research software, and can provide movable tables and chairs for digital scholarship research, discussion, training, counseling in order to promote digital scholarship exchange and cooperation.

· The consulting function is to set up a consulting room to provide one-to-one consulting services for digital scholarship projects.

3.4. Provide embedded course service in the digital scholarship space

University libraries can embed in classroom teaching seminars or teaching practice training on the premise of cooperation between librarians and faculty according to their needs in courses or disciplines[11-12]. Providing professional and in-depth guidance services will improve the trust of faculty and students, and the development of cooperation projects will move towards a virtuous circle and gradually enhance the value of the library.

In addition, writing guidance services can be addedto the DSS The undergraduate students have a high demand for writing guidance, and each freshman student will be arranged individually customized librarian to provide comprehensive guidance services, including assisting students in completing their academic research tasks, such as how to prepare research papers, narrow down research topics, give writing suggestions, guidance and organize research content and accurate quotation.

3.5. Promote Cooperation with other institutions to develop DSS

Cooperation is the foundation of DSS. University libraries should establish the concept of cooperation and jointly create DSS projects suitable for the development needs with the help of other institutions.

3.5.1. Cooperate with other departments of the library to build digital scholarship space and software and hardware tools

The construction of physical space and the configuration of hardware facilities need to submit planning opinions and planning applications to the relevant functional departments of the library. The provision of digital resources needs the participation of the staff of the library collection construction department. The configuration and installation of digital software require the professional staff of the technical department of the library to operate, implement, and provide technical guidance services [17]. The digitization and reading services of a special collection of digital or microfilm materials need to be completed in cooperation with the ancient books or special collection department of the library. Therefore, university libraries should coordinate and cooperate in human resources, technology, equipment, and other aspects to jointly complete the development of DSS in the university.

3.5.2. Cooperate with other university libraries to jointly promote the development of DSS

The DSS of university libraries in many universitiesare still in the stage of exploring and gradually forming their own service system [13]. In order to improve the ability of DSS, university libraries should also cooperate to carry out DSS and exchange relevant experience. For example, university libraries can cooperate with other libraries to develop services, form alliances, exchange experiences in the preparation of DSS, the content and methods of DSS, and create a good digital scholarship exchange environment and conditions, so as to improve the overall level of DSS of university libraries.

3.6. Configure digital scholarship resources

University libraries shouldconfigure various types of hardware equipment in the digital scholarship space, such as scanners, video recorders, digital cameras, mapping and positioning instruments, demonstration and projectors, display screens, tablet computers, and calibration tools on the premise of investigating and understanding the users'needs for digital scholarship research tools and in combination with the funding situation of the library.

At the same time, corresponding software is configured to match the use of these hardware facilities, such as office software, scanning software, digital editing software, audio and video digitization software, audio and video editing software, desktop publishing, and image editing software[2][17]. According to the characteristics of the digital scholarship space setting or the academic background and personalized needs, the resources and services of software and hardware are allocated, the use of tools is guided, and the value of the space is improved, so as to attract more users to carry out learning and scientific research activities.

The characteristic collection resources are important resources for the research of digital scholarship. University libraries should strengthen the development of the characteristic collection resources. First of all, university libraries should sort out the existing characteristic collection resources and excavate the characteristic resources such as local chronicles, ancient books and documents, and celebrity genealogy with research value. Secondly, university libraries should use data processing, data storage, system development, and other related technologies and provide resource guarantee for discipline professionals to carry out in-depth research on digital humanities.

4. Conclusion and perspective

DSSarethe future development trend of university libraries. Thevigorous development of DShas changed the original knowledge exchange ecology. The developments pose both a challenge and an opportunity for research university libraries to continue innovation and development. In this paper, we proposed some key suggestions which include six aspects to improve the development of DSS for university libraries.

The research university libraries need to re-embed into the whole process of academic life and academic exchange, undertake key functions in the fields of information acquisition, content digitization, content discovery, and dissemination, and expand the service content in the areas of copyright consultation, open access publishing, data monitoring, and management. The research-oriented university library consistently occupies the vanguard of innovation and enhancement endeavors, amassing a cohort of professional adept at leveraging cutting-edge technologies. Therefore, it should give full play to its own resource advantages and service advantages, learn from the digital scholarship service experience, concepts and models of some experienced libraries, form a digital scholarship service system suitable for its own development, fully support scientific research, promote knowledge innovation, and continuously enhance the academic influence of the library.

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Digitalization and Management Innovation III
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Inclusive Eduation Policy in Austria and Nepal: Developments and Challenges for an Inclusive School System

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Abstract. This study aims to bridge a significant research gap by comparing the implementation of inclusive education policies in Austria and Nepal, two countries with differing socio-political contexts but shared commitments to international frameworks, such as the UN Convention on the Rights of Persons with Disabilities (CRPD). Despite the global emphasis on inclusive education, there is limited comparative analysis exploring how national policies are adapted and implemented in diverse settings. This study analyses the developments and challenges both countries face in their pursuit of inclusive education, shedding light on the policy frameworks, teacher training reforms, and systemic barriers. Using qualitative content analysis based on the Mayring method, policy documents, government reports, and educational frameworks from both Austria and Nepal were examined. The analysis identifies key historical milestones and current efforts toward achieving inclusive education in each country. The findings reveal that while Austria has made significant strides in teacher training and policy adaptation, its education system remains partially segregated. In contrast, Nepal has focused on systemic reforms but struggles with inadequate resources and infrastructure for full implementation. The study highlights the necessity for both countries to align national policies more effectively with international recommendations, particularly in the areas of teacher preparedness and inclusive infrastructure.

Keywords. Policies, inclusive education, content analysis, Austria, Nepal

1. Introduction

Inclusive education, which seeks to provide equitable learning opportunities for all students regardless of their abilities, has become a global priority, particularly following the adoption of the UN Convention on the Rights of Persons with Disabilities (CRPD) and the Sustainable Development Goals (SDGs). Specifically, SDG 4 aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." Despite these international commitments, the implementation of inclusive education policies varies widely across countries, shaped by national contexts, resources, and

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socio-political factors. Previous studies have demonstrated the strong connection between political contexts and both opportunities and barriers to improving access to education and learning outcomes [1], [2], [3].

Austria and Nepal present two contrasting yet complementary case studies for understanding how inclusive education is implemented in different settings. The comparative study of Austria and Nepal is particularly relevant due to their differing socio-economic contexts, stages of development, and resource allocation, providing an opportunity to analyse how national policies align with international frameworks and what lessons can be drawn from each.

This study has two main objectives:

- To analyze the alignment between the national inclusive education policies of Austria and Nepal and international frameworks such as the CRPD and SDG 4.
- To provide a comparative perspective that shows the current status in both countries.

Therefor this research contributes to the field of education policy in several ways:

Comparative Analysis: By comparing Austria and Nepal, the study provides a nuanced understanding of how different socio-economic contexts influence the adaptation and implementation of inclusive education policies.

Policy Insights: The findings offer valuable insights for policymakers, especially in low- and middle-income countries, on how to effectively integrate international frameworks into national education systems.

Practical Implications: The study highlights the current status of both countries.

By addressing these objectives, this study not only fills a gap in comparative education policy research but also offers recommendations for enhancing inclusive education in diverse settings.

2. State-of-the-art

International policies have significantly shaped national education systems, particularly in the realm of inclusive education. Globalization has played a crucial role in framing national policy agendas, requiring countries to consider international recommendations while balancing local contexts. As Mansour [4] points out, there is often a tension between global policy spillover and the preservation of national sovereignty, particularly in times of crisis when governments tend to prioritize local concerns over intergovernmental cooperation. This dynamic is especially pertinent in the field of education, where international conventions such as the CRPD and global initiatives like the Sustainable Development Goals (SDG 4) emphasize inclusive and equitable education for all.

A major influence on national education reforms has been the role of International Large-Scale Assessments (ILSAs), which often serve as tools for legitimizing educational reforms. Although their results can drive policy changes, concerns have arisen about the potential misuse of these assessments in local contexts, where they may not fully align with national needs and capacities. This phenomenon highlights the complexity of translating global educational goals into national practice [5].

The case of India is particularly relevant when comparing the development of inclusive education policies in Nepal. India has made substantial progress toward inclusive education through initiatives such as the Right to Education Act (RTEA) and the Sarva Shiksha Abhiyan (SSA) [6]. These efforts align with international agreements, like the "Salamanca Statement and Framework for Action on Special Needs Education," and demonstrate India's commitment to fostering inclusive education [7]. The National Education Policy (NEP) 2020 further emphasizes inclusive education as a key driver of national development, focusing on providing equitable educational opportunities for all, including children with disabilities [8].

India's journey offers valuable insights for Nepal, which shares similar socio-economic challenges. Therefor it is interesting what the status in Nepal is.

These examples underscore the interconnectedness between international policies and national decision-making in education, highlighting the need for a global perspective when shaping domestic policies. For countries like Austria and Nepal, which operate within different socio-political and economic contexts, the process of adapting global frameworks to local needs is both challenging and essential. This study aims to further explore how Austria and Nepal are navigating this issue, contributing valuable insights into the broader discourse on inclusive education.

3. Aims and Research Questions

The primary aim of this study is to investigate how the inclusive education policies in Austria and Nepal align with international frameworks such as the Convention on the Rights of Persons with Disabilities (CRPD) and Sustainable Development Goal 4 (SDG 4), and to identify how each country implements these policies.

Specifically, the study seeks to:

- Examine the historical trajectory of inclusive education policies in Austria and Nepal.
- Analyse how national policies reflect global commitments, especially regarding inclusive education.

Research Question:

- How do inclusive education policies in Austria and Nepal align with international recommendations, and how is the current status in both countries?

4. Methodological considerations

This study employs qualitative content analysis, using Mayring's [9] approach, to analyse policy documents and official reports related to inclusive education in both Austria and Nepal. The document analysis [10] was chosen as the primary method due to the nature of the research materials, which consist of historical and policy texts.

Data were collected from a variety of official sources, using the snowball sampling technique [11] to ensure comprehensive coverage of relevant materials. This process began with identifying key documents and reports and then expanding the pool of sources based on references within these texts. The data sources include:

- Publications and policy documents from the Federal Ministry of Education, Science, and Research in Austria and the Ministry of Education in Nepal [12, 13].

- Expert group reports and independent evaluations from national and international bodies.
- Official government statements related to the ratification and implementation of international conventions like the CRPD.
- Curricula and study plans focused on teacher training for inclusive education in both countries.

Following Mayring's [9] step-by-step qualitative content analysis, the study analyses the content of the documents to extract meaningful insights about the alignment of national policies. The analysis proceeds in four main steps:

Category Definition: Initially, categories were defined based on the themes of interest, such as international policy alignment, teacher training reforms, and national implementation challenges. The analysis focused on identifying historical milestones and developments, using these categories as a framework for interpretation.

Timeline Construction: Key events and policy developments were mapped onto a timeline to visualize the progression of inclusive education efforts in Austria and Nepal. This timeline highlights the implementation of the CRPD and other major policy initiatives in both countries, providing a comparative perspective.

Contextual Analysis: The categorized data were further analyzed to place the identified policies and milestones within their historical and political contexts. This step was crucial for understanding how the socio-political environments of Austria and Nepal influenced their approaches to inclusive education.

Summarization and Interpretation: The final step involved summarizing the essential content from the analyzed documents. This summary type content analysis reduced the material to its core findings, enabling a clear comparison of policy alignment, progress, and challenges between the two countries.

By applying Mayring's qualitative content analysis [9], this study provides a structured and systematic examination of how Austria and Nepal are navigating their commitments to inclusive education, highlighting both achievements.

5. Results

Figure 1 summarizes the historical overview of the developments in the area of inclusive education in Austria and Nepal. The historical overview starts with the declaration of United Nations Convention on the Rights of People with Disabilities. Apart from the UN CRPD, other international developments on the way to inclusion are included in Figure 1 as well.

From the historical overview, there are different focal points in the implementation of inclusive education. In Austria, for example, teacher training was reformed, while the education system is characterized by segregated, integrative and few inclusive settings, with segregated special schools being further expanded. In Nepal, when planning implementation of inclusive education, the focus is on the systemic reform to ensure wider dimensions of inclusion in education system with the consolidated equity strategy in 2014 [12]. This is the departure to widen the perspectives of inclusive education beyond the disability concerns which is one of the dimensions among eight others.

The equity strategy has been implemented through other different programs of school reform such as scholarships for marginalized groups of people and providing day meals for health and nutrition to the students [13]. However, the focus of the children with disability was also priority of the government of Nepal to ensure inclusive education. In this regard, all kinds of schools, there are also special schools, integrated schools with resource classes, mainstream schools, and inclusive model schools in Nepal, are supported by the three tiers of government policies [13], international recommendations initiated the development of different types of schools. In both countries, national steps were taken upon international recommendations towards a more inclusive education system. However, these steps were taken in Nepal relatively later than in Austria. Especially the regulations based on CRPD were made at an earlier time in Austria when compared to Nepal.

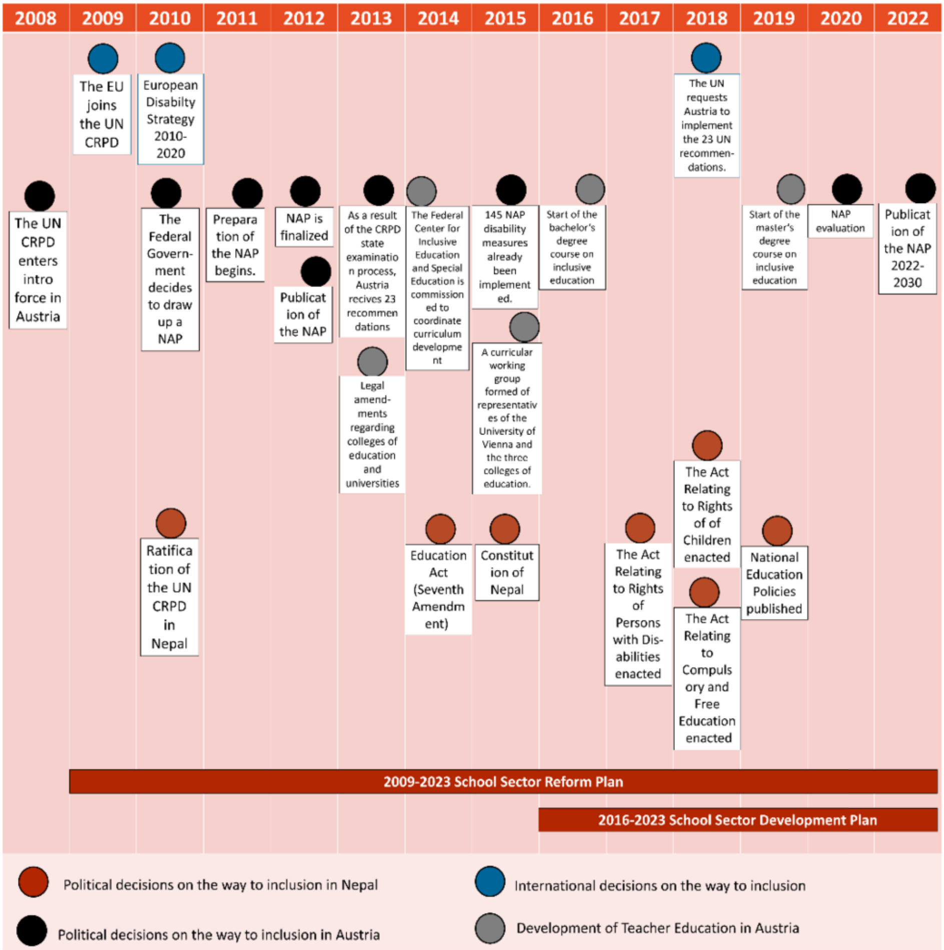

Figure 1: Historical Overview

The constitution of Nepal 2015 decentralized school education to the local government units which needs to give support to make more inclusive schools and education. Contemporary education policies (School Education Sector Plan 2022-2032) ensure the allocation of inclusive space in societies and schools to increase access, participation, and learning achievement of students. However, less adequate resources (human and technical) affect the full functioning of inclusive education. A scholarship system was established to support poor and disadvantaged groups of marginalized children in enrolling in school [13]. The local government has implemented such federal policies as per the constituted mandate and were less efficient in implementation [12].

Most of the initiatives of inclusive education in Nepal after 2007, when Nepal aligned with international development trends such as Education for All, Millenium Development Goals and Sustainable Development Goals [13]. The areas of inclusion are much concentrated with the Consolidated Equity Strategy introduced in 2014 to improve equity and inclusivity in society. Embraced UN Convention on the Rights of People with Disabilities in 2017 and the Inclusive Education Policy 2019 for ensuring increasing access to education.

With the recent change in the federal structure of the government, the local government is supposed to implement inclusive education policies in the schools. However, the local government has not prepared yet to implement the policies [14].

The development of inclusive education policies in Austria can be divided into three phases [15]. These three phases are the building of the special school system (the 1960s to mid-1980s), the establishment of integrative education structures and practices (mid-1980s to mid-2000s), and the efforts to make the Austrian education system more inclusive (2007 until today). The current situation of the Austrian inclusive education system is in the third phase which was influenced by the ratification of the UN Convention on the Rights of Persons with Disabilities (UNCRPD) in 2008, which sparked a new discourse around school-based inclusion of children with disabilities. The evaluation of the Austrian National Action Plan of Disability, which was developed to implement the CRPD, showed that the success of transformation into inclusive education was not at the desired level and there were several drawbacks in the implementation [16]. The evaluation also showed that the number of pupils attending special schools has not decreased despite the promotion of inclusive education in Austria in recent years. A recent comprehensive study conducted by several higher education institutions in Austria, could depict a very clear picture of the state of the art of inclusive education in Austria [17]. The aim of the study was (a) to survey the current state of special education practices in all Austrian federal states; (b) to describe the causes of disparities between the individual federal states in the accommodation of students with special education needs; (c) to conduct a process analysis of the various steps involved in the allocation of special education needs, taking into account the perspectives of all those involved. The main findings of this comprehensive study [17] were

a. The clear majority (76.9 %) of pupils with SEN experience a career loss due to repeating classes. Repeating the class instead of adjusting the curriculum or learning materials is still practiced often.
b. Socio-demographic characteristics show the likewise well-known disproportionate referral of boys and children with first languages other than German.
c. Big differences are to find between the federal states in terms of the number of impairments, the types of impairment, and the diagnosis process of impairments in connection with the SEN.

Therefore, the situation of inclusive schools in Austria is still far from ideal, and more efforts are needed to ensure that all students have access to quality and equitable education.

6. Discussion

The results show that international recommendations and agreements have been followed at the national policy level, but that the implementation is in the making [2]. Both countries have been engaged in adapting and contextualizing the international ratification of the convention and national policy framework for ensuring inclusive education for all.

As illustrated by Mansour [4], the political success of nation states varies despite the convergence of global political concerns. At national level in Austria, for example, the implementation of inclusive education has been carried out on the shoulders of future teachers, but the education system as such has not taken any steps towards inclusive education. Nepal, on the other hand, reformed its education system, but not teacher training. Nepal has progressively formed inclusive policies to ensure the students' access to school education but lacks the inclusive infrastructure and teachers' preparation for ensuring inclusive participation and learning achievement of the students. However, Puri et al. [18] indicated that inclusive education policies require synchronization with fundamental principles and societal transformation; disparities in educational and social aspects persist despite a commitment to inclusive education, and Nepal faces obstacles such as insufficient human resources, budget allocation, and awareness.

Common themes in a global context have been identified at international level, but decision-making and implementation remain largely within the nation states and are therefore the responsibility of the national governments to decide how these are implemented at this level.

Despite all efforts from the policies, feeble planning, and its implementation in the federal context of Austria and Nepal made it more challenging to make the schools and societies more equitable and inclusive.

7. Conclusion

This study highlights the importance of comparing the inclusive education policies of Austria and Nepal to understand how different socio-political contexts influence the implementation of global frameworks like the UN Convention on the Rights of Persons with Disabilities (CRPD). Using Mayring's qualitative content analysis [9], the research provides a systematic approach to trace historical developments, allowing for a structured comparison between the two countries.

The chosen methodology offers a systematic way to categorize and compare historical milestones, making it possible to visualize the progression of inclusive education efforts in both countries. By constructing timelines and analysing policy documents within their historical contexts, the method enables a clear understanding of how international frameworks have been adapted at the national level. This approach proves particularly useful in highlighting both achievements and ongoing challenges, offering practical insights for policymakers in low- and middle-income countries.

In conclusion, this study emphasizes the need for both Austria and Nepal to better align their national policies with international recommendations. For Austria, this involves reducing segregation within its educational system, while Nepal must focus on addressing its resource and infrastructure gaps to fully realize its inclusive education goals. The structured, systematic approach used in this study provides a valuable framework for future comparative policy analysis.

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Digitalization and Management Innovation III
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Mathematical Intelligence Blended Teaching Model Based on Knowledge Graph – A Case Study of Surgical Nursing

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Abstract. Digital intelligence refers to the integration of digital technologies and intelligent digitalization, which encompasses the development and application of data as a new productive force for societal benefit. Blended teaching has become essential in adapting to the educational advancements of the digital intelligence era. The deep integration of digital intelligence technology and classroom teaching has become the new norm of education and teaching reform. As the core technology of artificial intelligence (AI), a knowledge graph can express the knowledge system visually, integrate educational resources, collect learning process data to realize the monitoring and diagnosis of the learning process and meet the diversified needs of intelligent education applications. It is an effective tool for deeply integrating nursing education and AI. As healthcare technology continues to evolve and knowledge is rapidly updated, students need to continually learn and update their knowledge base so as to keep up with professional development. Therefore, this study explored the practical strategy of digital–intelligent blended teaching of Surgical Nursing by reshaping and integrating the course content, sorting out the course knowledge system, and constructing the course knowledge graph to enable students to systematically master the learning content and access high-quality learning resources. It provided a reference for the digital transformation of higher education, with a view to promoting the consolidation of students' mastery of basic knowledge, improving students' clinical thinking and comprehensive ability to implement holistic care for patients, and cultivating students' ability to acquire and use cutting-edge knowledge.

Keywords. Blended teaching, knowledge graph, mathematical intelligence, Surgical Nursing

1. Introduction

Courses are fundamental in achieving the goal of professional personnel training. Surgical Nursing is a core course in undergraduate nursing education and teaching, which helps nursing students meet the needs of job work, modern clinical nursing development, and health services [1]. This course is highly professional and practical, emphasizing scientific and standardized working procedures in teaching and application.

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In traditional teaching, teachers usually carry out routine teaching based on the theoretical framework of Surgical Nursing and nursing procedures. Teaching content, methods, and format are relatively fixed and monotonous. A large number of nursing students find it boring and difficult to understand. To address this issue, teachers should improve their teaching methods [2]. The Minister of Education, Mr. Huai Jinpeng, delivered a keynote speech on “Joining hands to promote the application, sharing, and innovation of digital education” at the 2024 World Conference on Digital Education. He proposed to widely gather wisdom, effectively build consensus, discuss and share, and join hands to build a new engine of digital education [3]. The digitalization of education is an inevitable outcome of the development of education in this new era. “Internet + education” has not only changed the way teachers teach and students learn but also begun to deeply affect the concept of education, educational culture, and educational ecology [4]. Digital intelligence is the integration of digital technology and intelligent digitalization, which refers to the cultivation and development of data, a new productive force, and the societal benefit of using digital intelligence technology [5]. Educational digitization, as one of the cutting-edge explorations to further advance digital education, aims to promote the digitization of education using the latest digital and smart technologies [6].

Blended teaching is an inevitable approach to adapt to the development of education in the age of digital intelligence. The deep integration of digital intelligence technology and classroom teaching has become the new norm of education and teaching reform, and its advantages have become increasingly prominent [7]. With the integration of “Internet + education” in recent years, platforms have gradually opened up, and various teaching resources have emerged. Examples include, such as catechism, national wisdom education public service platforms, and other online learning resources [8]. It makes students’ access to learning resources diversified and convenient [9]. However, the current online education resources, such as Massive Open Online Courses (MOOC), can neither clarify the relationship between various knowledge points of “Medical Nursing” nor accurately locate the weak knowledge points of students. Therefore, automatically recommending learning content such as prior knowledge points and key knowledge points for students is not possible [10]. Moreover, students usually lack an in-depth understanding of the overall knowledge structure, and finding suitable high-quality learning resources in a short time is difficult [11-12]. Given the large and complex number of Internet learning resources, students need to spend a lot of time selecting learning resources, resulting in information overload and low satisfaction with online learning [13-14]. However, educators need to resolve some issues brought about by online education, such as fragmentation of knowledge and uneven quality of online learning resources [15]. Using information technology to help students systematically master course content and quickly and purposefully recommend high-quality learning resources is worth exploring. As the core technology of artificial intelligence (AI), a knowledge graph can visually express knowledge systems, integrate educational resources, collect learning process data to enable monitoring and diagnosis of the learning process, and meet the diversified needs of intelligent education applications. It is an effective carrier for the deep integration of nursing education and AI [16]. Currently, the knowledge graph has become one of the research hotspots in the field of AI and natural language processing [17-18]. It is mainly used in education and teaching to assist teaching, knowledge management, and personalized learning [19-21].

Our school’s “Surgical Nursing” course is a provincial-level blended online and offline first-class course. Using modern information technology and the carrier of the

Super Star MOOC platform, this study maximized the use of all types of high-quality teaching resources and explored mixed online and offline teaching systems. It restructured and integrated the curriculum content, organized the curriculum knowledge system, and constructed a curriculum knowledge graph to enable students to systematically master the learning content and obtain high-quality learning resources. This approach helped students systematize the fragmented knowledge points in the learning process, allowed students to choose the learning content, arranged the learning progress and learning plan independently as the main learning body, built the overall knowledge network, and laid a solid foundation for learning. Through exploring a practical framework for digital–intelligent blended teaching in Surgical Nursing, we aimed to enhance students' understanding and retention of fundamental knowledge, refine their clinical reasoning and comprehensive capabilities in delivering holistic patient care, and foster their ability to acquire and apply cutting-edge information. This endeavor sought to provide valuable insights for the digital transformation of higher education.

2. Construction of Knowledge Graph for Surgical Nursing Course

2.1. Optimization of the curriculum system and enrichment of the curriculum resources

Based on the outcome-based education concept, which focuses on being "outcome-oriented and student-centered," we used a reverse-thinking approach to build the curriculum [22]. We changed the traditional lecture model with textbook chapters and then reshaped and integrated the course content using a "disease-oriented" approach. The content covered anesthesia, trauma, oncology, craniocerebral diseases, thoracic diseases, abdominal diseases, and so on. Teaching tasks were developed according to the teaching objectives, and the teaching tasks were organized into separate knowledge units. For this purpose, it was necessary to organize the entire course into modules according to the knowledge structure and refine these modules into hierarchical individual knowledge units based on the characteristics of the knowledge graph. The course system was restructured and integrated to incorporate the main content lines of typical clinical cases. It was based on teaching theoretical knowledge around the etiology and pathology of diseases, clinical manifestations, treatment, and nursing care, with reference to the latest research progress and clinical guidelines. The course team accurately constructed a high-quality teaching resource base based on knowledge points. The resources included 229 teaching videos, 365 nonvideo resources, and 746 other course materials. The types of resources included multimedia courseware, videos, cases of course ideology, mind graph, CiteSpace-based visualized knowledge graph, references of the latest research progress, quiz questions, and so on. They were prepared as materials for students to construct the knowledge framework.

2.2. Design of the overall framework of the knowledge graph

The curriculum team built a knowledge graph of the curriculum from the four levels of knowledge system, knowledge domain, knowledge unit, and knowledge point, from top to bottom level by level, and then formed a structured knowledge system. Guided by the curriculum objectives, we adopted the two routes of "chapter–section–knowledge point–

curriculum resources" and "knowledge area–knowledge unit–knowledge point–curriculum resources" to design the overall framework of the knowledge graph. We extracted key knowledge points and constructed a multi-level, net-like structured knowledge point system based on the structured data in the syllabus and textbooks, taking diseases of the urinary system as an example (Table 1).

Table 1. Design of the overall framework of the knowledge graph for Surgical Nursing

Knowledge area	Knowledge unit	Knowledge point	
		Level 1	**Level 2**
Nursing of patients with urinary system diseases	Nursing of patients with urinary calculi	Upper urinary tract stones	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Lower urinary tract stones	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
	Nursing of patients with urinary system injury	Kidney injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Bladder injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Urethral injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
	Nursing of patients with hyperplasia and tumors of the urinary and male reproductive system	Benign prostatic hyperplasia	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Carcinoma of the bladder	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation

2.3. Association of the knowledge graph

Starting from the extracted knowledge points, the course team analyzed the connection between them and the logical relationship between various course resources (covering multiple subcategories such as textbooks, videos, exercises, etc.). Then, the sequential and containment relationships among them were clarified. We connected the knowledge points through the curriculum resources, analyzed the inclusion and sequential relationships according to the two lines of the design, used the knowledge points to support the curriculum objectives, and distinguished the relationship to which the knowledge points belonged (Fig. 1). The specific steps were described next.

The first step was to organize the knowledge points of the course according to the syllabus. Starting from the knowledge domain, the knowledge units (chapters and sections) were related, and the knowledge points at all levels (level 1 and level 2) were deconstructed to achieve "granularity" refinement.

The second step was to establish the relationship between knowledge points. The knowledge points were linked together based on different logical structural relationships, such as hierarchical relationships, antecedent relationships, correlation relationships, and so forth, to facilitate the formation of the knowledge system.

In the third step, course resources, such as multimedia courseware, videos, cases of course contemplation, mind maps, references to the latest research advances, quiz questions, and so on, were linked to knowledge points. This process focused on student development and was aligned with graduation and professional certification requirements. Then, tags were created for each knowledge point, such as key points, difficult points, test points, and course ideology and politics, to be associated and retrieved in the knowledge graph.

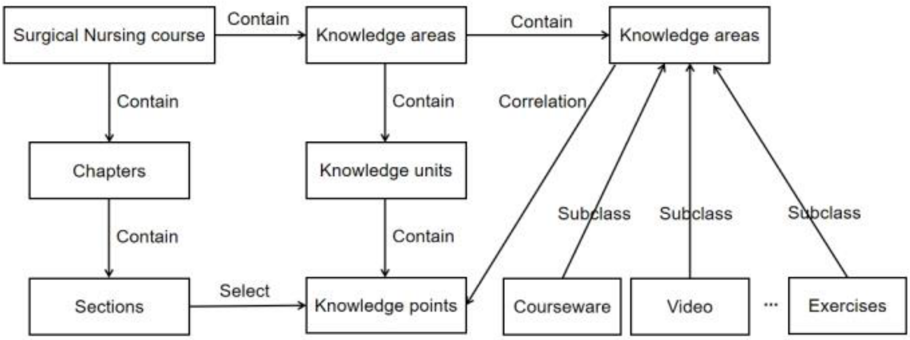

Figure 1. Relationship between the attributes of the Surgical Nursing course.

3.Knowledge Graph–based Mathematical Intelligence Blended Teaching

The course team constructed a knowledge graph-based digital–intelligent blended teaching model based on the knowledge graph from the three major elements of system, subject, and activity, using the Super Star Catechism platform as the carrier and making full use of the modern digital technology in the era of digital intelligence. System refers to the platform and tools supporting the development of smart classroom teaching. Subject refers to teachers and students. Activity refers to the three teaching segments of smart classroom teaching practice: before, in, and after class. We designed a flowchart of the knowledge graph–based mathematical intelligence blended teaching model (Fig. 2) to make the model more replicable and operable, with the smart teaching process as the main axis, starting from the dual roles of teachers and students.

The operation of the whole model included three links before, in, and after class, combining knowledge graphs with classroom teaching. It provided a positive cycle of support for smart teaching and constituted a process cycle of continuous improvement of education through the four steps of guiding–teaching–learning–assessing. The specific process of the model was discussed in the following sections.

3.1. Learning online (Guide)

Before class, the teachers assigned learning tasks online, guided students through relevant course chapters using the knowledge graph and showed students the chapter’s knowledge points and their relevance. Students could initially master the lower-order knowledge learning in Bloom's cognitive law through cases and independent learning tasks (with teaching content, teaching objectives, discussion topics, etc.) through micro-class learning and online discussion. Teachers checked students' mastery of knowledge online before class to provide a basis for offline classroom instruction.

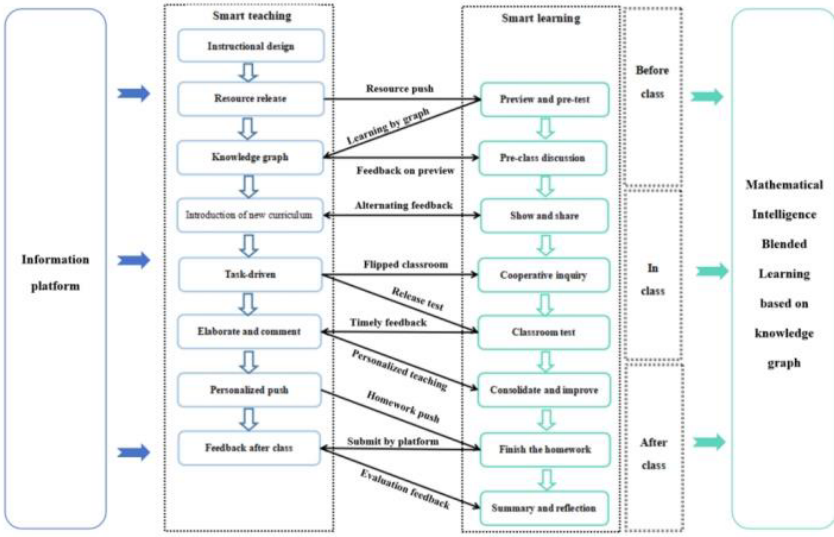

Figure 2. Flowchart of knowledge graph–based mathematical intelligence blended teaching model.

3.2. Raising competence offline (Teaching)

Offline, the teacher first showed the knowledge graph of each chapter, learning along the "map", and grasping the teaching objectives, key points, and difficulties of the course from a global perspective. Different forms were used for different teaching difficulties, such as etiology and pathophysiology, which could be taught by the heuristic teaching method to guide students in understanding the process of disease occurrence and development. Taking the chapter "Upper Urinary Tract Stones" in Surgical Nursing as an example, using a heuristic teaching method to explain the cause of disease and pathophysiology could guide students in understanding the disease occurrence and development process. The case teaching method was applied because the clinical manifestations were the key knowledge. This helped students independently refine the characteristics of the clinical manifestations of diseases from clinical examples, which enhanced their memory. Treatment methods were explained in detail using illustrations, which covered complex topics. Nursing measures belonged to operational knowledge. The content could be visualized more vividly by playing relevant operation videos and other online teaching resources. Nursing operations could be simulated and practiced by applying the scenario-based simulation teaching method and role-playing. After completing some content-intensive lectures, teachers conducted flipped classroom knots or Problem-Based Learning (PBL) pedagogy. Students were asked to follow pre-assigned groups for staged classroom in-group discussions to enhance their understanding and higher-order learning skills. In addition, teachers used the Super Star Learning Pass platform for classroom check-in, questioning, discussion, testing, voting, and so forth to fully mobilize students' participation and enthusiasm in classroom learning.

3.3. Consolidation and internalization after class (Learning)

After the class, the teacher assigned online homework and pushed personalized learning resources based on the self-study portrait before the class and the effectiveness of teaching during the class. Teachers answered questions or communicated online. Students further consolidated and internalized their knowledge and skills through AI-teaching assistants and chapter quizzes.

3.4. Double-drive assessment using diagrams and numbers (Assessment)

Teachers could understand the students' mastery of each knowledge point through the feedback of the knowledge graph in the Super Star Catechism platform. Students could discover their knowledge weaknesses in this class through the "personalized chemistry diagnosis" of the knowledge graph. They also carried out personalized learning for some knowledge points that they had not mastered well through the personalized learning path and learning resources recommended by the knowledge graph. Taking "Nursing of transplant patients" as an example, the average completion rate of students was 93%, the average completion rate of watching the video of "3D animation demonstrating the process of kidney transplantation" was 91.86%, and the average completion rate of reading references in recommended resources was 93.02%. Students showed significant interest in expanding resources. However, the mastery rate of the chapter test was 100% at the highest level, 30% at the lowest level, and 63.14% on average, which needed to be further improved. The lowest correct rate was for the 10th question, which was only 38.2%, indicating that students had a poor grasp of the clinical manifestations of different rejection reactions of organ transplantation.

3.5. AI-assisted smart teaching

- Intelligent recommendation resource

The knowledge graph could automate the crawling of associated resources on the Internet to obtain cutting-edge multimodal teaching resources. It dynamically provided students with more timely, cutting-edge, and higher-quality resources to share so as to meet their personalized development needs as well as competency development goals. Teachers could add multimodal teaching resources with one click and link them with related knowledge points. Students also selected relevant resources for extended learning according to their interests in the Student Terminal of Learning Pass, such as open classes, journals, books, and so forth. Thus, student-centered intelligent learning was realized.

- AI-teaching assistant

In addition, an AI-teaching assistant was introduced in the online course of Surgical Nursing. The AI-teaching assistant extracted all the knowledge from micro-classes, catechisms, textbooks, lesson plans, problem libraries, and other digital teaching resources in the course system to form a powerful knowledge base. It also used large models to train the question-and-answer bank and course materials to realize intelligent questions and answers in course content. Teachers used AI-teaching assistants to intelligently generate lesson plans, intelligently write chapter contents, intelligently generate courseware PPT, and intelligently issue questions. They also used AI-teaching assistants to complete intelligent marking of subjective questions, checking assignments, and analyzing learning conditions. Students could communicate conversationally with AI-teaching assistants in the form of text and voice, and quickly find various learning resources such as books, journals, papers, course resources, and so on at the same time. They could also complete study behavior supervision, study companion reminders, personalized study paths, personalized self-test practice, and so forth through AI-teaching assistants.

4. Limitations and Prospects

A knowledge graph serves as a structured repository that systematically represents and organizes information in graphical form. The integration and organization of fragmented knowledge have positively contributed to the systematic mastery of curriculum content and the linkage of high-quality learning resources to some extent [23-24]. Developing a curriculum knowledge map necessitates extensive medical expertise and data, alongside significant time and resource investment, complicating its construction [25]. This study achieved preliminary development of the curriculum knowledge graph; however, it was subject to certain limitations. It is essential to engage experts from relevant fields for evaluation and guidance in subsequent phases, such as ensuring that each knowledge point aligns with practical topics, clarifying phased learning tasks, and constructing problem graphs, which will be highly beneficial for further enhancement of the knowledge graph.

Moreover, this study was not comprehensively implemented in a complete cycle of teaching practice research. The evaluation of learners' learning outcomes was limited to two indicators: the completion rate of certain knowledge points and the mastery rate, which failed to provide a holistic representation of learners' profiles and necessitated further exploration and innovation. Zhao Linglang [26] explored the design and application of learner portrait models based on knowledge graphs and demonstrated that such models could facilitate functions including data acquisition and preprocessing, construction and analysis of portrait models, generation of portraits, and precise application thereof. An accurate curriculum evaluation index system should be established to assess learners' knowledge mastery, skill attainment, and learning preferences at each knowledge node in future endeavors. This may allow for separate analyses of learner groups as well as individual students, ultimately leading to the creation of personalized learner portraits alongside group portraits reflecting students' abilities, preferences, and knowledge characteristics [27].

5. Summary

The construction of a curriculum knowledge graph with the help of AI is of profound significance, as it can not only promote students' personalized learning and teachers' precise teaching but also effectively link curriculum resources [28]. The construction of online courses based on knowledge graphs helps effectively integrate the resources of different teaching platforms, form a three-dimensional knowledge network, and improve the knowledge system of students. It no longer requires that teachers complete the relevant teaching tasks simultaneously. Students can also learn independently according to the actual learning situation. The teaching mode under this curriculum system is more flexible and free, which aligns with the new concepts of precision education and intelligent education. In addition, this model helps cultivate students' independent learning ability, logical thinking ability, and knowledge creation ability, thus laying the foundation for lifelong learning [29].

Knowledge graphs can dynamically assess students' mastery of knowledge in real time in blended learning. They provide learners with personalized learning experiences such as tailored learning paths and rich learning resources, thereby providing a new solution for tailored teaching at scale [30]. Knowledge graph-based mathematical intelligence blended teaching caters to the Smart Education trend of openness, individuality, and precision. It also sheds light on the development of online courses for other professional fields, which is worth further exploration and promotion.

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The Factors Influencing the Success of Homestay Development in Hunan Province: Based on the Rooted Theory

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Abstract. This study aims to explore the key success factors in the development of homestays in Hunan Province, employing grounded theory and a mixed-methods approach. The research involves analyzing tourist reviews from 15 five-star homestays in Hunan Province and conducting in-depth interviews with 10 homestay owners. Through text coding of the reviews and interview content, the study identifies major factors influencing the success of homestays development, including Service Reception, Facilities and Equipment, Decoration Design, Cultural Ambiance, Homestay Management, Surrounding Environment, Government Support, and External Collaboration. Based on these factors, a theoretical model was developed to explain the success of homestays. Additionally, a survey was conducted targeting homestay consumers, and SPSS was used for regression analysis of the collected data, verifying the significant relationships between internal and external factors. The results indicate that external factors influence customer perceptions, which in turn affect internal factors, collectively determining the success of homestays. This study not only provides theoretical support for understanding the mechanisms behind homestay success but also offers practical guidance for promoting the sustainable development of rural homestays.

Keywords. Homestay development; successful development; rooted theory; homestay success

1. Introduction

In recent years, the homestay industry has flourished under the strategic backdrop of rural revitalization [1]. A homestay refers to the use of spare rooms in private residences to provide personalized accommodation for travelers, integrating local cultural, natural, ecological, environmental resources, and agricultural activities [2]. High-grade tourism homestays significantly boost local tourism consumption and economic development

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and positively impact rural revitalization, particularly in the construction of new rural areas. According to statistics from the China Tourism and Homestay Development Association, the number of online homestay listings in China grew from 592,000 to 1,340,000 between 2016 and 2019, an increase of 126.35% [3]. In Hunan Province alone, there are over 4,800 homestays, with a total of approximately 187,200 beds, generating an annual comprehensive income of around 30 billion yuan and directly creating employment for over 100,000 people, demonstrating a broad development prospect [4].

This study aims to utilize grounded theory to analyze the success factors of homestay development in Hunan Province, using a mixed-method approach. By examining the key mechanisms influencing homestay development, this research seeks to provide theoretical support and practical guidance for promoting the sustainable development of rural homestays.

2. Literature Review

2.1. Quantitative Research Perspective on Homestay Success Development

Current research on homestay success development primarily adopts quantitative research methods, focusing on two aspects: defining homestay success and selecting evaluation metrics, and assessing homestay development from the perspective of entrepreneurial success.

In terms of defining homestay success and selecting evaluation metrics, homestay success is evaluated from multiple dimensions. Scholars generally agree that homestay success can be measured through various performance indicators, including economic, socio-cultural, and growth benefits [5]. From the perspective of business survival, scholars have linked "homestay success" to business performance or efficiency, using survival performance indicators (such as revenue and occupancy rates) and growth performance indicators (such as business achievements, personal accomplishments, and social impact) for measurement [6,7].

In the field of studying factors influencing homestay success, scholars have validated the diversity of influencing factors through quantitative research paradigms. These factors include community participation, leadership, tourism management, and creating a safe and relaxed atmosphere [8].

In the area of community participation and leadership, scholars emphasize the critical role of leadership in improving homestay success rates. They believe that community leadership and homestay leaders who provide high-quality services can significantly enhance the tourist experience and create a cooperative environment [9]. Additionally, empirical research on homestay hosts has demonstrated the undeniable influence of individual-level factors on homestay success. The research indicates that personal traits are the key factors determining homestay success, followed by social capital, human capital, and strategic considerations [10].

In the context of tourism business management, the importance of social media as a modern promotional tool for homestays has become increasingly prominent. Researchers have found that establishing an effective social media presence has been proven to significantly increase the visibility of homestays, showcase their unique cultural experiences and natural beauty, and enhance the interaction between homestay hosts and their audiences [11,12].

From the perspective of marketing strategies and the utilization of core resources, homestays that incorporate local traditions, customs, and natural scenery tend to be more attractive, as they appeal to tourists seeking immersive and meaningful travel experiences [13]. Further empirical analysis has confirmed the direct impact of homestay operators, pricing, rural charm, and location on the economic benefits of homestays [14]. Scholars have also emphasized the importance of cultural preservation and environmental sustainability in promoting homestay success when developing business strategies. Increasingly, tourists are favoring accommodations that effectively integrate cultural and natural resource preservation into their offerings [8].

2.2. Mixed Research Perspective on Factors Influencing Homestay Success Development

In recent years, as research on homestay success development has deepened, grounded theory as a qualitative research method has been increasingly applied in this field. Grounded theory enables researchers to delve into the complex mechanisms and relationships underlying social phenomena [15]. This method uses techniques such as open coding, axial coding, and selective coding to extract concepts with universal and theoretical value from empirical data, which is crucial for revealing the complexity of factors influencing homestay success [16].

While some scholars have combined grounded theory with quantitative research to form a mixed-methods approach, the mechanisms behind homestay success development remain underexplored. For example, Cao Xingping combined grounded theory with structural equation modeling to investigate the mechanisms of homestay entrepreneurial success, finding that rural tourism attractions and supporting facilities serve as external stimuli, while nostalgia and self-realization act as internal driving forces [17]. These factors, mediated by entrepreneurial opportunities, social networks, and policy guidance, ultimately influence the business models and environmental decisions of homestay entrepreneurs.

Therefore, this paper combines grounded theory with quantitative analysis to explore the mechanisms of homestay success development through a mixed-methods approach, addressing the gaps in existing research and providing new perspectives and methodologies for future studies.

3. Research Approach

3.1. Interviews and Text Coding Process

The study began with an analysis of tourist reviews for 15 five-star homestays in Hunan Province, sourced from the Tujia and Meituan online platforms. Tujia is one of China's largest online homestay operators, supported by multiple major online platforms, while Meituan offers a rich resource base and extensive user group, making it highly representative. Using the Outlier Collector reviews from 2020 to 2023 were gathered, totaling 926 valid reviews. Both positive and negative reviews were included to identify key factors for model construction.

To enhance data reliability and address the issue of single-source bias, the study also involved in-depth interviews with the owners of 10 five-star homestays in Hunan. These semi-structured interviews, lasting between 30 and 60 minutes each, were designed to be flexible around the research topic. Transcriptions of these interviews produced approximately 40,000 words of text.

Through online text analysis and in-depth interviews, the data collected was coded in conjunction with Nvivo 11 software to construct a preliminary theoretical model of successful homestay development.

In the absence of subjective bias and preconceptions, qualitative data were conceptualized and categorized sentence by sentence, leading to the formation of additional concepts and categories through comparative analysis. NVivo 10 software was used to code the homestay review texts (e.g., reviews from a particular homestay were denoted as C). Each review was analyzed, classified, and restructured sentence by sentence, ultimately resulting in 62 concepts and 24 categories.

Table 1. Examples of open coding

Original Representation Statement	Conceptualization	Categorization
C5: The housekeeper drove himself to the airport to pick up the plane, very enthusiastic	a257 Free pick-up	A1 Service content (a88, a257, a414...)
C9: The accompanying gift when we left was exquisite	a414Give a gift of companionship	
C14: The waitress in the store contacted in advance to go out to meet, the service is warm and thoughtful!	a167 Excellent service	A2 service attitude (a12, a167, a378...)
C14: The staff was warm and sincere, helped a lot, gave a lot of useful advice, and was patient even when it was late and troublesome.	a378 Service patience	
C4: The days we stayed happened to be wedding anniversaries, thanks to the hotel's careful decoration.	a201 Layout of rooms to suit preferences	A3 Personalized service (a145, a201, a468...)
C14: I rushed to the high-speed train early the next morning, the restaurant a sister made breakfast in advance, eaten full on the road, warm heart warm stomach ~	a468 specializes in making breakfast in advance	
C5: The rooms are cozy and modern, with automatic curtains, floor-to-ceiling windows, projection TVs, etc.	a105 Modernization of facilities	A4 Quality of facilities (a28, a105, a421...)
C10: Very good soundproofing and quiet	a421 Room soundproofing is good	
C1: The store's facilities are all very complete, leisure area, tearoom, entertainment area, observation deck	a36 Fully equipped	A5 Plenty of facilities (a36, a109, a206...)
C6: One of the highlights of the homestay is a nettlesome pool	a109 Netflix swimming pool	

Categories with considerable similarity were merged to extract primary categories, thereby enhancing the completeness of category meanings. In-depth interviews with the owners of 10 five-star homestays were conducted to further validate and refine the necessity of the 24 categories, as well as to explore the presence of any overlooked categories. The final confirmation yielded 30 categories, from which 9 primary categories were distilled: Surrounding Environment, Government Support, External Collaboration, Service, Facilities and Equipment, Decoration Design, Cultural Ambiance, Homestay Management, and Customer Perception.

Table 2. Examples of associative coding

Main Categorization	Categorization
AA1 Service Reception	A1 Service content, A2 service attitude, A3 Personalized service
AA2 Facilities and Equipment	A4 Quality of facilities, A5 Plenty of facilities, A6 Security and hygiene
AA3 Decoration Designs	A7 Architectural style, A8 Decoration Designs, A9 Scale placement
AA4 Cultural Ambiance	A10 Host Culture, A11 Local culture, A12 Atmosphere of home
AA5 Homestay Management	A13 Publicity and promotion, A14 Organization of the event A18 Employee Management, A19 Product upgrades

AA6Surrounding Environment	A15 Beautiful environment, A16 Transportation, A17 Distance
AA7 External Collaboration	A20 Cooperation with peers, A21 Community cooperation, A22 Cooperation with associations
AA8 Government support	A23 Government policies, A24 Business license, A25 Other government incentives
AA9 Customer Perceptions	A26 Price perception, A27 Expectation gaps, A28 Satisfaction
AA10 Benefits of Homestay	A29 Economic benefits (occupancy rate, willingness to re-stay, willingness to recommend) A30 Social benefits (boosting the economy, providing employment, beautifying the countryside, social honor)

Selective coding aims to identify and extract the "core category" from the main categories and systematically analyze its relationship with other categories to construct a theoretical framework. In this study, the research objective guided a deep analysis of each main category, formulating a theoretical model of factors contributing to homestay success. The "Model of Factors and Mechanisms Influencing Homestay Success" emerged as the core category. The influencing factors are divided into internal and external dimensions, with factors in each dimension interacting with one another, directly or indirectly affecting customer perception, which in turn influences the successful development of the homestay. Based on the paradigmatic model of "Influencing Factors/Phenomena/Causal Conditions—Intermediary—Action/ Interaction Strategies/Outcomes," this study constructs a theoretical model for the successful development of homestays, as illustrated in Figure 1.

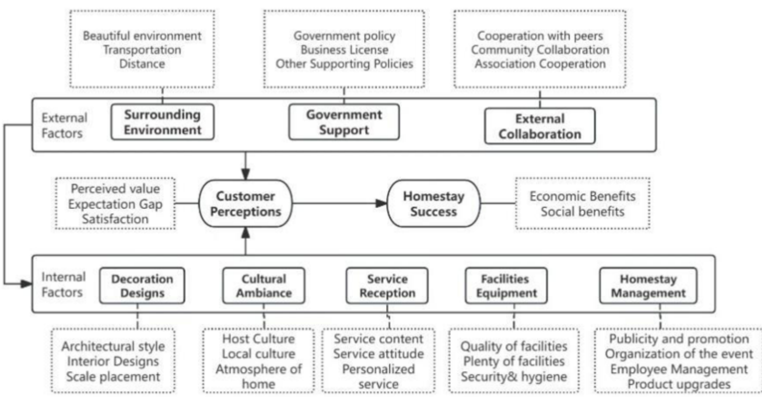

Figure 1. The Model of Factors Influencing Homestay Success and Their Mechanisms

3.2. Questionnaire Design and Data Collection

Building on the prior qualitative research and the theoretical model already constructed, the questionnaire was designed by integrating coding results with relevant domestic and international studies, as well as established scales. The questionnaire was also aligned with the Hunan Provincial Standard, Classification and Evaluation of Tourism Homestay Grades, to ensure its applicability and validity. A Likert five-point scale was employed, with response options ranging from "strongly disagree" to "strongly agree," scored from 1 to 5, where higher scores indicate stronger agreement.

The survey was primarily conducted online, with questionnaires distributed via social media platforms such as WeChat. A total of 330 questionnaires were collected, of which 315 were valid, yielding a response rate of 95%. After data collection, SPSS software was used to perform regression analysis, which further refined and validated the theoretical model, allowing for more accurate identification of the key factors influencing homestay success.

3.3. Reliability and Validity Analysis

To ensure the authenticity and consistency of the scales used, this study employed SPSS 22.0 to conduct reliability and validity analyses. Reliability was assessed using Cronbach's alpha coefficient, which in this study was 0.922, indicating excellent internal consistency (values range from 0 to 1, with 0.5 to 0.7 being acceptable and values above 0.7 indicating good reliability).

Validity was evaluated using the KMO (Kaiser-Meyer-Olkin) measure and Bartlett's test of sphericity. The KMO value for this study was 0.865, confirming the high validity of the questionnaire (KMO values closer to 1 indicate data suitability for factor analysis, with values above 0.8 indicating very high validity). Furthermore, correlation coefficients among internal factors, external factors, homestay success, customer perception, homestay management, Cultural Ambiance, decoration design, facility equipment, service reception, External Collaboration, government support, and surrounding environment were all greater than zero, indicating significant correlations between these factors and homestay success.

4. Key Success Factors and Model Interpretation for Homestay Development

4.1. External Factors

External factors refer to objective conditions and external relationships that influence the successful development of homestays, including the surrounding environment, government support, and external collaboration.

Surrounding Environment: The selection of a homestay location should consider natural and cultural resources, transportation accessibility, and proximity to attractions. Favorable environmental conditions and convenient transportation enhance a homestay's competitiveness and attract more customers. For instance, C11 stated, "Situated behind Longxin Academy and facing the Yuanjiang River, it is indeed a great place with first-rate surroundings. Guests can stroll by the river in the morning and evening." Similarly, C14 mentioned, "The location of the homestay is excellent, providing tranquility amid the town. Everything is conveniently accessible."

Government Support: Government-provided support, including policies on land, funding, and credit, creates a conducive development environment for homestays. This support aids in optimizing resource allocation and promotes high-quality development. I6 noted, "The government has introduced numerous policies, particularly in terms of subsidies following the rating of Grade A and five-star homestays. There is now substantial governmental support for the development of tourism homestays."

External Collaboration: This involves establishing cooperative relationships with other industries, community organizations, or associations to conduct joint promotions, resource sharing, and community activities, thereby enhancing market competitiveness. I2 highlighted, "During traditional festivals, such as March 3rd, Harvest Festival, and Double Ninth Festival, we take our guests to rural areas, engaging in consumer assistance, which is part of rural revitalization efforts."

4.2. Internal Factors

Internal factors refer to the subjective and intrinsic operational elements that influence the successful development of a homestay, including service reception, facilities and equipment, Decoration Design, cultural ambiance, and homestay management.

Service Reception: This encompasses the range of services provided by the homestay, including the quality of service, attitude, and personalized experiences. Effective service reception is crucial for meeting guest needs and enhancing their accommodation experience. For instance, C4 noted: "During our stay, which coincided with our wedding anniversary, we appreciated the thoughtful decorations provided by the homestay."

Facilities and Equipment: This pertains to the physical amenities and equipment available for guest use, including their quality, variety, and standards of safety and hygiene. High-quality facilities and good hygiene conditions significantly enhance guest satisfaction. C1 remarked: "The homestay is well-equipped with complete facilities, including a leisure area, tearoom, entertainment zone, and observation deck."

Decoration Designs: This involves the architectural style, Decoration Design, and layout of the homestay. Thoughtfully designed interiors contribute to creating a distinctive environment that aligns with the homestay's character, thus enriching the guest experience. C14 described: "The entire guesthouse is decorated in a classical Chinese style, with picturesque scenes at every turn, featuring pavilions and terraces that are breathtaking."

Cultural Ambiance: This refers to the unique cultural environment cultivated by the homestay, including the host's cultural background, local culture, and the homely atmosphere. A rich cultural ambiance can attract guests and foster a sense of connection. C4 mentioned: "The Cultural Ambiance is strong, with outdoor barbecue dinners and the host personally serving drinks to each guest, which was very warm and welcoming."

Homestay Management: This encompasses the management and coordination of various operational aspects of the homestay, including staff management, marketing, event planning, and product upgrades. Effective management is essential for providing high-quality service and enhancing guest satisfaction. I10 noted: "Our homestay features a camping site and hosts music festivals. During the off-season, we have festivals every weekend, and in peak season, there are different music festivals daily."

4.3. Relationships Between Factors

Through grounded theory research, it has been identified that internal factors and external factors are key determinants of homestay success. There is a logical relationship between internal and external factors. The following regression analysis reveals that with a p-value less than 0.05, significant linear relationships exist between the external factors—External Collaboration, government support, and surrounding environment—and the internal factors—service reception, facilities and equipment, Decoration Design, cultural ambiance, and homestay management. This confirms that external factors significantly influence internal factors within the model.

Table 3. Significance Test for Linear Regression

	SS	df	MS	F	p
Regression	44.577	1	44.577	157.965	0.000
Residuals	88.328	313	0.282		

Table 3. Significance Test for Linear Regression

	SS	df	MS	F	p
Totel	132.905	314			

4.4. Mechanism of the Model's Effects

In the process of homestay development, multiple factors interact to produce an overall perceptual effect after the guest experience, which subsequently impacts the success of the homestay. The mechanism of the homestay success model essentially establishes a path of "factors → perception → outcome." Grounded theory research has identified eight factors affecting homestay success, which collectively influence tourist perception and, ultimately, homestay success. Improved customer perception enhances the likelihood of achieving economic and social benefits. According to Feng Cheng et al., homestay management and service reception positively impact homestay success [18]. Therefore, the regression model has been adjusted to reflect "homestay management positively impacts homestay success" and "service reception positively impacts homestay success." Furthermore, Hou Yuxia found that Decoration Design positively affects homestay success [19]. Thus, the model has been updated to indicate that "Decoration Design positively impacts homestay success," resulting in the revised structural model.

Table 4. Adjusted Regression Analysis Between Variables

Dependent Variable	Independent Variable	Adjusted R^2	B	Standard Error	β	t	p
Customer Perceptions	External Factors	0.164	0.650	0.082	0.408	7.909	0.000**
	External Collaboration	0.161	0.232	0.066	0.193	3.503	0.001**
	Government Support		0.278	0.091	0.200	3.060	0.002**
	Surrounding Environment		0.156	0.075	0.135	2.065	0.040*
	Internal Factors	0.159	0.671	0.086	0.402	7.775	0.000**
	Cultural Ambiance	0.123	0.177	0.060	0.160	2.950	0.003**
	Decoration Designs		0.332	0.063	0.287	5.290	0.000**
Homestay Success	Customer Perceptions	0.170	0.347	0.043	0.415	8.069	0.000**
	Homestay Management	0.367	0.174	0.041	0.200	4.237	0.000**
	Facilities&Equipment		0.459	0.062	0.410	7.388	0.000**
	Service Reception		0.143	0.049	0.162	2.929	0.004**

Based on the empirical research results, a model illustrating the factors influencing the success of homestay development is constructed, as shown in Figure 2. The model indicates that whether a homestay complies with government requirements and receives government support is crucial for providing a good guest experience. External factors, including the Surrounding Environment, Government Support, and External Collaboration, have a positive impact on Customer Perception, with Government Support being the most significant ($B=0.278$, $p=0.002<0.01$).

Customer perception is primarily influenced by the homestay's architectural style, Decoration Design, and layout, with distinctive Decoration Design leaving a stronger impression. Internal factors such as Cultural Ambiance and Decoration Design also positively affect Customer Perception, with Decoration Design having the most significant effect ($B=0.332$, $p=0.000<0.001$). Customer Perception positively impacts Homestay Success, indicating that the success of a homestay largely depends on customer satisfaction, which can translate into subsequent benefits.

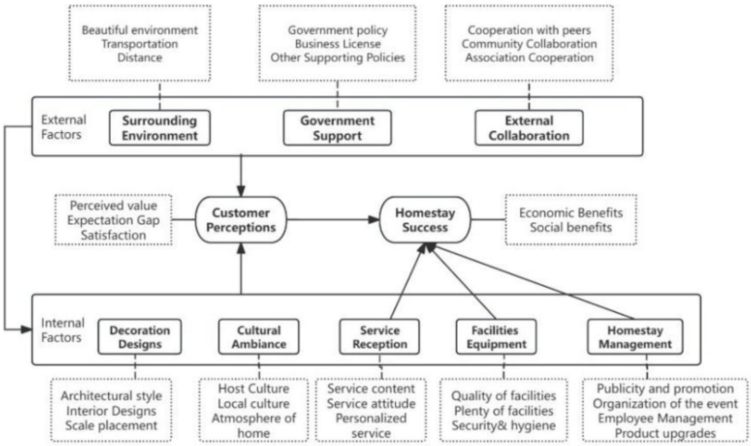

Figure 2. Revised Theoretical Model

5. Conclusions and Implications

5.1. Research Conclusions

A theoretical model based on the "Factors-Perception-Outcome" framework was constructed and subsequently validated through empirical analysis.

Surrounding Environment, Government Support, External Collaboration, Service Reception, Facilities and Equipment, Decoration Design, Cultural Ambiance, and Homestay Management are eight critical factors significantly impacting the success of homestays. External factors include Surrounding Environment, Government Support, and External Collaboration, while internal factors encompass Service, Facilities, Decoration Design, Cultural Ambiance, and Homestay Management.

These factors influence customer perception, which in turn drives the intention to revisit. Regression analysis reveals a significant positive correlation between influencing factors and customer perception, as well as between perception and homestay success. Enhanced customer perception facilitates the likelihood of recommendations or repeat visits, generating both economic and social benefits for homestays, thereby promoting their successful development.

5.2. Practical Implications

(1) Creating a Favorable External Environment for Homestay Development

Homestays should prioritize site selection, opting for areas with scenic beauty, convenient transportation, and well-developed facilities to enhance attractiveness. Governments should improve and enforce relevant regulations, and homestay operators should stay informed about government support policies, ensuring compliance with local laws to gain governmental support. Additionally, forming partnerships with local restaurants, attractions, and other homestays, and establishing connections with community residents can collectively increase visibility and foster a harmonious social network.

(2) Ensuring the Improvement of Homestay Product Quality
Staff should be trained in professional service skills to provide personalized and attentive service. Regular maintenance and updates of facilities should be conducted to ensure a comfortable and convenient living environment. Thoughtful Decoration Design, aligned with the homestay's theme, can create a unique atmosphere, enhancing customer satisfaction. Finally, effective management of staff, promotional efforts, activity planning, and product upgrades can improve operational efficiency and service quality, increasing customer satisfaction and loyalty.

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Research on the Mixed Study and Teaching Mode of Rural Teachers Under the Background of Digital Transformation of Regional Education

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Abstract. The digital transformation of education is an important trend of the current education development. Through the introduction of digital technology and tools, it promotes the reform of education and teaching and improves the quality and effect of education. In the context of the digital transformation of regional education, classroom teaching also needs to carry out corresponding changes to adapt to the new educational environment, improve the quality of education, and promote the all-round development of students. Based on this, starting from the background of digital transformation of regional education, this paper builds the classroom teaching mode of mixed research and study, drives the reform of education and teaching, explores the development path of digital literacy of teachers and students, in order to provide program reference and case reference for regional classroom teaching reform, and realize the balance of education.

Keywords. Digital transformation; education balance; classroom reform

1. Introduction and background

With the breakthrough and extension of the new generation of information technology represented by artificial intelligence and 5G technology, human society has gradually stepped into the digital era of "Internet + artificial intelligence", and the huge change potential of digital technology in the field of education has made the digital transformation of education has gradually become an international consensus [1]. During the 13th Five-Year Plan period (2016-2020), China put forward the concept of "Internet + education" and emphasized the innovative application of information technology in education and teaching. During the 14th Five-Year Plan period (2021-2025), China put forward the strategic task of digital transformation of education, emphasizing that digital transformation should drive the reform of education and teaching. The policy is oriented to take the region as the construction application unit, promote digital transformation and information development, optimize the allocation of educational resources, promote

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educational equity and improve the quality of education. During this period, the Ministry of Education carried out the pilot work of information technology to support students' comprehensive quality evaluation and launched the selection activities of educational information construction and application. Based on this, this study, based on the digital transformation at the regional level, constructs the mixed research and classroom teaching mode of teachers from the perspective of reform and achieves some application results, in order to provide program reference and case reference for the digital transformation of regional education. Therefore, it is very important to improve the role of information technology in education, especially in rural teachers.

2. The theoretical basis of the practice of rural teachers

2.1. Digital literacy

Cultural and digital technical literacy is a necessary condition for democratic citizenship in an information society. Citizens who do not know how to use digital technology intelligently (know how to connect and browse the Internet, search for useful information, analyze and reconstruct information, and communicate with other users) will not be able to enter the culture and market of the information society [2]. Digital literacy has become an essential core skill for educators. It not only covers information technology capabilities, but also extends to innovative thinking, data awareness, and information management capabilities.

Digital literacy is a basic quality for both educators and students. In the information age, information technology has become one of the key skills of educators. Teachers need to master various information technology tools and resources to carry out education and teaching work more effectively. At the same time, students also need to have a certain digital literacy, so as to use information technology for independent learning and inquiry learning, and better adapt to the learning style of the information age. Classroom reform provides an effective implementation strategy for the improvement of teachers 'digital literacy. Teachers can better integrate digital technology into classroom teaching, promote communication and cooperation among teachers, and provide more practical opportunities, so as to improve teachers' digital literacy and education and teaching level.

2.2. Knowledge and action should go hand in hand

Teachers should master educational theories, methods, subject knowledge and educational psychology, so as to design teaching plans, select teaching methods and evaluate teaching effects. Theory is the foundation, but also needs to communicate and cooperate with peers, and share resources. Teachers need to combine theory and practice, apply theory to practice, reflect on experience, in order to improve the teaching level.[3][4].

The cross-school mixed study mode expands the boundary of teachers' research and study, is conducive to the integration of theory and practice, and promotes the integration of knowledge and practice. Through the training and practice of mixed training, teachers can master various information technology tools and resources, such as multimedia courseware making, network teaching resources development, online course design, etc., and apply them to classroom teaching. The cultivation of this ability can not only improve teachers 'teaching effect and students' learning effect, but also lay a solid foundation for teachers' career development.

3. Theoretical concepts in teacher training

3.1. Teacher training community

Teacher training community is a learning exchange organization in teachers 'continuing education. It aims to improve teachers' professional ability [5], emphasizing common beliefs, vision and cooperation, sharing insights and information, and solving teachers' practical problems collectively, reducing the burden and improving the quality of [6].

3.2. Constructivism theory

Constructivism teaching is student-centered, and teachers play various roles. They use situation, collaboration and dialogue to stimulate students' initiative and realize knowledge construction. Constructivism emphasizes students' meaning construction of knowledge, and the application and transfer of skills[7].

4. The construction of the classroom teaching mode under the mixed study

4.1. Teacher training community

With the progress of information technology and intelligent teaching, various teaching methods and modes of subjects are constantly emerging. Based on the realistic demands of teachers to develop digital literacy and the needs of students to improve digital literacy, this paper constructs a model of literature research and a classroom teaching mode based on collective lesson preparation, so as to provide strong support for the digital transformation of regional education. This model is applied in the pilot teachers of the pilot schools, and has achieved good results.

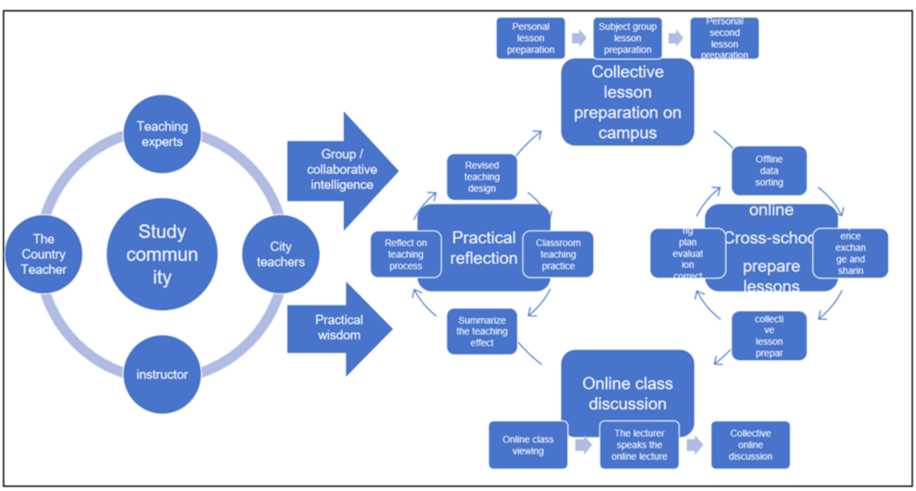

Figure 1 Cross-school online teaching and research mode diagram

The cross-school online teaching and research mode includes four links: collective lesson preparation, teaching preparation, course observation and discussion, and practice reflection, forming a closed loop. Combined with online and offline, using online platform interaction. The research community includes teaching and research staff, experts, rural and urban teachers, each performing their own duties. With the support of the information technology platform, we will promote students' core competence and teachers' professional development through research activities.

4.2. Flow chart of subject classroom teaching based on collective lesson preparation and study

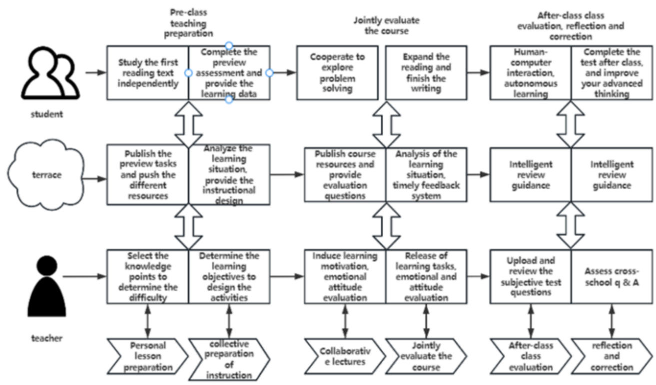

Figure 2. Flow chart of subject classroom teaching based on collective lesson preparation and study

The subject classroom teaching flowchart based on the collective lesson preparation mode is divided into three links: classroom teaching preparation, in-class teacher teaching and after-class student development. In lesson preparation, the teachers at our school adopt the advanced network classroom interaction of the same frequency, and then conduct students' study and teacher study based on the platform. In class, the platform is used for effective teaching, and after class, the platform corrects students 'homework to effectively support students' self-study. With the support of the information technology learning platform, students can learn the subject knowledge from all aspects and angles, improve students' core literacy, and realize the professional development of teachers.

5. Application of the Model and Outcomes

Through the introduction of advanced information technology, the classroom teaching mode has been greatly improved, and the teaching quality and efficiency have also been significantly improved. The whole process of school education and teaching management is informationized, forming the teaching mode of Chinese, mathematics, English and other subjects, improving the quality of classroom education and teaching, and realizing the quality and efficiency under the background of "double reduction".

5.1. Information-based teaching enables students to improve their academic performance

Taking mathematics as an example, background data analysis can provide teachers with personalized teaching reports. Pre-class analysis helps teachers to master students and adjust teaching; classroom data is used for personalized homework, tutoring and after-class content.

5.2. Development of teachers' information technology ability

The reform of information technology classroom has achieved remarkable results: first, the classroom mode is improved, students are paying attention to personalization; the teaching quality is improved, students master skills more effectively. Secondly, teachers get more resources and management interaction is more convenient; evaluation is a more scientific and timely solution. These achievements promote education modernization and help students develop in an all-round way.

5.3. Teachers' TPACK level is improved

To effectively evaluate the teacher TPACK level, the pilot-school teachers were surveyed by questionnaire survey, and 28 valid questionnaires were collected. TPACK analysis of teachers is shown in figure 3.

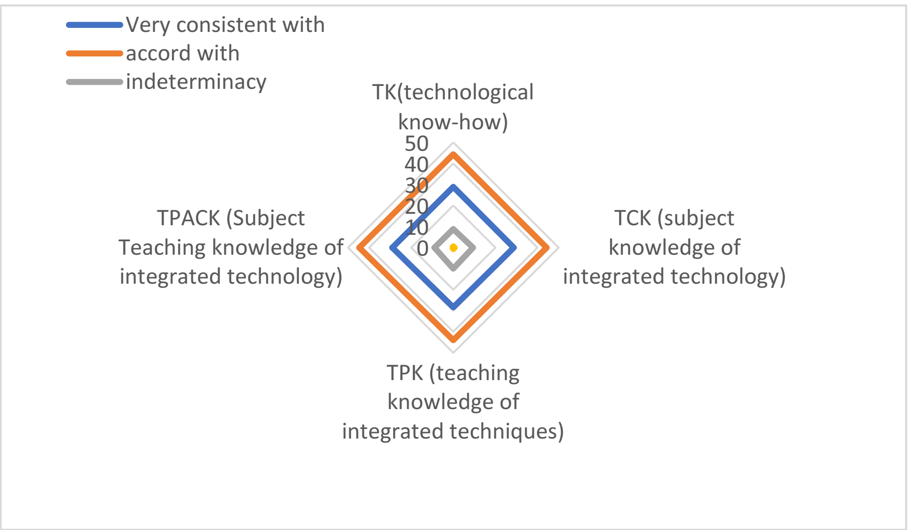

Figure 3 questionnaire survey radar map

Through the analysis of these four dimensions, the relevant knowledge level of teachers can be observed to a certain extent. Most teachers have a good grasp of all kinds of knowledge (TK, TCK, TPK, TPACK), teachers have a high level of information teaching ability, and the level of school information construction is good. From the perspective of TK (technical knowledge), teachers have the consciousness of integrating subject knowledge and information technology. Most of them can skillfully apply information technology software related to teaching, which can solve teaching problems through information technology, and timely repair teaching equipment in case of emergency. Most teachers hold a positive attitude towards information technology to promote teaching and learning. From the perspective of TCK (subject knowledge of integrated technology), most teachers have a certain grasp of the integrated application of information technology and disciplines and can flexibly use information technology and put it into teaching practice. From the two dimensions of TPK (teaching method knowledge of integrated technology) and TPACK (subject teaching knowledge of integrated technology), teachers have an ideal mastery of technology and can effectively adjust their teaching with the help of information technology.

According to the above dimensional analysis, the situation of the pilot teachers in this school is relatively good, but they still need to be further improved. In order to realize the integration of information technology and subject, teachers need to deepen subject knowledge, find application scenarios, integrate technical resources, design innovative activities, and encourage students to practice evaluation, so as to promote knowledge dissemination and improve students' literacy and ability.

6. Conclusion

The cross-school mixed training model promotes teachers 'exchange and learning, improves teaching quality, promotes education reform, and promotes teachers' professional development. This model is helpful to broaden teachers' horizons, learn new teaching ideas and strategies, and improve the teaching level. At the same time, teachers can jointly discuss the problems encountered in teaching together, study the curriculum design, and jointly develop a more scientific and practical teaching plan. This cooperation helps teachers to learn from each other, improve the quality of teaching, and promote cooperation and common development between schools. Some teachers' courses have been rated as municipal quality basic education courses. Central schools and subject teaching and research base schools give full play to their advantages of teachers and education resources and share generative resources such as teaching and research results to all schools through the platform, so as to realize the sharing of high-quality education resources and drive the development of weak schools. In addition, the cross-school mixed training model also helps to break the shackles of traditional educational concepts and promote the innovation and development of education and teaching. In the future education practice, will continue to study the effective use of informatization in education teaching, improve and improve the existing education teaching management application, further optimize the intelligent teaching mode of various disciplines, in order to improve the efficiency of classroom teaching and teaching quality as the goal, improve teachers' information technology literacy, build a sufficient scale, quality qualified teachers to adapt to the development trend of education informatization of strong teachers.

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Digitalization and Management Innovation III
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Exploration of Training Practice for Rural Teachers in the New Era Under the Guidance of Core Literacy

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Abstract. The introduction of new curriculum standards for various subjects in compulsory education has accelerated the pace of new curriculum reform. How to better cultivate students' core literacy and enhance their ability to solve practical problems in real life has become the primary task that teachers need to solve. However, teachers in rural areas often tend to adopt traditional teacher led teaching methods, and have limited learning opportunities, making it difficult for them to receive guidance from new ideas and technologies from the outside world. Implementing teaching reforms guided by literacy poses certain challenges. To this end, a special training program for rural teachers has been launched in pilot schools, which comprehensively cultivates the teaching content organization ability, learning evaluation integration teaching ability, intelligent technology application ability, classroom data analysis ability, etc. of rural teachers, in order to enhance their professional literacy from multiple aspects, bring new learning methods to rural students, and promote the development of students' literacy.

Keywords. core literacy; teacher training; new standards; integration of learning and assessment

1. Introduction

The release of curriculum standards for various subjects in compulsory education in 2022 emphasizes the cultivation of students' core literacy and their ability to apply knowledge to solve practical problems in real life. The cultivation of core literacy in subjects has become the fundamental task of the new curriculum standards, while emphasizing the focus on learning. It is recommended to carry out project-based learning that integrates subjects. This also puts forward higher requirements for teachers, who need to truly play the role of guides and lead students to gradually develop core literacy.

Guo Shaoqing pointed out that digital technology reconstructs teaching relationships and processes, changes teaching evaluation methods, and effectively promotes core literacy education[1]. In the context of digital transformation in education, teachers should carry out training activities under the guidance of expert teams, focusing on improving their own intelligent technology application ability and classroom data analysis ability, attaching importance to the integration of learning and evaluation in teaching, and improving students' literacy level through the reconstruction and optimization of teaching content.

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Liu Jingcui and others pointed out that there are three major practical difficulties in school-based training: arbitrariness, passivity, and fragmentation[2]. Yao Gang and others pointed out that there are problems in teacher training at the basic education stage, such as obstacles to joint participation, vague shared vision, and weak shared resources[3]. This requires authoritative teaching experts to carry out systematic top-level design, pay attention to the internal needs of teachers, and under the guidance of theoretical experience from dynamic experts, form a research and training community to help promote the normalized development of training.

At present, China's compulsory education is in a critical stage of moving from basic balance to high-quality balance, and it is urgent to carry out targeted training for rural teachers to promote their professional development[4]. However, in rural areas, teachers lack guidance from new theories and experiences, as well as support from new technologies and tools. It is difficult to collect process data on students' learning in a timely and comprehensive manner, which is not conducive to timely evaluation and feedback on students' learning situation. At the same time, there is a lack of cultivation and evaluation of students' core literacy. Due to the constraints of work pressure and environmental conditions, the learning process of rural teachers is mostly fragmented, mainly conducted through expert lectures, and there are few opportunities for hands-on practice for rural teachers, which is not conducive to their continuous improvement.

To this end, the research team led by the author focuses on the cultivation of students' core literacy in some rural schools in western Inner Mongolia and conducts continuous special training. Through the process of lesson preparation, presentation, polishing, teaching, and reflection, a teaching model with school characteristics is gradually formed to systematically enhance rural teachers' understanding of the new curriculum standards and provide support for teaching reform in rural areas guided by core literacy.

2. Overall Design Plan for Rural Teacher Training Aimed at Cultivating Core Literacy

This training mainly adopts the methods of literature review, questionnaire survey, interview, and case study. Through extensive literature review in the early stage, the training content that is in line with the current situation and development of rural teaching is determined, providing support for the subsequent training. Through a preliminary questionnaire survey of 132 frontline teachers from 8 primary schools in a certain city in Inner Mongolia, it was found that the main types of training activities that teachers are currently participating in include classroom observation (84.38%), communication and discussion (70.31%), and lesson presentation and evaluation (67.19%), with a relatively single type of training activity. Although it also involves activities such as special lectures (40.63%), experience sharing (29.69%), remote training (26.56%), teaching reflection (25%), and visits and inspections (15.63%), it has not yet delved deeply into the actual teaching of teachers, making it difficult for them to achieve significant improvement and gains. Further investigation found that teachers believe that the main reasons for the impact of online training on their participation in interaction are that other members did not actively participate (56.8%), time and energy were insufficient (54.3%), they were not interested in the discussion content (52.9%), online communication was fragmented (46.2%), problems were often not effectively answered (42.7%), and were not related to teaching practice (40.40%).

To truly solve the existing practical problems of rural teachers and promote the participation of all members. Throughout the entire training process, information technology teaching experts provide technical guidance and teaching theory experience support, frontline teaching masters provide high-quality case introductions and practical experience guidance, rural teachers generate characteristic cases based on the school's characteristics and class student situation and drive the overall implementation of the school. Information technology teaching and research personnel coordinate the time of various activities, organize teachers to participate in training activities, and extract the school's characteristic teaching mode. Group dynamics experts pay attention to the participation of members at different stages in order to adjust the training content and focus on a timely manner and promote active participation from all parties.

As the core issue of training is to enhance the core literacy cultivation ability of rural teachers, it is divided into teaching goal design, smart classroom mode, and teaching design process as branch issues, allowing rural teachers to experience the implementation process of teaching design guided by core literacy in their learning and improve their professional literacy. The overall design plan for rural teacher training aimed at cultivating core literacy is shown in Figure 1.

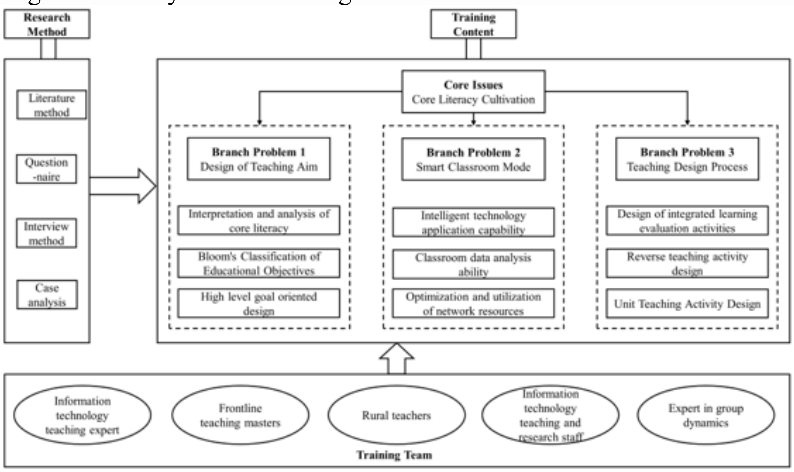

Figure 1. Overall design plan for rural teacher training aimed at cultivating core literacy

2.1. Branch Problem 1 Design of Teaching Aim

Reasonable teaching objective design is the key to whether a class can be efficiently completed. The promulgation of the new curriculum standards has clarified the core literacy of each subject. Only by truly defining the purpose of cultivating core literacy and skillfully integrating them into teaching objectives can we truly promote students' development. Taking primary school Chinese language teaching as an example, the "Compulsory Education Chinese Language Curriculum Standards (2022 Edition)" points out that the core literacy of Chinese language subject is cultural confidence, language application, thinking ability, and aesthetic creation. Therefore, in the teaching of Chinese language classes, it is important to focus on improving students' language expression ability, enabling them to independently organize the structure of articles, while also enabling them to discover and create beauty, and enhancing their sense of cultural identity. Conducting specialized training on the interpretation and analysis of core literacy for rural teachers can help them further understand the connotation of subject core literacy and begin to try to integrate core literacy into teaching objectives, achieving the transformation of competency-oriented teaching.

After integrating core literacy into teaching objectives, it is also necessary to pay attention to the hierarchical classification of objectives. Bloom divides students' cognitive processes into six dimensions: memory, understanding, application, analysis, evaluation, and creation. In actual teaching, teachers often focus on cultivating these two low-level goals, memory and understanding, and lack the cultivation of higher-level goals. Through the guidance of the book "Bloom's taxonomy of educational goals", teachers can shift the focus of teaching to the cultivation of high-level goals, which is conducive to triggering students' higher-level thinking and continuously strengthening their own abilities. And based on the SOLO classification evaluation, we focus on addressing issues related to the hierarchical structure and abstract extension level, in order to enhance students' ability to integrate, deepen, and expand.

Guided by high-level goals and relying on core literacy, we aim to assist rural teachers in innovating their teaching goal design, making it more in line with the requirements of student development and breaking free from the limitations of exam-oriented education.

2.2. Branch Problem 2 Smart Classroom Mode

With the rapid development of artificial intelligence technology, various teaching techniques have emerged. This training is based on the Jiaokewang platform, which explains the usage norms of the Jiaokewang platform for rural teachers, realizes online resource expansion and interactive writing, and allows students to evaluate each other and learn from each other's strengths on the platform. In addition to uploading resources and evaluating students, teachers can also observe the student answer data generated by the platform, understand the students' process learning situation through question accuracy, typing time and word count, discussion participation, etc., infer the achievement of teaching goals, and indicate the direction for the next teaching step.

In addition, teachers can also observe the design of other courses on the platform, select the most suitable plan for class students for optimization, and promote the occurrence of high-quality teaching through shared wisdom.

2.3. Branch Problem 3 Teaching Design Process

To achieve objective and comprehensive evaluation of students and promote learning through evaluation, the support of the concept of integrating learning and evaluation is needed. The integration of learning and evaluation is a new evaluation concept based on the digital world of education, which integrates the learning and diagnostic aspects of comprehensive evaluation and emphasizes the promotion of students' active development in various ways[5]. Teachers are required to make good use of various data generated by technology in the learning process of students, provide positive and constructive evaluations in a timely manner, guide students to evaluate other classmates through evaluation criteria, encourage parents to participate in the interactive exhibition and evaluation of students' creative homework, and maintain students' curiosity and thirst for knowledge.

Reverse teaching design first requires teachers to determine goals and evidence of achievement, and design teaching activities based on the goals and evidence, in order to judge the distance between students' existing experience and goals[6], fully play the diagnostic role of evaluation, and improve teaching in a timely manner. By pre-evaluating, the directional design of teaching activities for rural teachers is enhanced, facilitating the smooth achievement of goals.

The design of unit teaching activities needs to focus on six elements: the theme and class hours of the large unit, learning objectives, evaluation tasks, learning process, homework and testing, and post learning reflection, under the core element of nurturing people goal system[7]. Through the design of the overall teaching of the unit, it cultivates the high-level thinking and organizational ability of rural teachers, making teaching more systematic.

3. Training Process for Rural Teachers Focused on Cultivating Core Literacy

After determining the training content, it is also necessary to determine the specific process of the training to provide a space for communication and development for rural teachers. The training process for rural teachers aimed at cultivating core literacy mainly consists of self-directed lesson preparation, online lesson presentation, collaborative lesson grinding, and teaching reflection supported by technology, as shown in Figure 2. Rural teachers conduct lectures based on teaching cloud platforms, collect teaching data, and engage in communication and interaction with training teams through online training platforms; The expert team proposed targeted improvement plans based on the teaching effectiveness of rural teachers' lectures and the analysis of teaching data recorded in the classroom.

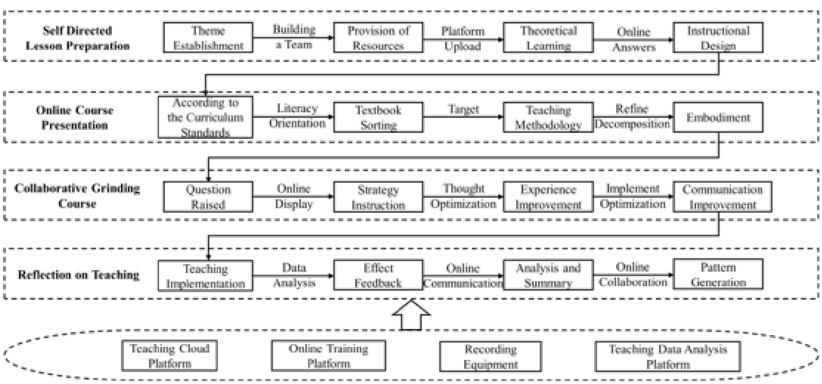

Figure 2. Training process for rural teachers focused on cultivating core literacy

3.1. Self-Directed Lesson Preparation

Firstly, the information technology teaching expert team establishes the training theme, and rural teachers select suitable teaching themes based on their own teaching situation, build a teaching cooperation circle, and facilitate communication, interaction, and resource sharing among teachers. After the information technology teaching experts upload the necessary resources for this training topic, rural teachers can carry out theoretical learning based on the resources. Any problems that arise during the learning process can be answered online by the information technology teaching expert team, which facilitates the smooth progress of theoretical learning and collaborates to generate the initial version of the teaching design.

3.2. Online Course Presentation

After the completion of the teaching design, rural teachers will give lectures online to clarify their own design ideas. Lesson presentation requires rural teachers to start from the curriculum standards, sort out the content of textbooks based on the core competencies required for each age group, determine teaching objectives based on the actual learning situation of students in the class, set up independent exploration and cooperative discussion activities at different levels, and refine and decompose them into specific implementation plans. Corresponding learning resources will be published to students through online interactive platforms.

3.3. Collaborative Grinding Course

Rural teachers actively present their team's problems and confusions in the form of lists or tables during the design process, in order for information technology teaching experts and frontline teaching masters to provide strategies and experience assistance. Information technology teaching experts mainly evaluate and guide the rationality of activity settings and core literacy orientation of rural teachers, focusing on the theoretical level. Frontline teaching masters focus on evaluating and guiding the teaching process design and time control of rural teachers, imparting experience to rural teachers at the practical level, enabling them to continuously optimize teaching through communication.

3.4. Reflection on Teaching

After online discussions, rural teachers can make self-adjustments based on the discussion content to make their teaching more suitable for the students in the class. Then, they can officially start teaching and pay attention to the implementation of new concepts and strategies learned, as well as the collection of teaching data during the teaching process. After class, summarize and reflect on the visual charts generated, clarify the differences between the teaching of this lesson and previous teaching, summarize the benefits and impacts of improving teaching design on students, and reflect on the problems that exist in the teaching process, providing feedback on teaching effectiveness. Through online communication, analyze and summarize the advantages and disadvantages of this implementation, and jointly generate the final teaching model for rural teachers to carry out regular teaching improvement implementation. The differences before and after improving teaching are shown in Table 1.

Table 1. Table of Differences Before and After Improving Teaching

Difference points	Old version teaching	New version of teaching
Teaching objectives	Three-dimensional target	Core literacy
Teaching method	Emphasis on teacher instruction	Carry out more independent exploration and exchange seminar activities, focusing on student subjectivity
Teaching evaluation	Teacher evaluation	Teacher student joint evaluation
Teaching tools	Multimedia courseware	Multimedia courseware, online interactive website

4. Conclusion

As of now, the author's team has conducted a 3-year special training program in two districts and counties in western Inner Mongolia Autonomous Region, with over 300 rural teachers participating in the training. More than 80% of the teachers participated in the entire training process and wrote a complete case study of smart teaching design guided by core literacy; More than half of the teachers are proficient in interpreting and applying student data generated by the platform, cultivating students' core subject literacy in teaching activities, constantly observing and reflecting on their own teaching, and continuously improving their teaching design abilities; More than 40 teachers are able to write high-quality teaching cases, generate their own unique teaching models, and share teaching experience in various activities in the county and district, providing a demonstration role for other rural teachers.

In the future development process of training, the team will continue to focus on research to truly understand the needs of rural teachers, while also paying attention to data ethics, protecting the privacy of teachers and students in pilot schools, continuously cooperating with rural schools, exploring unique teaching models that are truly applicable to rural areas, and empowering the development of rural education.

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A Path Study on the Effectiveness of Online Training for Primary and Secondary School Rural Teachers Assisted by Universities, Key Project of the 2022 Higher Education Science Research Plan of the Chinese Higher Education Association (22JS0308).

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Digitalization and Management Innovation III
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Analysis of AI Ethics Courses in Chinese and Japanese Universities

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Abstract. With the rapid development of artificial intelligence, ethical issues surrounding it have also gained increasing attention. However, AI ethics education has lagged. Based on the current state of course offerings, this paper provides guidance for the development of future ethics courses. The paper analyzes the AI ethics courses offered by universities in China and Japan ranked within the top 500 in the QS 2024 rankings, covering multiple aspects of the courses. A comparative analysis is made of the differences between the two countries' universities, including course content and assessment characteristics. Based on these analyses, the paper offers several suggestions for the future development of AI ethics courses.

Keywords. Artificial intelligence, Ethics, Course analysis

1. Introduction

With the rapid development of AI, related ethical issues have also attracted the attention of many institutions. In 2021, UNESCO's "Ethical Guidelines for AI" emphasizes that education is key to promoting AI ethics awareness. It advocates for cultivating sensitivity to ethical issues like fairness, privacy, and transparency through the education system to foster sustainable AI development globally [1]. In 2021, the White House issued the "Blueprint for an AI Bill of Rights." It sets out specific principles and guidelines to address the potential social, legal, and ethical challenges posed by AI [2]. In 2023, the United States updated the "National Artificial Intelligence Research and Development Strategic Plan" [3]. The plan highlights the importance of education and skill training in the field of AI ethics, especially Strategy 3, which emphasized the critical nature of understanding the ethical, legal, and social impacts of AI. It encompasses developing strategies to promote the responsible use of AI [4].

The importance of AI ethics in higher education teaching is also emphasized. In June 2024, the article "AI and Ethics: Investigating the First Policy Responses of Higher Education Institutions to the Challenge of Generative AI" was published on the official website of *Nature*. It identifies key ethical dimensions related to the use of

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generative AI in academia by analyzing five key international documents released by the United Nations, the European Union, and the OECD. The paper [5] also points out that education must be prioritized in our technological advances. AI technologies require considerable expertise to be produced and operated, including AI ethics education. In early 2024, ACM/IEEE-CS/AAAI released CS2023. It emphasized the education of Society, Ethics, and the Profession (SEP) to expand awareness of the field's requirements beyond technical talent [6]. In addition, as early as 2017, scholars published research papers on the teaching of AI ethics courses [7].

In this paper, we have collected information on the offering of AI ethics courses in Chinese and Japanese universities. Based on a comparative analysis and referring to the requirements of institutions, we have outlined the direction for the future development of such courses. By analyzing the ethics course development at prestigious universities, we also hope to provide a basis for the development of AI ethics in general universities.

2. Data collection methods

2.1 Data collection methods

We obtained the information through the following three methods: (1) We searched for information related to AI ethics courses by using university names on search engines such as Google and Baidu. (2) We explored the official websites of the universities to find details about AI ethics-related courses. (3) We checked online platforms like edX, iCourse, and XuetangX to identify universities offering AI ethics courses. We have also searched for papers on AI ethics course teaching in online databases. The content within the papers contains relatively little useful information for us.

We focused exclusively on the prestigious universities according to the QS Rankings. Due to limitations in our search methods, some universities may have been overlooked, primarily because of the lack of publicly available course information.

2.2 University names

We have gathered data from the 2024 QS World University Rankings [8], which includes a total of 1,497 universities. Among the top 500 universities in the QS ranking, China has 43 and Japan has 15. Among the top 500 universities according to QS, China and Japan have the largest number in Asia. Therefore, we selected universities from Japan and China as the subjects of our study.

In China, 17 universities offer AI ethics courses, including: Peking University[9],[10], Tsinghua University[11], Zhejiang University[12], Fudan University[13],[14], Shanghai Jiao Tong University[15],[16], University of Science and Technology of China[17], Nanjing University[18],[19], Wuhan University[20], Huazhong University of Science and Technology[21], Sun Yat-sen University[22], Beijing Institute of Technology[23], Beihang University (formerly BUAA)[24], The University of Hong Kong[25], The Hong Kong University of Science and Technology[26], The Hong Kong Polytechnic University[27],[28], National Taiwan University[29], and National Cheng Kung University[30].

In Japan, 8 universities offer AI ethics courses, including: University of Tokyo[31], Kyoto University[32], Osaka University[33], Tokyo Institute of

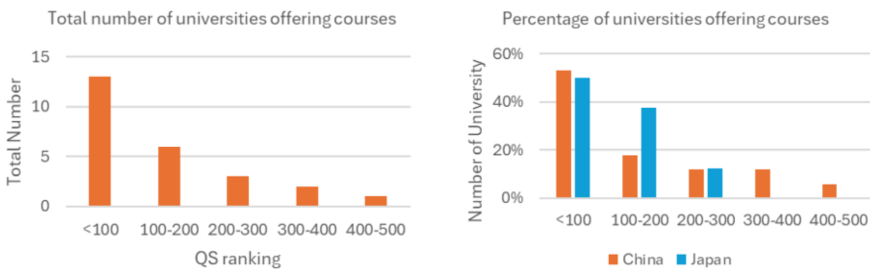
Technology[34], Tohoku University[35], Nagoya University[36], Hokkaido University[37], Keio University[38].

3. The data of AI Ethics Course in Chinese and Japanese Universities

We gathered information on courses related to AI ethics, including details such as course names, course types (whether elective or compulsory), credits, course codes, assessment methods, course schedules, instructors, and the colleges offering the courses. Some information from certain universities is missing, and we will indicate any missing details during our analysis if necessary.

3.1 University number of QS top 500

According to the QS World University Rankings, 25 universities from China and Japan ranked in the top 500 offer courses related to AI ethics (some even offer two such courses). Among them, 17 Chinese universities and 8 Japanese universities provide these courses. Based on the QS rankings, we have divided these 500 universities into five different ranking ranges. Figure 1(a) presents the overall data on AI ethics courses offered by universities in China and Japan, while Figure 1(b) compares the differences between the two countries.



(a) (b)

Figure 1 QS Top 500 universities offering AI ethics courses

Figure 1(b) provides the detailed proportions of universities offering AI ethics courses in China and Japan separately. From the chart, it can be observed that among universities ranked within the top 100, the proportion of institutions offering such courses in China and Japan is relatively similar. However, among universities ranked between 100 and 200, a higher proportion of Japanese universities offer these courses compared to Chinese universities.

3.2 Course nature

The nature of the course refers to whether the course is offered as an elective or a compulsory one. Compulsory courses are typically considered key components of the curriculum, and it reflects the university's emphasis on the subject. Since the course nature is not clearly specified for Japanese universities, this analysis focuses only on the course nature of Chinese universities offering AI ethics courses. This analysis covers 21 courses from 16 universities, of which 13 are compulsory and 6 are elective. Among them, 5 universities offer two AI ethics courses.

The specific findings are shown in Figure 2. Among the Chinese universities offering such courses, about 13% have not disclosed the course nature. 56% of the universities have disclosed the nature of their courses, with 25% of them offering two compulsory courses. This indicates that most top Chinese universities attach great importance to AI ethics courses.

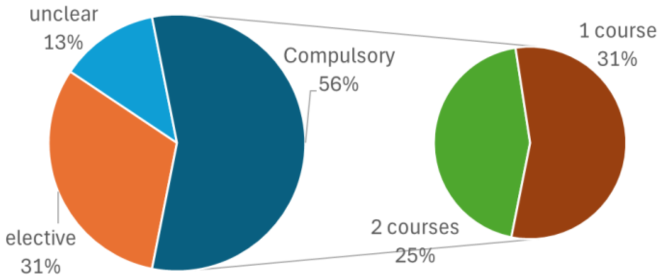


Figure 2 Distribution of course natures of Chinese Universities

3.3 Credits statistics

Credit is a unit of measurement used to quantify a student's completion of coursework and achievement. Different credit values represent the amount of content that the course requires students to master. We did not use credit hours, as most courses did not provide credit hour data.

Among the 30 AI ethics courses from 25 universities we surveyed, 25 courses offer credits, ranging from 1 to 9 credits. The proportion of courses with different credit values is shown on the left side of Figure 4. Additionally, we calculated the proportion of courses with varying credit values relative to the total number of courses, with a comparison between Chinese and Japanese universities presented on the right side of Figure 3.

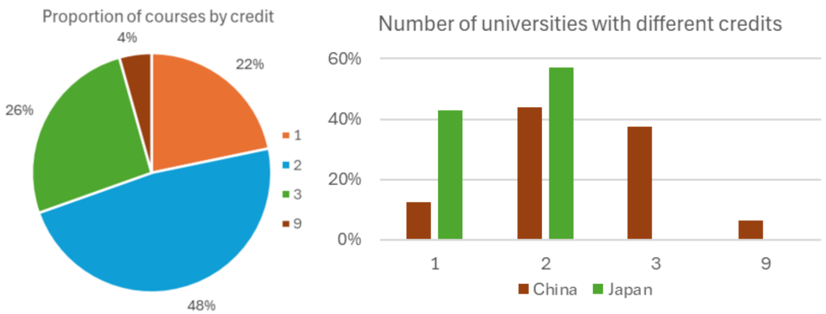


Figure 3 Distribution of credits

3.4 College of the courses

Among the 30 surveyed courses, the offering colleges include computer science-related departments, humanities departments, and interdisciplinary research centers. ***Figure 4*** shows the proportion of courses offered by different faculties at Chinese and Japanese universities. The data indicate that more than half of the courses in China are offered by computer science faculties, while over 30% of the courses in Japan are provided by interdisciplinary research centers. This contrast highlights the differing approaches to AI ethics course development in the two countries.

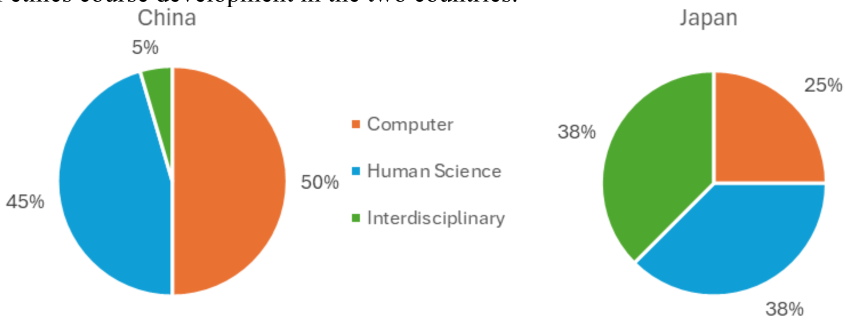


Figure 4 Distribution of colleges offering the course

The research indicates that the curriculum in the Computer Science College tends to focus on artificial intelligence technology, while the Philosophy College emphasizes ethical theory and dialectics. The curriculum content of the Interdisciplinary Research Institute aligns with the established requirements and expectations.

4. General data analysis

4.1 Comparison analysis

We compared the differences between Chinese and Japanese universities in offering AI ethics courses from five aspects, including:

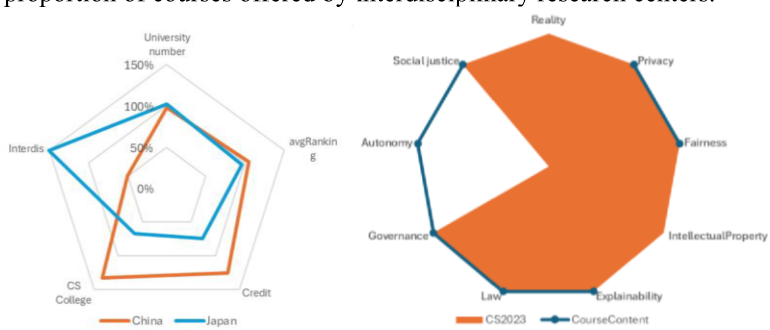
(1) Average QS Ranking of Offering Universities: This refers to universities within the top 500 QS rankings.

(2) Number of Offering Universities: Due to the large difference in the number of universities between the two countries, a direct comparison is not possible. Therefore, we calculated the proportion of offering universities within the QS top 500 in each country.

(3) Credits: We calculated the average number of credits for courses in both countries.

(4) Number of Courses Offered by Computer Science Faculties: We calculated the proportion of courses offered by computer science faculties.

(5) Number of Courses Offered by Interdisciplinary Research Centers: We calculated the proportion of courses offered by interdisciplinary research centers.



(a) (b)

Figure 5 Radar chart for feature comparison and content

Due to the significant differences in the values of the various indicators, we used the average to make a comparative analysis. The comparison results are of two countries shown in Figure 5(a).

We have conducted a comparative analysis of the ethical teaching key terms in CS2023 and current AI ethics courses, which is shown in Figure 5(b). There is partial overlap in the key terms. Future AI ethics courses should consider all the key terms in the diagram. The union of these keywords can be used as the content of AI ethics course.

4.2 Trend analysis for AI Ethics course

From the data visualization analysis, we can see that nearly half of the top 500 universities in China and Japan have offered AI ethics courses. The average ranking of universities that offer AI ethics courses is around 120th. There is a trend that the higher the ranking of the university, the greater the proportion of universities offering such courses.

According to a report from Tokyo Tech, the "Science, Engineering, AI & Data Ethics" course was initially launched in 2017 and started on the edX platform in 2020. It was taught by former Institute for Liberal Arts Professor Jun Fudano [34]. According to a notice from Beijing Institute of Technology, the university offered an AI ethics course as early as 2018[23]. With the rapid development of AI, AI ethics education has gained increasing attention. The Computer Science Curricula 2023 (CS2023)[6], released in early 2024, defines 17 knowledge areas in computer science, one of which is "Society, Ethics, and the Profession," emphasizing the importance of ethics education in the field of computer science. In August 2024, Nanjing University issued a notice making AI ethics courses a core curriculum for the entire university[18],[19]. In September of the same year, the "Taiwan Universities Artificial Intelligence Program Alliance" (TAICA) mandated that every credited program must include a compulsory 3-credit AI ethics course [39].

In addition to undergraduate education, the Hong Kong Polytechnic University launched the "Master of Science in Generative AI and the Humanities" program in 2024 [27], and the University of Hong Kong introduced the "Master of Arts in AI, Ethics and Society" program in 2023, both offering AI ethics courses. Among these, the University of Hong Kong's "Ethics: AI, Data and Algorithms" course offers up to 9 credits [25].

5. Analysis of course development

We have found the syllabi for some courses and analyzed the course content and assessment methods.

5.1 Interdisciplinary course content needs further study

Interdisciplinary approaches are crucial for addressing ethical issues in AI[40]. This paper [41] demonstrates how interdisciplinary methods can be effectively employed to teach AI ethics. Our research found that AI ethics courses provided by the School of Computer Science usually focus on AI technology, while those offered by the Department of Philosophy delve deeper into philosophical theories.

In most Chinese universities, AI ethics courses are offered by computer science department or the philosophy department, with only a few courses available as general education courses. Among the 8 universities in Japan that offer AI ethics courses, 3 of them have their courses established by interdisciplinary research institutes. For example, the "AI and Social Justice" course at the University of Tokyo is offered by the School of Interdisciplinary Information Studies, and the "AI and Policy" course at Keio University is provided by the Institute for Policy and Information. To summarize the data, Japanese universities offer 38% of their courses as interdisciplinary, while in China, only 5% of courses are interdisciplinary—both figures are relatively low.

From the data we have collected, we can conclude that AI ethics courses encompass a range of disciplines including philosophy, law, psychology, computer science and so on. This interdisciplinary collaboration is crucial for cultivating responsible AI professionals. Establishing interdisciplinary AI ethics research centers for course development will be an essential trend.

5.2 Diversified assessments should be designed

We've gathered assessment methods for a third of AI ethics courses, revealing a variety of methods like reports, papers, presentations, products, and quizzes, with 90% using reports or papers, and some universities adding unique requirements.

Papers and course reports foster open exploration and critical thinking in students, but their subjectivity and quantification challenges are drawbacks. For AI ethics to be a core course, it needs content integration in teaching and assessment. Diversified assessments, like group projects, and linking to professional fields are essential for deeper engagement and continuous course improvement.

6. Conclusion

In this paper, we first present several organizations and institutions related to AI ethics education, such as UNESCO, the European Union, and so on, highlighting the urgency of AI ethics education. We then analyze the situation of AI ethics courses offered by the top 500 Chinese and Japanese universities in the QS 2024 rankings. The data shows that 17 universities in China and 8 universities in Japan offer AI ethics courses.

Through comparative analysis, we found that AI ethics courses are receiving increasing attention from prestigious universities, with course credits gradually increasing. Some universities have even established programs related to AI ethics. Overall, Japanese universities tend to have lower course credits than Chinese universities. In Japan, about one-third of the courses are taught by professors with an interdisciplinary background, which is an advantage over Chinese universities. However, there are still deficiencies in course content development and assessment methods, which do not fully meet the current demand for AI ethics courses.

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Impact of Parent-Adolescent Relationship, Parental Education, and Family Income on High School Students' Anxiety and Depression

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Abstract. Adolescence is a crucial time for the emergence of depressive and anxiety symptoms, and the quality of the parent-adolescent relationship is consistently linked to these mental health outcomes. It is important to recognize the differing perceptions of parents and adolescents regarding their relationship quality. This study explores how the quality of parent-adolescent relationships, parental education, and family income impact anxiety and depression levels among high school students. A sum of 690 students from the eastern and central regions of China participated by completing both paper and electronic questionnaires. The analysis shows a significant negative correlation between the quality of parent-child relationships and students' anxiety and depression levels. Additionally, higher parental education is positively related to better mental health outcomes for children. While family income influences environmental conditions and resource availability, it is not a primary factor affecting student anxiety and depression. These findings emphasize the importance of family-related factors in shaping the mental health of high school students and provide valuable insights for future interventions.

Keywords. Parent-adolesent Relationship, parents' education level, family income, anxiety, depression

1. Introduction

Adolescent mental health has become a significant area of study, with a substantial amount of data being reported [1]. Adolescent depression and anxiety are serious global issues [2], especially prevalent in China, where around 26.4% of adolescents face mental

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disorders, including anxiety and depression. These conditions pose significant risks to youth aged 5-19[3] , attracting attention from education, sociology, and psychology.

While numerous studies have been conducted on adolescent depression and anxiety, they are often limited by relatively small sample sizes. Socioeconomic status is typically defined by components such as family income, parental education, and occupational status. These factors are well-established risk indicators for depression, with lower SES linked to higher vulnerability [4].

The parent-adolescent relationship is key to adolescent development and well-being, shaped by emotional closeness, communication, and conflict [5]. Positive, supportive relationships lead to better outcomes, while negative ones harm health and behavior. Studies show that strong parent-adolescent bonds reduce internet addiction and promote healthier lifestyles [6]. However, understanding how depressive symptoms impact family dynamics in Chinese societies is limited [7]. Family systems theory suggests that family members are interconnected, with marital and parent-child relationships influencing adolescent mental health [8]. Research in Western families shows these relationships are mutually dependent [9].

This research seeks to address these gaps by investigating the efforts socioeconomic status and parent-adolescent relationships on adolescent depression and anxiety in China. By clearly defining and measuring these concepts, we aspire to provide an additional nuanced comprehension of the factors that influence adolescent mental health in the specific context.

2. Literature review

2.1 Parent-adolescent relationships and adolescent mental health

The parent-adolescent bond is vital for healthy development. Positive parenting behaviors, such as emotional availability, strengthen this relationship and enhance career decision-making self-efficacy, often more than peer influence. Involvement in school and leisure activities reduces alcohol use, improves academic performance, and boosts emotional well-being[10].Poor relationships characterized by hostility can lead to emotional problems, increased alcohol use, and suicidal thoughts [11].

Various factors, including cultural context, affect the quality of these relationships. For instance, parental body image influences adolescents' body esteem[12]. Adolescents' rapid changes require adjustments from both parents and teens [13]. Cultural orientations toward independence and interdependence shape parental emotion socialization, impacting adolescents' socio-emotional functioning [14]. Alignment in perceptions of parental emotional support correlates with better developmental outcomes [15]. A strong parent-adolescent relationship can alleviate the adverse impact of less effective parental approaches, especially for daughters [16]. Understanding the factors influencing the parent-adolescent relationship is essential for effective interventions to support adolescent mental health.

2.2 Impact of parental education on child's mental well-being

Parental education significantly impacts children's mental health, with a lack of social support explaining much of the variation in outcomes[17].Studies show linear relationships between parental education and adverse mental health outcomes in young children[18]. Higher parental education is associated with improved psychological well-being in children, while parenting styles influenced by education also affect adolescent mental health[19].

The relationship between youth suicidal behaviors and parental education varies by geography and economics, highlighting the importance of taking cultural and family factors in prevention and intervention strategies[20].Grasping the connection between parental education and adolescent depression is crucial[21], emphasizing the importance of addressing educational disparities and providing targeted mental health support for children from low socioeconomic backgrounds.

2.3 Role of family income in shaping adolescent mental health outcomes

Numerous studies show strong links between income and health, impacting educational outcomes and mental health in children and adults[22]. Poor economic conditions predict mental health issues, with declining income associated with increased depressive symptoms [23].The interconnectedness of children's and parents' mental health with poverty underscores the importance of addressing structural issues for effective interventions[24]. SES indicators impact adolescence brain structure differently, with a favorable income-to-needs ratio providing defensive benefits against neighbor-hood disadvantages[25]. Despite extensive research on parent-adolescent relationships, parental education, and family income, gaps remain, particularly in non-Western contexts. More longitudinal research with greater, diverse samples are required to establish causality and understand long-term effects.

3. Methods

3.1 Sample and Sampling

The study utilized convenience and snowball sampling methods, involving 690 participants aged 13 to 19 from middle schools across various provinces. All participants were currently enrolled in school and attending classes normally, ensuring a diverse representation of socioeconomic statuses, parental education levels, and parent-child relationship dynamics.

3.2 Instruments

Three instruments were used to assess adolescent mental health and relational dynamics: the SCL-90 Anxiety and Depression Scale, the Parent-Adolescent Relationship Scale (PARS), and a Socioeconomic Questionnaire. These instruments were selected for their validated reliability and relevance to the study's objectives.

3.3 Data Collection

Data was collected using the Questionnaire Star platform over two months, from December 2023 to January 2024. The study received approval from the Institute of

Sociology, Academia Sinica, with participants providing informed consent and school principals. Surveys were conducted anonymously to ensure confidentiality.

3.4 Data Analysis

Preliminary data analysis verified assumptions before the main analysis. SPSS 24.0 was used for common method bias, descriptive statistics, correlation, and regression analysis. Once presumptions were met, Partial Least Squares (PLS) path modeling was performed with Smart PLS software to assess the conceptional framework. Additionally, AMOS 24.0 was utilized for path analysis and model fit tests, considering a p-value of less than 0.05 as significant.

4. Results

The reliability of the data was measured by Composite Reliability (CR), while validity was assessed through convergent validity, measured by Average Variance Extracted (AVE), and discriminant validity. Tables 1 and 2, along with Figure 1, present the values for individual item loadings or cross-loadings, Cronbach's alpha coefficients, composite reliability, and AVE.

The cross-loading values in this study ranged from 0.560 to 0.819, indicating sufficient internal consistency[26]. Both Cronbach's alpha and composite reliability values exceeded the recommended threshold of 0.70[27].

Table 1. f-square-Matrix analysis of factors influencing anxiety and depression

	Parent-adolescent relationship	Family income	Parents education level
Depression and anxiety	0.862	0.003	0.006

The effect sizes for family economic level and parental education level were both less than 0.2, indicating minimal impact. Conversely, the effect size for the parent-adolescent relationship was greater than 0.35, suggesting a substantial effect.

Table 2. Reliability and validity of constructs

	Cronbach's Alpha	Composite Reliability	AVE
Parent-adolescent relationship	0.902	0.904	0.561
Depression and anxiety	0.933	0.934	0.578

Convergent validity was evaluated through Average Variance Extracted (AVE), with all values exceeding 0.5, indicating satisfactory validity[28]. Discriminant validity was evaluated through cross-loadings and the Fornell and Larcker criterion, showing that the square root of each construct's AVE is greater than its correlations with other constructs[29].Additionally, no item had greater loading on any competing construct[30].

Figure 1 illustrates the Partial Least Squares (PLS) algorithm assessing the structural model among parental education, family economic level, parent-adolescent relationship, and adolescent anxiety and depression.

- **Path Coefficients**:

  Parental Education Level: 0.094 (minimal direct effect)
  Parent-Adolescent Relationship: 0.484 (substantial effect)
  Family Economic Level: 0.000 (no significant direct effect)

Latent variables (blue circles) are measured by multiple indicators (yellow rectangles), each with a loading value reflecting representation quality. The framework clarifies 35.9% of the variation in adolescent anxiety and depression, indicating moderate explanatory power.

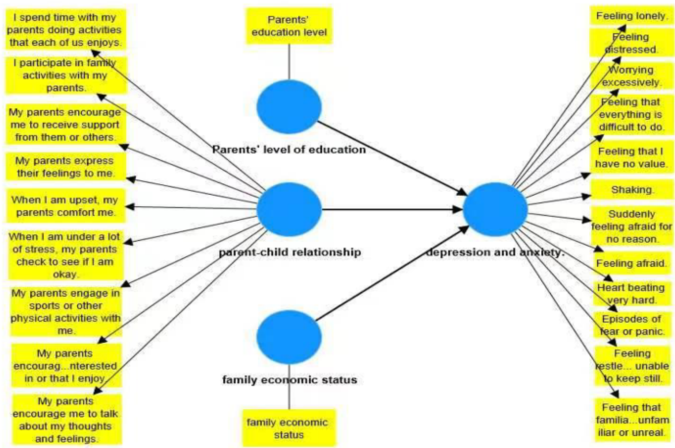

Figure 1 PLS Algorithm

Table 3. Significant positive relationship

Hypotheses	Relationship	Beta	Standard deviation	T Statistics	P Value
H1	Parent-adolescent relationgship > Depression & anxiety	0.590	0.035	17.067	0.000
H2	Parents education> Depression & anxiety	0.030	0.042	0.700	0.484
H3	Family income> Depression & anxiety	-0.058	0.035	1.676	0.094

Table 3 illustrate the relationships within the structural model were evaluated by PLS-SEM with 5000 bootstrapping iterations to determine the importance of the correlations[31].The findings reveal significant relationships between the independent variables and the dependent variable in the PLS-SEM analysis. Specifically, the result of the structural model indicates a significant positive relationship between the parent-adolescent relationship and adolescent depression and anxiety (β = 0.590, t = 17.067, p < .000), thereby strongly supporting the hypothesis.

Figure 2 illustrates the direct effects of parental education, family income, and parent-adolescent relationship quality on high school students' anxiety and depression levels. The arrows represent direct relationships, with path coefficients indicating strength. The attribute of the parent-adolescent relationship has a significant positive impact on mental health outcomes (path coefficient = 0.484), whereas family income shows no significant direct effect (path coefficient = 0.000)

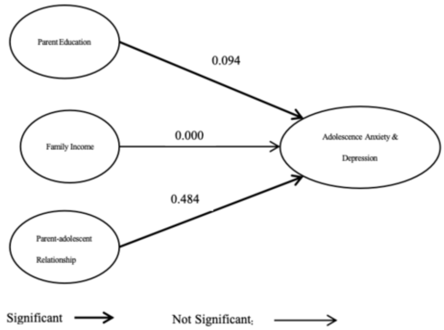

Figure 2. Path diagram of Varialbles Influencing Depression and Anxiety

5. Discussion

This study conducts a thorough statistical analysis of depression and anxiety among adolescent students in various regions of China, focusing on three key factors. It finds that economic status affects family functioning, with lower socioeconomic backgrounds linked to poorer mental health. There is a positive correlation between parental education levels and adolescent depression and anxiety, although some lower-educated parents excel in promoting their children's psychological development.

While parental education and family income have a minimal effect on adolescent anxiety and depression in Asia compared to Western countries, cultural differences shape parenting styles. Asian cultures emphasize collectivism and emotional control, often leading to stricter and more authoritative parenting, which may neglect emotional communication[32]. In contrast, Western parents typically encourage emotional expression and prioritize open dialogue[33].

To improve parent-child communication and emotional support, strategies can include regular family meetings, training in communication skills, and shared activities. Schools and communities can enhance these relationships by organizing parent-child activities and providing mental health education[34].

Consistent with prior research, this study finds that parent-adolescent relationships significantly impact adolescent depression and anxiety, more so than family income and parental education. The results emphasize the criticalness of nurturing parent-adolescent relationships in promoting adolescent mental health.

6. Conclusion

The main findings indicate that among these factors, the parent-adolescent relationship has the most significant impact on adolescent depression and anxiety. Although economic status and higher parental education do influence mental health, its impact is diminishing due to the overall positive economic development in Chinese society and excel in supporting their children's psychological development.

However, this study has several limitations. It lacks quantitative analysis and an experimental design, which could have identified additional potential factors and the nuanced connections between them. The exclusive reliance on self-reports from adolescents is another limitation, as incorporating various respondents might have yielded more trustworthy and accurate measures of extrinsic concepts.

The research is founded on cross-sectional data, which restricts the capacity to make causal inferences regarding the relationships among variables. Future research could benefit from using a longitudinal structure to track changes in parent-adolescent relationships and mental health outcomes over time. This method would offer a more dynamic insight into how these relationships evolve and affect mental health in the long term.

Future research should address these limitations by incorporating quantitative analysis and experimental designs to explore the nuanced connections between various factors affecting adolescent mental health.

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Digitalization and Management Innovation III
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Research on the Reconstruction of Core Competencies for Vocational College Teachers in the Era of Generative Artificial Intelligence

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Abstract. Recognizing the transformative impact of AI on education, the study underscores the necessity for teachers to adapt and evolve their skill sets to effectively navigate this new landscape. The redefined core competencies encompass three primary dimensions: humanistic literacy, intelligent literacy, and lifelong learning literacy. Humanistic literacy emphasizes the importance of emotional guidance and empathy in teaching, enabling educators to foster holistic student development amidst technological advancements. Intelligent literacy entails proficiency in leveraging ChatGPT, for enhancing teaching methodologies and personalizing learning experiences. Lifelong learning literacy underscores the need for teachers to engage in continuous skill updates and professional growth, staying abreast of the rapidly evolving AI technologies and their applications in education. The paper further suggests concrete strategies aimed at enhancing these core competencies among vocational college teachers.

Keywords. Generative AI, vocational education, teacher competencies, lifelong learning

1. Research Background and Current Status of Domestic and Foreign Studies

1.1 Research Background

1.1.1 Application of Generative AI in Vocational Education

In November 2022, OpenAI launched ChatGPT, a cutting-edge product in the realm of generative artificial intelligence (AI). This innovation has redefined the informatization revolution and marked the beginning of a new era in AI [1]. ChatGPT, renowned for its conversational interactivity, can "understand" user inquiries and provide appropriate responses, offering a more natural and fluid conversational experience compared to other language models. The rapid advancement and widespread application of generative AI technologies in recent years have been gradually transforming teaching models and concepts within the education sector [2].

Generative AI can autonomously create suitable teaching content and learning resources for students by leveraging vast amounts of data and information. This technology offers significant convenience and benefits in vocational education, including the generation of course content,

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personalized learning plans, virtual experiments and simulations, intelligent evaluation and feedback, auxiliary teaching tools, interactive learning and discussions, and online resource recommendations [3]. The concept of "AI in education" has gained traction among scholars both domestically and internationally, promoting the development of flexible, inclusive, and personalized educational environments and driving educational reform and innovation [4].

1.1.2 Connotation of Core Competencies for Vocational Teachers

Competence, or cultivation, refers to the refinement a person gains through training and practice. "Competence" encompasses three dimensions: knowledge, ability, and attitude. As times change, the definition of teacher competence is continually being updated and expanded [5]. Core competencies for teachers refer to the key qualities that educators acquire through professional training and practice to meet job requirements.

Prior to the AI era, the core competencies of vocational teachers included professional teaching, digital literacy, practical guidance, educational research, staying current with industry knowledge, student management, and professional ethics [6]. These competencies form the foundation of vocational teachers' competitiveness and are essential for enhancing the quality of vocational education and developing students' professional skills. AI has transformed human social life and production methods, reshaping social ecosystems. It is inevitable that AI will also reshape the integration of educational and social ecosystems to deliver high-quality talent [7]. Consequently, reconstructing vocational teachers' core competencies in the generative AI era is crucial, requiring new definitions and standards.

1.1.3 Challenges Faced by Vocational Teachers in the Era of Generative AI

As the use of AI technology in education becomes more widely recognized and adopted, vocational teachers are facing new challenges in the generative AI era, necessitating a redefinition of their core competencies. The primary challenges in developing technical talents in this era stem from several key transformations [8]:

- Transformation in Educational "Cultivation": In the era of generative AI, while AI technology can assist in teaching, AI systems often lack the capacity for humanistic care and emotional understanding. This can lead to a mechanized approach to education, potentially stifling students' emotional development. Some students may become overly dependent on AI, overlooking the importance of human autonomy and creativity. To address these challenges, vocational teachers need to cultivate strong humanistic qualities, focusing on emotional and value-based guidance, emphasizing the importance of human agency and creativity, and fostering positive teacher-student relationships to support the holistic development of students [7].
- Technological Transformation in AI: With the rapid advancement of AI technology, the education sector is undergoing significant changes. Vocational teachers, who play a crucial role in developing high-quality technical skills, must enhance their digital literacy. AI introduces new educational methods, and vocational teachers should be adept at using various intelligent educational technologies, such as intelligent teaching platforms and support tools, to provide personalized instruction, intelligent tutoring, and online assessments. These tools can greatly improve students' learning experiences and outcomes [6].
- Transformation in Learning and Teaching Methods: As technology and industry evolve rapidly in the generative AI era, teaching methods and learning approaches must also adapt. Vocational teachers need to embrace lifelong learning to stay current with these changes and effectively impart knowledge and skills to their students.

1.1.4 Reconstruction of Core Competencies for Vocational Teachers Guided by the Spirit of Educators

On September 9, 2023, President Xi Jinping introduced and elaborated on the concept of the "spirit of educators" in a letter to a symposium of outstanding national teacher representatives.

This spirit is characterized by a deep commitment to serving the country, upholding high moral standards, demonstrating educational wisdom through insightful and individualized teaching, maintaining a diligent and innovative attitude, showing benevolence and dedication in teaching, and pursuing cultural enrichment with a broad perspective [9].

Guangdong, a major educational hub, has over 1.66 million teachers across various levels, which both ensures the province's educational strength and presents a challenge for the high-quality development of the teaching workforce. Teachers are central to educational efforts, serving as the primary resource for building a strong educational system, a critical factor in creating a technologically advanced nation, and a key support for fostering a talent-rich country. The spirit of educators, with its emphasis on lofty ideals, noble morals, diligent attitudes, and benevolence, provides a clear framework for developing the core qualities of vocational teachers [10].

Guided by the spirit of educators, the cultivation of core competencies in teachers during the AI era is a complex and ongoing process. Vocational teachers are expected to embody core competencies such as strong ideals and moral qualities that align with national development goals, the practical application of teaching wisdom, the guidance of values, skill training, lifelong learning, and innovation. They should also demonstrate dedication and compassion in their professional development and competency building, while pursuing educational goals with a vocational education ethos [11].

To support vocational teachers in enhancing their core competencies, we can provide educational training, establish incentive mechanisms, and emphasize practical applications. This approach will better equip them to meet the evolving demands of the AI era [12].

1.2 Summary of Current Research Status Domestically and Internationally

- Research on Teacher Competence Transformation in the AI Era: As AI becomes integrated into education, teachers must update their competencies to leverage technology effectively for quality education [13]. This includes enhancing skills in moral and ethical development, maintaining professional ethics in a digital context, and integrating AI into teaching practices and curricula.
- Research on Opportunities for Teachers in the AI Era: ChatGPT accelerates educational transformation, offering both positive and negative impacts. It facilitates human-machine integration, enables personalized learning, enhances teaching quality, improves evaluation systems, generates educational materials, and automates routine tasks. Additionally, "ChatGPT+" can support teachers' professional development by aiding in lesson preparation and assignment design, promoting individualized growth.
- Research on Challenges for Teachers in the AI Era: The capabilities of ChatGPT present challenges, including the risk of cheating, fragmented knowledge acquisition, impacts on traditional learning methods, data security issues, and difficulties in verifying information accuracy. Researchers are investigating these challenges and proposing guidelines and strategies for teachers to effectively navigate the risks associated with AI in education.

2. Research Methodology

2.1 Research Methods

The study employed a quantitative approach by distributing 400 electronic questionnaires to vocational teachers across various schools in Guangdong, encompassing industries such as IT, e-commerce, and manufacturing. The aim was to assess the current status and potential paths for reconstructing vocational teachers' core competencies in the generative AI era. Using random and stratified sampling, 450 valid questionnaires were ultimately collected with the support of school administrations.

2.2 Research Focus

2.2.1 Reconstruction of Core Competencies for Vocational Teachers in the Era of Generative AI

This study identifies three core competencies crucial for vocational teachers in the AI era: humanistic literacy, intelligent literacy, and lifelong learning literacy. Humanistic literacy emphasizes emotional support, cultural awareness, and social responsibility, counterbalancing the "coldness" of technology. Intelligent literacy involves proficiency in AI tools, data analysis, and technical innovation, enhancing educational quality and efficiency. Lifelong learning literacy entails a commitment to continuous professional development and adaptability in an evolving educational landscape [14]. These competencies address the primary challenges faced by vocational teachers in the AI era and are essential for preparing students for future success.

2.2.2 Empirical Research Design and Analysis

The theoretical basis of this research is rooted in Hutchinson & Waters' (2002) needs analysis, which outlines four criteria for core competencies: relevance, completeness, usefulness, and satisfaction. This empirical research explores how to build an effective core competency system for vocational teachers that meets these criteria and aligns with employer needs.

3. Research Subjects and Sampling Methods

This study surveyed vocational teachers from diverse industries in Guangdong, using a combination of physical and online surveys to collect 450 valid questionnaires. Additionally, interviews with employers provided insights into their competency requirements for teachers.

3.1 Survey Content

The survey categorized vocational teachers' core competencies into three modules: Humanities Literacy, Intelligent Literacy, and Lifelong Learning Literacy. Each module was tailored for the survey and measured using a Likert 5-point scale, ranging from "very unimportant" to "very important".

3.2 Data Collection and Processing

SPSS software was used for statistical analysis of the data, focusing on the importance ratings of various core competencies as evaluated by both employers and teachers.

4. Survey Results and Analysis

The statistical analysis of the 450 valid questionnaires yielded mean scores and standard deviations for each core competency module, as presented in Table 1. These results provide insights into the current status of vocational teachers' core competencies and highlight areas for improvement in the generative AI era.

Table 1 shows that the Intelligent Literacy Module has the highest mean score of 4.45, highlighting the importance of AI application skills for both employers and teachers. This reflects the need for strong technical literacy as generative AI reshapes vocational education. The Humanities Literacy Module follows with a mean score of 4.30, emphasizing the need for teachers to balance technical skills with humanistic care and emotional guidance. Lastly, the Lifelong Learning Literacy Module scores 4.22, underscoring the ongoing importance of self-learning and growth in a rapidly evolving landscape.

Table 1 Mean and Standard Deviation of Core Competency Modules for Vocational Teachers

Core Competency Module	Mean	Standard Deviation
Humanities Literacy	4.30	0.95
Intelligent Literacy	4.45	0.87
Lifelong Learning Literacy	4.22	0.90

Based on the results of this survey, the following conclusions can be drawn:

a. Humanities Literacy Should Not Be Overlooked: Even in an intelligent teaching environment, teachers' humanities literacy remains a key factor in ensuring teaching quality, especially in the areas of emotional guidance and cultural education.
b. Lifelong Learning Capabilities Need to Be Enhanced: In a rapidly changing technological landscape, teachers must maintain a strong motivation for learning and continuously update their knowledge to meet the evolving demands of education [15].
c. Emphasis on Intelligent Literacy: The rapid development of generative AI raises the requirements for teachers' technical capabilities. Vocational schools should strengthen training on the application of intelligent technologies to help teachers master new technologies.

5. Strategies for Reconstructing Vocational Teachers' Core Competencies Guided by the Spirit of Educators

Guided by the Spirit of Educators, strategies for reconstructing vocational teachers' core competencies encompass several key aspects. Vocational teachers should first clarify their professional ideals, recognizing their pivotal role in national education and committing to nurturing skilled professionals who drive innovation aligned with societal goals. Enhancing ethics and humanistic qualities is equally important, as teachers must exemplify high moral standards and provide compassionate guidance to foster holistic student development, bridging the gap between technology and human connection. To keep pace with advancements, teachers should promote technological proficiency by mastering emerging technologies and intelligent educational tools, implementing personalized teaching methods that enhance learning quality. Fostering a lifelong learning philosophy is crucial, ensuring teachers proactively seek new knowledge and skills to remain relevant in their evolving roles. Institutions should support these efforts by implementing effective training programs in AI and humanistic education, creating a collaborative and innovative environment. Lastly, incorporating design thinking into the curriculum empowers teachers to help students develop innovative thinking and adaptability, preparing them for real-world challenges.

6. Conclusion

The study highlights the profound impact of AI on education and emphasizes the importance of teachers adapting their skill sets to navigate this transformative landscape. The redefined core competencies of humanistic literacy, intelligent literacy, and lifelong learning literacy are crucial for teachers to effectively integrate AI into their teaching practices.

The survey results underscore the significance of each core competency, with intelligent literacy emerging as the most critical due to the increasing importance of AI application skills in vocational education. However, the results also emphasize that humanities literacy and lifelong learning capabilities remain essential components of high-quality teaching. Teachers must balance technical skills with humanistic care and emotional guidance to foster holistic student development.

To reconstruct vocational teachers' core competencies, the study proposes several strategies, including clarifying professional ideals, enhancing ethics and humanistic qualities, promoting technological proficiency, fostering lifelong learning, implementing effective training, and incorporating design thinking. These strategies aim to equip teachers with the necessary skills and knowledge to excel in an AI-driven educational environment while maintaining a strong focus on humanistic values and ethical standards.

In conclusion, the study emphasizes that teachers must continuously adapt and evolve their skill sets to keep pace with the rapid advancements in AI technologies. By embracing these new core competencies and implementing the proposed strategies, teachers can effectively leverage AI to enhance teaching methodologies, personalize learning experiences, and ultimately drive innovation in vocational education.

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Digitalization and Management Innovation III
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Teaching Effectiveness of Online - Merge - Offline (OMO) Teaching Method for EFL Students in Chinese Higher Vocational Colleges

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Abstract: The Online-Merge-Offline (OMO) teaching method presents a promising approach to transcending temporal and spatial limitations. This study focuses on elucidating a specific OMO model wherein offline teachers instruct both online and offline students. Employing a case study design, the research examines the implementation of OMO practices for English as a Foreign Language (EFL) students in a Chinese Higher Vocational College (HVC). A comprehensive satisfaction survey was administered to both teachers and students who participated in the OMO teaching sessions. The findings reveal a prevailing sense of satisfaction among both teachers and students regarding the effectiveness of the OMO teaching method, highlighting its potential as a viable and efficacious instructional approach in the context of Chinese HVCs.

Keywords: Online - Merge - Offline teaching; EFL students; implementation pathway; teaching effectiveness; blended learning

1. Introduction

With the advancement of information technology, the blended learning mode has been gradually adopted by higher education institutes. Due to the COVID-19 pandemic, many higher institutions are taking opportunities provided by the technology to offer Small Private Online Courses (SPOCs) [1]. The Online-Merge-Offline (OMO) teaching method, representing the seamless integration of online and offline educational modalities, has emerged as a prominent approach in the field of education. This innovative method not only accommodates the needs of students and educators when on-campus learning is disrupted due to health concerns but also ensures uninterrupted in-person education for those who can return to physical classrooms. By facilitating

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synchronized learning for both remote and on-site students, blended learning promotes inclusivity and enhances teaching effectiveness [2]. It transcends the mere juxtaposition of online and offline education, emphasizing the convergence of educational objectives, curriculum content, pedagogical strategies, and assessment methods to maximize teaching and learning efficacy [3].

In contrast to the temporary and large-scale nature of exclusive online education, OMO exhibits traits of locality and long-term sustainability. This approach offers an innovative solution to address challenges related to quality degree programs and promotes equitable educational development, thereby becoming a prevalent and enduring teaching method. Previous researchers, such as Shi et al. (2021), have made significant contributions to our understanding of OMO [4]. However, as OMO matures and becomes normalized in the post-pandemic era, new challenges arise. Ensuring smooth implementation, maintaining educational effectiveness, and providing a high-quality learning experience for students are now paramount concerns.

This study takes as an example the OMO teaching practice conducted for EFL students in a HVC in Guangdong Province, China, in 2023. Drawing on relevant educational theories, including online teaching and blended learning, the study summarizes a typical OMO model in HVCs: a model where offline teachers instruct both online and offline students. The research explores the practical implementation of this model and conducts a quantitative analysis to examine overall satisfaction among teachers and EFL students regarding the impact of OMO on their teaching and learning experiences. The findings of this study contribute to a deeper understanding of the effectiveness and potential of OMO as a teaching method for EFL students in Chinese HVCs.

2. Literature review

The OMO teaching approach represents an innovative educational model that integrates traditional face-to-face instruction with online learning. One particular variant of this model focuses on offline teachers instructing both on-site and remote students simultaneously. In this setting, teachers deliver in-person lessons within a physical classroom, while the content displayed through classroom technology, such as electronic whiteboards and interactive displays, is synchronised in real-time to remote students via an online platform [5]. This approach ensures a synchronous learning experience for all students, aiming to prevent any from falling behind.

The distinctive characteristic of this OMO model is its accommodation of both on-site and remote students. Teachers must, therefore, adhere to the standards of traditional face-to-face teaching while also addressing the needs of online learners. To facilitate this dual approach, the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, originally proposed by Rossett (1987) [6], is employed. The ADDIE model comprises five critical stages: analysis, design, development, implementation, and evaluation (Wang & Xie, 2006). This structured framework guides the development and implementation of specific strategies tailored to each teaching mode, as depicted in Figure 1.

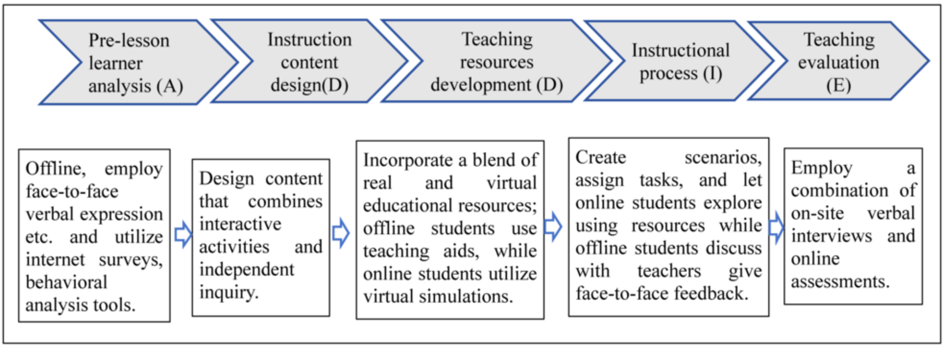

Figure 1 Implementation pathway of OMO model: teaching method of offline teachers with online and offline students

Previous research has highlighted the potential benefits of OMO models in various educational contexts. For instance, studies have shown that such models can enhance student engagement, promote collaborative learning, and improve overall learning outcomes. In the realm of English as a Foreign Language (EFL) education, OMO models have been found to be particularly effective in providing flexible and accessible learning opportunities for students in diverse settings.

However, despite its promise, the OMO model also presents challenges for teachers and institutions. Teachers must adapt to new technologies and teaching methods, while institutions must invest in the necessary infrastructure and provide adequate support. Furthermore, ensuring the quality and consistency of teaching across both on-site and remote settings remains a critical concern.

HVCs are an integral part of China's higher education system, where students typically study for three years before entering the workforce. On the whole, these students tend to exhibit weaker foundations in overall English proficiency and lower learning motivation compared to undergraduate students [2]. Meanwhile, China boasts the largest population of English as a Foreign Language (EFL) learners globally. By focusing on EFL learners in HVCs and exploring the effectiveness of the OMO teaching model among this group, this research holds significant guidance for implementing OMO-based educational reforms in China's HVCs. Furthermore, it offers valuable insights for English teachers and designers of blended learning platforms within these institutions.

3. Research design

To evaluate the teaching effectiveness of the OMO method for EFL students in Chinese HVCs during the pandemic, a comprehensive research design was implemented in September 2023. The study aimed to ensure continuous teaching progression and guarantee the inclusion of all EFL students. The primary method of data collection was a detailed questionnaire survey administered to both students and teachers, focusing on various dimensions of the OMO teaching method.

For students, the questionnaire included sections on Teaching Satisfaction, Learning Outcomes, and Academic Performance. For instance, students were asked to rate their satisfaction with the OMO teaching method on a scale of 1 to 5, with 1 being

Very Dissatisfied and 5 being Very Satisfied. Additionally, they were queried about the effectiveness of the OMO method in helping them understand EFL concepts, using a scale ranging from 1 (Not Effective at All) to 5 (Extremely Effective). Students also assessed their academic performance in the EFL class since the adoption of the OMO method, rating it from 1 (Poor) to 5 (Excellent).

On the teacher's side, the questionnaire explored Teaching Effectiveness, Instructional State, and Implementation Challenges. Teachers were prompted to evaluate how effective the OMO method was in engaging their EFL students, using a scale of 1 (Very Ineffective) to 5 (Very Effective). They also rated the extent to which the OMO method improved their ability to assess and provide feedback to students, with options ranging from 1 (Not Improved at All) to 5 (Greatly Improved). Furthermore, teachers were asked to describe any challenges or difficulties they faced in implementing the OMO teaching method in their EFL classes, providing valuable qualitative insights.

Ethical considerations were paramount in this study. Ethical approval was obtained from a relevant institute, and the research was conducted in strict adherence to the college's research ethics guidelines. By utilizing a consistent Likert scale format for the majority of the questions and ensuring clarity in all prompts, the data collected was easily quantifiable, comparable, and conducive to a straightforward analysis of the results. This comprehensive approach allowed for a nuanced evaluation of the OMO teaching method's effectiveness in the EFL context.

4. Data analysis

The data collection for the study was completed by the end of December 2023, with a total of 286 valid student questionnaires and 15 valid teacher questionnaires collected. To ensure the reliability and validity of the questionnaire data, the study employed SPSS 24 for statistical analysis. The results indicated that the overall Cronbach's α coefficients for the student and teacher questionnaires were 0.901 and 0.818, respectively, signifying good questionnaire reliability. Furthermore, the KMO coefficients were 0.912 and 0.726, and Bartlett's test of sphericity reached significance ($p < 0.01$) for both questionnaires, demonstrating adequate questionnaire validity, as it shows in Table 1.

Table 1 OMO Teaching Method Satisfaction Questionnaire Data

Participants	Numbers	Cronbach's α Coefficient	KMO coefficient	Bartlett's Test of Sphericity p-value
Students	286	0.901	0.912	<0.01
Teachers	15	0.818	0.726	<0.01

Notes:
1) Cronbach's α coefficient is used to evaluate the reliability of the questionnaire, with values closer to 1 indicating higher reliability.
2) The KMO coefficient is used to assess the validity of the questionnaire, with values closer to 1 indicating better validity.
3) A p-value of less than 0.01 in Bartlett's test of sphericity indicates that the questionnaire data are suitable for factor analysis, further supporting the validity of the questionnaire.

5. Results and Discussion

The analysis of the questionnaire data collected in this study yields a comprehensive understanding of the teaching effectiveness of the OMO method for English as EFL students in Chinese HVCs.

Firstly, regarding student satisfaction with teaching quality, a notable majority of EFL students, specifically 65%, expressed satisfaction with the OMO method. This finding resonates with existing literature that emphasizes the potential of blended learning approaches to elevate student satisfaction [7], [8], [9]. Surving deeper into the data, it was observed that students particularly appreciated the flexibility and accessibility offered by the OMO method, which allowed them to learn at their own pace and revisit materials as needed. This aspect of the OMO method was crucial in addressing the diverse learning needs of students in the HVC context.

Furthermore, an overwhelming percentage of teachers, 85.3%, also reported satisfaction with the OMO method. They highlighted the method's ability to enhance student engagement and motivation, which in turn facilitated more effective teaching practices. This finding underscores the viability of the OMO method as a valuable tool for educators in HVCs, especially in the context of the ongoing pandemic.

In terms of the quality of OMO resources, the results were equally encouraging. A staggering 86.4% of EFL students expressed satisfaction with the teaching materials and courseware used by their teachers. This high satisfaction rate suggests that the OMO method provides students with access to well-designed and relevant resources that cater to their learning needs. Consistent with previous research [10], [11], [12], this finding emphasizes the importance of high-quality resources in supporting student learning in blended learning environments. Teachers, too, were impressed by the quality of online resources, with 82.3% considering them to be good. This perception aligns with Tran's research [13], which highlights the potential of technology to enrich teaching practices.

Regarding teaching and learning outcomes, the results were particularly promising. A large majority of EFL students, 84.2%, reported that they could understand most of the content taught through the OMO method. This finding not only supports the effectiveness of blended learning approaches in improving student learning outcomes [14, 15], but also underscores the OMO method's ability to facilitate content comprehension in the EFL context. Additionally, 85.6% of students believed that their digital literacy skills had improved, indicating that the OMO method contributes to the development of essential 21st-century skills. Teachers, too, reported enhanced educational technology proficiency, with 88.5% noting an improvement after implementing the OMO method. This finding highlights the method's potential to support the professional development of educators, enabling them to stay abreast of technological advancements and integrate them into their teaching practices.

6. Conclusion and recommendations

This study has investigated the satisfaction of EFL students and faculty at HVCs with the implementation of the OMO teaching method during the pandemic period. The results indicate that both students and teachers generally express satisfaction with OMO, which has significantly improved their digital literacy. By blending elements of pure online education and traditional face-to-face instruction, OMO emerges as an innovative instructional model. This study has outlined a typical OMO model and proposed an implementation framework based on the ADDIE model. The satisfaction survey conducted provides valuable insights into the effectiveness of OMO, guiding similar educational contexts aiming to adopt comparable teaching practices.

However, the study acknowledges its limitations, primarily relying on subjective indicators such as student and teacher satisfaction, and societal sentiment, which do not offer a comprehensive assessment of teaching effectiveness. To address these limitations, the following recommendations are proposed for future research:

Future studies on the Online-Merge-Offline (OMO) teaching method should incorporate both objective metrics, such as EFL students' academic performance, grades, test scores, and proficiency levels before and after OMO implementation, and subjective indicators to provide a comprehensive evaluation. Additionally, assessing teachers' instructional capabilities through observations, peer evaluations, or student feedback would offer a deeper understanding of OMO's impact on teaching quality. Long-term impact studies are also necessary to investigate OMO's effects on teaching and learning outcomes in the post-pandemic era, tracking the progress of EFL students and teachers over an extended period. Furthermore, exploring the implementation of OMO in diverse educational settings, including primary and secondary schools, as well as other higher education institutions, would provide valuable insights into the potential challenges and opportunities associated with this method, contributing to its broader understanding and application.

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Section 4

Interdisciplinary Applications of Digitalization and Management Innovation

Digitalization and Management Innovation III
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Research on the Existing Problems and Countermeasures of the Live Broadcast Marketing Mode of Publishing Institutions

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Abstract. Nowadays, it has become the norm for publishing organizations to take the live broadcast marketing route. Through literature research and case study analysis, the article explores the positive role of live broadcast marketing in enhancing book sales and brand awareness from the reconstructed "people-goods-field" marketing theory in the context of new retail, and points out the problems existing in the marketing mode of "publishing + live broadcast", including the improper "goods" selection strategy, ignoring the consumer's potential demand for "content goods"; poor effect of "field"; poor operation of "people" -community operation and poor user viscosity. Scientifically locate consumer needs and create a high-viscosity private community; seek differentiated market positioning, select products, explore the value of books, stimulate the potential needs of users, do a good job of "content merchandise" planning, show the characteristics of the content, utilize the cross-border marketing of other industries, and seize the hotspots to feed the "Publishing + Live" marketing; and use technological empowerment and scenario-based strategies. Finally, it is concluded that publishing institutions need to Improve these issues, make full use of the advantages of live broadcast marketing, and promote the digital transformation and sustainable development of the publishing industry.

Key words. publishing + live broadcast; live broadcast marketing; publishing organization; marketing optimization strategy

1.Introduction

1.1. Research Background

According to The 53rd Statistical Report on The Development of Internet in China released by China Internet Network Information Center (CNNIC), as of December 2023, the scale of Internet users in China reached 1.092 billion, and the scale of online live broadcast users reached 816 million, accounting for 74.7% of the total Internet users. The scale of the users of e-commerce live broadcast was 597 million, an increase of 82.67 million compared with December 2022, accounting for 54.7% of the total Internet users.

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The Internet has played an important role in accelerating the new type of industrialization, developing new quality productive forces, and boosting economic and social development [1].

In the publishing industry, live broadcast marketing, as an emerging marketing means, is gradually changing the traditional book sales and promotion mode. With the popularization of 5G technology and the rapid development of mobile Internet, publishing institutions are exploring the marketing mode of "publishing + live broadcasting" in order to find new growth points in the process of digital transformation. This marketing mode is an activity in which the publishing house promotes, promotes and sells publishing products and services based on the live broadcast platform, broadcast content and interact with the live audience, so as to increase the sales of publications and expand the influence of the publishing brand [2]. To become a powerful driving force for the development of publishing institutions in the new era. Although the marketing model of "publishing + live broadcasting" has achieved excellent results, there are still resistance problems in the application. In order to give full play to the advantages of live broadcasting marketing, targeted strategies should be adopted to improve the problem.

1.2. Research method, purpose, and significance

Article using literature research and case study method, using the new retail background reconstruction "people-goods-field" marketing theory, the background of publishers live marketing, concept, characteristics, advantages, development, related cases, existing research results, from the publishers live marketing practice, summarizes the advantages and problems, and put forward targeted optimization strategy, aims to improve the current publishers live marketing difficulties and live marketing for other publishers to provide strategy reference.

1.3. Literature review

Live-streaming marketing has brought new opportunities and challenges to the publishing industry. On the one hand, live broadcast marketing can effectively improve the sales of books and brand awareness. For example, CITIC Publishing Group achieves significant growth of book sales through the live broadcast activities on TikTok platform; on the other hand, live broadcast marketing promotes the transformation and upgrading of marketing in publishing industry, and the publishing industry can make better use of network live broadcast to carry out the transformation of marketing [1].

Publishing agencies are gradually realizing that it is not enough to rely only on traditional book promotion, and they need to combine the characteristics of live broadcasting to create attractive content and interactive experience. For example, through carefully designed live broadcast scripts and scene Settings, as well as the emotional interaction between anchors and audience, it can effectively improve user participation and purchase intention [2]. In addition, the construction and maintenance of communities is also one of the key factors for the success of live streaming marketing. By building a stable community, publishing institutions can better manage private traffic and improve user loyalty and re-purchase rate [3]. Although the current live broadcast marketing route is helpful to promote the realization of marketing goals, there are still problems in this model, and the improvement strategy should be put forward from different perspectives.

2.Features and advantages of "publishing + live broadcasting"

The first is the openness and the strong interactivity. The marketing mode of "publishing + live broadcasting" conforms to the historical background of media convergence and obtains the technical support of the information age. It has the characteristics of timely, interactive, user as entry and so on. Therefore, it has prominent advantages in marketing and publicity. In the live broadcast, all parties can realize the collision of ideas between different subjects, which has a positive significance for the promotion and marketing of the publishing house [2].

Secondly, the characteristics of community and fans are obvious. In the era of mobile Internet, community transformation has become a new popular way of life. With the popularity of Weibo, wechat and other we-media, publishing houses have a group of readers and author groups with traffic base and user stickiness. Based on the fan effect, pooling specific groups of people for live broadcast activities can greatly improve the efficiency, pertinence and precision of live broadcast marketing, and improve the utilization rate of resources and live broadcast effect.

Finally, there is a strong sense of experience. Under the mode of "publishing + live broadcast", the supply chain of the traditional publishing mode has been overturned, and a new cultural field in which authors, editors, publishers and readers participate at the same time, a cultural social space has been created, and the "real" scene experience in the virtual network is completed[4].The live broadcast scene creates a scene atmosphere that matches the publishing products and services, prompting readers to produce the desire to purchase and consume under emotional drive, and realizing the goal of product and brand marketing [5].

3.Development and application status of "publishing + live broadcasting"

3.1. The development process of the "publishing + live broadcasting" mode

In 2015, publishing organizations began to integrate live broadcasting technology into their marketing activities and opened a new mode of "publishing + live broadcasting". Below is the evolution and characteristics of live streaming marketing practices of publishing institutions since 2015.Through combing, we can better understand the trend and development direction of publishing marketing in the digital age.

In 2015, Humanities Society, CITIC Publishing Group began to try marketing activities through network live broadcast, such as online reading parties, press conferences and other [2]. As an emerging attempt, live broadcast marketing in this stage is mainly used to supplement the time-space limitations of offline activities and improve the accessibility and coverage of activities. From 2017 to 2018, Weibo, wechat and other community platforms were used to carry out live broadcast activities with knowledge dissemination as the core. At this stage, live broadcasting marketing began to develop rapidly, characterized by knowledge sharing on community platform to enhance brand image and cultural influence. From 2019 to 2020, it began to sell books through live streaming with the main purpose of driving book sales. At this stage, live broadcast marketing began to be commercialized, with the purpose of book promotion. Live broadcast room direct selling and preferential activities become an important means to attract the audience [5]. In 2020, it will fully enter the short video platform and make use of the traffic advantage of the short video platform to promote books. At this stage, the live broadcast marketing channels are diversified, and the short video platform has become a new marketing position, taking advantage of its high user activity and extensive coverage. Since 2021, the number of live marketing organizations has been increasing, and live marketing has become a normal marketing means [6] for publishing organizations. Live broadcast marketing at this stage has gradually matured. Combined with the convenience of direct selling in the broadcast room, publishing institutions have attracted a large number of audiences through carefully selected book lists and accurate explanations, which has become an important way to develop online sales.

At present, the common marketing mode of "publishing + live broadcast" in China are celebrity live broadcast and activity live broadcast. Celebrity live broadcasting mainly refers to the cooperation of publishing houses with Internet celebrities, well-known writers, scholars, and stars to achieve brand communication through anchor promotion [2]. Live activity broadcast is an event-style marketing model focusing on live broadcast activities and highlighting the content, highlighting the characteristics of topic, dynamic and scene. Under the mode of "publishing + live broadcast", the method of event marketing is more conducive to catching the attention of the audience, and attention resources can be obtained at a low cost to achieve the effect of "detonating".

3.2. Typical cases at home and abroad

3.2.1. Domestic success cases

The sales results of serious literary books in Via Live have broken the publishing industry's mindset on serious literature marketing. After three additional inventory sales of Life Hai Hai, 30,000 copies of the book were sold out in five seconds, demonstrating the powerful influence and potential market of live broadcast marketing. CK New Century teamed up with celebrities to save physical bookstores. Facing the impact of the epidemic, CK New Century launched a series of live broadcasts of "The Spring of Bookstores - Saving Brick-and-Mortar Bookstores". The first live broadcast, hosted by Bai Yansong, attracted a total of 1.469 million viewers, with cumulative sales of books exceeding 2 million yuan, effectively helping brick-and-mortar bookstores alleviate operational pressure. Fan Deng, as the Chief Book Recommender of Racer, made his debut in Racer's live broadcast, which attracted 2 million online viewers in nearly 3 hours, with cumulative sales of 130,000 books, amounting to nearly 10 million yuan. This case proves the important role and influence of personal brands in live marketing.

3.2.2. Foreign success cases

"The Grand Canal through Time and Space" omni-channel marketing. This case shows the successful practice of omni-channel marketing through books, digital images and new media interaction. The foreign language version is responsible for global marketing and promotion by DK UK. Through the marketing and promotion of live short video platform, public account community, e-commerce platform and ground stores, it has effectively carried forward the traditional Chinese culture to the world.

Penguin Random House is one of the largest publishing groups, conducting book launches and author interviews through live streaming platforms such as Facebook Live and Instagram. For example, in order to promote a new work of a best-selling author, the author may be arranged to have a reading group, a question-and-answer session or interact with fans in a live broadcast, so as to increase the exposure and interactivity of the book. HarperCollins uses live-streaming technology for virtual book fairs and literary events. During the epidemic, the publisher held a "HarperCollins Virtual Book Fair" through live broadcasting, inviting readers to visit online, and participating in various reading and creation related activities, such as writers' workshops and editorial consulting, which improved the exposure rate and brand influence of the publisher.

3.3. Innovation points and enlightenment in the case

The innovation lies in the fact that the publisher's live broadcast marketing combines multiple channels online and offline, combining live broadcasting with book sales, and realizing the balance between culture and business. Utilizing the celebrity effect and the high traffic and interactivity of the live streaming platform, it provides new channels and opportunities for book sales, and also raises public attention to the plight of brick-and-mortar bookstores, expanding the audience scope and market influence of the books.

Live streaming marketing, as an emerging marketing tool, has huge market potential and development space. The publishing industry should continue to innovate the content and form of live broadcasting and provide valuable and attractive live content. The publishing industry should also make full use of the personal brand effect of authors and celebrities to enhance the market recognition and sales of books. Finally, looking at other countries, publishing organizations around the world are actively using live streaming marketing to boost business revenue and brand influence. For developing countries, live marketing is a platform to showcase local culture and enhance cultural soft power, and it can also draw on the successful experience of developed countries to accelerate digital transformation. Developed countries can enrich cultural diversity, broaden readers' horizons and introduce new business models, as well as gain new inspiration and innovate marketing practices through exchanges. Through the above case analysis, we can see the successful application and great potential of the live marketing model in the publishing industry. We should actively embrace this new model, constantly innovate and optimize the live marketing strategy, so as to achieve better market performance.

4.Existing problem

Based on the logical perspective of "human goods yard" marketing reconstructed under the background of new retail [7], Analyze the problems existing in the current marketing model of "publishing + live broadcasting".

4.1. "People" -improper community operation and poor user engagement

From the perspective of the marketing status of "publishing + live broadcasting", various publishing institutions attach varying importance to the construction of the reader community. For example, Humanities Society has established 6 live reader communities on Taobao platform, and Sanlian Life Weekly establishes a separate reader community through the operation of "Pinecone Life" APP [2]. In addition, many publishing houses have established a reader community through WeChat platform to conduct live preview and book promotion. However, more publishing houses have not established their own reader community, and even if they establish a community, they also lack systematic user maintenance, resulting in readers' lack of understanding and interest in live broadcasting. Some publishing houses have unsatisfactory reader communities' operation and low community activity, which affects user engagement; it is difficult to attract potential readers outside the community, and the scale cannot be expanded.

4.2. Improper "goods" selection strategy, ignoring the potential demand of consumers for "content goods"

First of all, some publishing institutions have limitations in their selection strategies, failing to accurately target the audience, and live content is out of line with market demand. These institutions tend to show only their own books, ignoring the market dynamics and hot trends. Compared with the mode of talent delivery, the single product selection strategy limits the expansion of the audience group and user retention and reduces the attraction and conversion rate of live broadcasting [8].

Secondly, content is king, which is the fundamental reason for the development of the publishing industry in any period. Invisible "content goods", on the one hand, refers to the book content provided to readers in the live broadcast, on the other hand, refers to the dissemination of cultural knowledge based on the books in the live broadcast [2]. "Content goods" implicitly have a significant impact on the effect of live broadcasting, user stickiness and conversion rate. Many organizations focus on the book specifications, prices and details, and users' content and emotional resonance needs are ignored to some extent. But to really improve business effectiveness, the key is to focus on the nature and unique value of content in the book industry. Integrating rich knowledge content and story elements into the live broadcast helps to enrich the connotation of the product and promote users' emotional resonance and purchase decisions [9], is an important strategy to achieve business goals.

4.3. The poor construction effect of "field" will affect the user experience

In 2023, among the 566 publishing and distribution organizations monitored by Publishers, 279, accounting for nearly 50%, made live streaming [10]. However, some publishing institutions have not yet explored the way of live broadcast marketing, with little effect. The problems are two points.

First of all, the design of live broadcast activities is homogeneous, which makes consumers aesthetic fatigue. At present, the publishing house pre-sells new books in the form of press conference, and sells them through the author's live broadcast promotion, or chooses the form of cooperation with stars and Internet celebrities to promote book sales. These live broadcast activities are the same, single form, lack of interaction, unable to show the advantages of books and the professionalism of the publishing house, to attract more audiences. Secondly, the construction effect of the field is poor. During the live broadcast, the publishing house pays more attention to the introduction and publicity of products and services and ignores the interaction with the audience and the creation of scene atmosphere, resulting in the lack of participation of the audience. These are not conducive to the promotion of products and brand, stimulate consumption desire and obtain user emotional identity.

5. Suggestions

In the business situation, people, goods and field are always the core elements of marketing. Traditional retail is "goods-field-people", while new retail is "people-goods-field", which emphasizes the people-centered, pushing products and creating consumption scenarios according to user needs [6]. Combined with the characteristics and status quo of "publishing + live broadcast", based on the marketing logic of "people-goods-field" under the background of new retail, the optimization strategy of live broadcast marketing is expounded.

5.1. "People" scientifically positions consumer demand and creates a high-viscosity private domain community

In order to attract users' attention and improve user stickiness, the publishing house should clearly locate the readers, seize the target user groups, meet the needs of the audience, and gradually form a stable fan community to ensure the loyalty of users. Both publishing institutions, celebrity authors and celebrities can use the "nested" effect of social media to attract fans and help publish live broadcast marketing [2].

Therefore, when carrying out live broadcast marketing, we should consciously convert the low-value and public domain traffic to the high-value private domain traffic [11]. Community building is an important way to build private domain traffic. The establishment of the community should be based on the same platform, supplemented by cross-platform drainage. For example, in the early stage, East China Normal University Press tried to stream to the TikTok broadcast room through the wechat public account with more than 300,000 fans, but it was difficult to convert the traffic in progress. The publishing house gives up cross-platform drainage and focuses on the establishment of TikTok community. It attracts the TikTok fan group through the broadcast room, and then leads the traffic back to the broadcast room through the way of live broadcast preview of the fan group. In this way, the private domain traffic becomes more concentrated and controllable, and the repurchase rate of fans is also significantly improved. When building a community, we should also fully develop the advantages of the network community formed by the channels of publishing houses and authors.

5.2. "Goods" optimization strategy

First of all, we should seek differentiated market positioning and select products based on the characteristics of live broadcasting platforms and users. Publishing institutions have many new books every year, they should make use of their resource characteristics and market demand to select certain vertical books for recommendation, so as to achieve differentiated market positioning. For example, East China Normal University Press, as a university publishing house, has great advantages in teaching books. It takes high-quality teaching series as its main content and gained a group of loyal "Bao Ma" and "Bao Dad" fans in the first three months of self-broadcast. Robust product selection strategy can accurately connect with user needs and effectively promote book sales [9].

Taking TikTok platform as an example, it has a wide range of users, and consumers use Douyin for a short time and high frequency. Therefore, they should choose books that are more popular, interesting and can quickly catch the attention of users. As can be seen from the TikTok book bestseller list, the public books account for a relatively high proportion, and the professional books account for a relatively low proportion [12].

Based on this, China Machine Press chooses social science books rather than the professional books that it is good at. This selection strategy has proved more successful. The social science book published by the agency, "Being hated with courage", set a record sales volume of 1 million copies in 2015 and 2019. Since 2020, with the help of TikTok and such interested e-commerce companies, it has become popular again, becoming a hot seller with annual sales of more than one million yuan [13].

Secondly, publishing institutions should start from different perspectives, comprehensively explore the product value, find the pain points of target groups, and stimulate the potential needs of users. For example, when publishing institutions recommend products such as children's picture books in live broadcasts, they usually highlight the educational and interesting characteristics of picture books. On this basis, the book can be given a new "value". For example, it is pointed out that reading picture books together is conducive to improving the parent-child relationship, and the audience of picture books also includes adults. In addition, in the process of live broadcast marketing, the stories behind the books can be fully explored, and transformed into new knowledge services in live broadcast, to extend the added value.

Again, we should do a good job of "content goods" planning, display the content characteristics. As an invisible commodity in live broadcasting, it is obvious to help the effect of live broadcasting and commercial realization. Under the marketing mode of "publishing + live broadcast", only by building brands with high-quality content and well-designed live broadcast activities and providing readers with quality products and tasteful content output, can we attract and retain users, build the brand and achieve development. Taking Zhonghua Book Company as an example, a series of live broadcast of traditional culture-related themes combining its advantages has been widely praised. Among them, "The story behind the revised edition of The Golden History", in which the executive director Xu Jun is the keynote speaker, has become a classic case of self-broadcast in the publishing industry [14]. The "cultural gene" of the publishing industry itself means that we must take the road of culture and quality in the "publishing and live broadcast". Only by grasping this core and completing the output of high-quality content commodities can we achieve the goal of marketing.

Live-streaming marketing is a "pay attention" economy. Many organizations out of the live broadcast activities are not attractive enough and fail to catch the attention of users. In order to attract users from the source, we should focus on displaying the content characteristics of live broadcast, make a good preview of live broadcast, convene the audience, and increase the influence of live broadcast. Liu yuxin, an independent planner of the grinding iron planet, said bluntly that treating the audience as customers to sell will cause the audience aversion, the need to tell stories, show the content, and chat with the audience. Motie always takes "script copy" as the content center of live broadcast, highlights the story of books in the copy. The key to the success of the live broadcast is to prepare the copywriting from the perspective of user needs, make a good process plan according to the goal and create a good atmosphere for the purpose of live broadcast. Live broadcast "content products" are constantly enriched, attracting users with valuable materials and scenes; interactive methods keep pace with The Times, and keep the live broadcast audience interested with continuous changes, so as to retain users and help the realization of live broadcast marketing goals.

Finally, we should take advantage of other industries for cross-border marketing and seize the hot spots to feed back the "publishing + live broadcast" marketing. In the era of "Internet +", various new media platforms are constantly emerging. The rise of fan economy is the basis for the success of the cross-border marketing model of "book + film and television". In this context, "traffic IP" is extremely popular, and many original literary works have been adapted into films and television, enabling many publishing enterprises to obtain huge economic benefits. Publishing institutions should consciously capture and predict hot spots when carrying out live broadcast marketing, integrate them into product selection strategies and live broadcast planning, and inject new impetus and marketing scenes into live broadcast marketing. For example, according to data monitoring by JingDong Book, During the 2023 airing of the explosive drama Rampage, the number of searches for Sun Tzu's The Art of War and the number of users who purchased the book increased by more than 50 times year-on-year, driving the overall turnover number of related books to increase by nearly 27 times year-on-year. Such cases show that literary works provide materials for film and television adaptation, while successful film and television works promote the sales of original works, forming an IP ecological chain from literature to film and television and then to books, producing resonance effect.

5.3. "Field" application technology enabling and scenario-based strategy, to do a good job in emotional interaction

In live broadcast marketing, building an effective "field" is crucial for sales promotion and user experience. The "field" of the live broadcast room includes many elements, such as anchor performance, product display, set design, hardware facilities, material presentation and the rhythm of the live broadcast [13]. Taking Oriental Selection as an example, its scenario-based marketing strategy has successfully attracted a large number of consumers. Different from the traditional live broadcasting mode, oriental Selection pays more attention to creating a cultural atmosphere and emotional resonance. The anchors 'knowledgeable, warm live broadcast environment and exquisite book display jointly create a shopping atmosphere full of cultural atmosphere and emotional experience, which meets the target audience's expectation for reading and the pursuit of book quality, and effectively meets the psychological needs of consumers [14]. Successful implementation of this scenario-based marketing strategy provides a reference for other publishing institutions.

The key to building "field" is to make the broadcast room become a marketing field with rich content, strong sense of atmosphere, diverse scenes and ornamental and entertainment. The construction of the scene should give full consideration to the theme, anchor setting, target audience and product characteristics. For book promotion, you can choose live broadcast in the warehouse to highlight the price advantage; need to highlight the quality of books, select bookstores and strong reading atmosphere [9].

Secondly, the studio scene construction can highlight the advantages of online setting. On the one hand, live broadcasting breaks the time-space limit and can be used as a supplement to offline shopping. For example, publishing institutions can choose to conduct live broadcast in printing houses, publishing houses and other places, and guide users to "immerse" in the process of book production from another perspective, so as to satisfy users' curiosity hunting and promote placing orders. On the other hand, technology enables the publishing industry, so that users can get a better experience, so as to promote the realization of the goal of product and service marketing. The application of VR, AR, AI and other cutting-edge technologies in the live promotion of science fiction books can vividly reproduce the science fiction world and greatly enrich the immersive experience of users. With the power of technology, publishing houses can choose and switch dynamic live broadcast scenes at any time in live broadcast activities, so as to give users a strong visual impact with life-oriented, rich and diversified scenes, and play the effect of emotional infection and consumption rendering.

6. Conclusion

"Publishing + live broadcast" marketing is the marketing mode opened up by the publishing industry to adapt to the development of The Times and technological progress. Publishing institutions should make full use of live broadcast marketing mode and new technologies, keep in mind the nature of content in the publishing industry, focus on user needs, follow the law of Internet communication, constantly seek differentiated advantages and track, and promote the transformation and sustainable development of themselves and the new retail background of the publishing industry. But at the same time, how can publishing institutions effectively take into account social and economic benefits when carrying out live broadcast marketing, To further broaden its content and value dimensions, actively assume its own social responsibility as a cultural unit, and give full play to the maximum value of live broadcast marketing, which is also the problem that is not discussed in this paper and needs to continue to study.

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The Causal Mechanism of Domestic Camping Tourism Safety Accidents Under the Grounded Theory

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Abstract. With the booming development of the camping tourism market, research on camping tourism safety accidents has become increasingly important. Based on 216 camping safety accidents, this article uses grounded theory methods and software Nvivo 20 to explore the causes and mechanisms of camping safety accidents. The research results indicate that the causes of camping tourism safety accidents are mainly influenced by human factors, environmental factors, equipment factors, and management factors. This study provides recommendations for government departments and relevant industry personnel to prevent camping tourism safety accidents and emergency response.

Keywords. Grounded theory, Camping tourism, Safety accident, Cause mechanism

1. Introduction

In recent years, camping has quickly become popular among consumers due to its advantages such as short distances, strong experience, and high personalization. Safety is the lifeline of the tourism industry and the premise and foundation of tourism activities [1]. However, due to reasons such as the lack of relevant safety skills and knowledge among camping tourists and the lack of scientific management of travel teams, camping tourism safety accidents occur frequently in China. Therefore, scientifically identifying the cause mechanisms of camping tourism safety accidents is of great significance to deepening risk awareness, and also provides a basis for camping tourism safety management.

Camping tourism in this study refers to tourism activities carried out with tents and other facilities for the purpose of leisure, entertainment and adventure, and carried out in the form of outdoor camping. In 1906, Thomas Hiram Holding, the father of modern leisure camping in the United States, published the first edition of the book "The Camper's Handbook," which summarized his camping experiences worldwide. There is relatively more research on camping tourism, covering a wider range of fields, such as COVID-19 and camping tourism [2-5], weather and camping tourism [6-9], camping tourism trends [10], camping tourism attractiveness [11], camping site selection and experience [12], etc. In terms of research on camping tourism safety, scholars have mostly focused on methods to ensure safety [13], safety measures in the face of danger [14], and factors that interfere with safety constraints [15].

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Research on camping tourism safety accidents using grounded theory typically involves qualitative analysis to understand the underlying factors contributing to safety incidents. Weber analyzes various studies on accident prevention strategies in camping settings [16]. Klein utilizes grounded theory to explore safety concerns among campers and identifies key factors contributing to accidents [17]. Schott investigates how social dynamics among campers affect safety behaviors and accident occurrences [18]. Patterson focuses on risk management strategies in outdoor recreation, including camping safety [19]. Hsu examines how perceptions of safety and risk influence camping behaviors and decisions [20].

Understanding the causal mechanisms behind safety accidents in domestic camping tourism is crucial for developing effective prevention strategies. Grounded theory provides a framework for identifying and analyzing these mechanisms through qualitative data. The causal mechanisms of domestic camping tourism safety accidents are multifaceted, involving environmental, equipment-related, human behavioral, social, communication, and regulatory factors. Understanding these mechanisms through grounded theory allows for the development of targeted interventions to enhance safety in camping tourism.

2. Research Methods and Data Sources

2.1 Research methods

The grounded theory method is a method that uses continuous comparative analysis, repeated sampling and coding, and gradually generates concepts and categories from the original data from the bottom up, presenting core categories and basic social processes, and finally forming a theory.

Domestic research on grounded theory covers a wide range of fields, such as enterprise operation management. China's systematic research on grounded theory is later than abroad, and in the field of camping tourism safety, the application of grounded theory has not yet received sufficient attention. Therefore, this article is based on 216 camping tourism safety accident cases that occurred in China from 2012 to 2022, using Nvivo20.0 to conduct a grounded analysis, research and refine the factors causing camping tourism safety accidents, and further analyze the cause mechanism of the accident, with a view to providing guidance for camping tourism in China. Provide effective countermeasures and suggestions for safety accident prevention, emergency warning and other work.

2.2 Data source

This article is based on Chinese web crawler technology and collects network cases related to camping tourism security from multiple websites such as Weibo from 2012 to 2022. Subsequently, these cases were processed using natural language processing techniques and screened according to specific relevant standards. The comprehensive application of this research method can effectively obtain and process a large amount of network case data, providing strong support for further research. In addition, other search engines such as Baidu and Google use Chinese "camping" as the main keyword and Chinese "safety", "accident", "tourism" as secondary keywords to assist in improving the case selection. The selected cases need to meet three major conditions:

first, the time period for the case to occur must be from January 2012 to December 2022; Secondly, the basic information elements of the case, such as time, location, reason, and result, need to be complete; Based on the above conditions, after sorting and screening, 216 case materials were ultimately selected for research and analysis. On this basis, 2/3 were extracted for coding analysis and model construction, and the remaining 1/3 cases were used for theoretical saturation verification. The purpose of theoretical saturation verification is to ensure that the research data is sufficient and detailed. This method helps to improve the reliability and effectiveness of research, avoiding ineffective data collection.

3. Grounded Analysis

3.1 Open coding

Open coding refers to the process in which the researcher breaks up the collected original data, organizes and analyzes them, assigns conceptual categories and then recombines them in new ways. This article first used the free coding function of Nvivo20.0 to freely code the case data, and summarized a total of 216 original statements, secondly, the content of the statements was separated and extracted, and 47 initial concepts were obtained. On this basis, the generic coding function was used to refine the included categories, and finally 17 categories were obtained. The results are shown in table 1.

Table 1. Open coding

Conceptualization	Categorization	Examples of original data
Altitude sickness, sudden illness	Feeling unwell	A 52-year-old man suffered a heart attack after drinking alcohol and climbing a mountain. Died from exhaustion and hypothermia while climbing. died from altitude sickness.
Insufficient staff familiarity	Inadequate preparation	A fellow traveler acted alone due to differences of opinion and eventually died of hypothermia.
Lost and trapped	Inadequate outdoor experience	Lost his way and was trapped on a cliff overnight and was rescued.lost his way and was trapped on a cliff.
Improper heating, The fire is not extinguished, Discard flammable materials at will	Not very vigilant	Heating causes carbon monoxide poisoning.using gas stoves for heating. The charcoal fire on the barbecue grill "smolders".the glass bottle burns under the spotlight.
Animal attack	Poor environment at the campsite	He was trampled to death by an elephant,his arm was bitten off by a lion that broke into the camp.Venomous insect bites cause skin pain, redness and swelling.
Thunderstorm, Flash flood	Extreme weather	Lightning strikes injured 5 people and one person died.a family of 13 drove themselves and were trapped by floods, but there were no casualties.heavy rains caused flash floods, but they refused to listen and 5 people died.
Children are free,Playing with fire and water	Supervisory personnel failed in their duties	The child fell into the water and was rescued. Children were allowed to set off firecrackers, causing forest fires.
Public security crime	Poor management	The driver's improper operation caused the sightseeing car's brakes to malfunction.
Car brake failure	Equipment failure	The driver's improper operation caused the sightseeing car's brakes to malfunction. Woman was camping alone when a RV lost control and she was crushed to death

3.2 Spindle encoding

Axial coding is a process of finding the intrinsic connections between the initial concepts and phenomena derived from open coding and extracting main categories. This article uses Nvivo20.0 generic coding to sort out and analyze the 47 concepts formed by open coding, establish effective connections between main categories and secondary categories, and finally summarize and extract 10 main categories (Table 2).

Table 2. Spindle coding and selective coding

Conceptualization (open coding)	Categorization (developmental coding)	Spindle coding	selective coding
Altitude sickness, sudden illness, Exhausted and seriously injured	Feeling unwell and exhausted	Poor physical fitness	Human Factors
Acting alone, lack of familiarity with personnel, lack of leadership	Inadequate preparation	Lack of preparation	
Trapped in a cave, lost, food poisoning	Inadequate outdoor experience and weak safety awareness	Lack of experience	
Dispose of flammable materials at will, Entering undeveloped areas, improper heating, Suicide, drowning, drunken accident	Poor vigilance and risky behavior	Lack of security awareness	
Injury due to slipping, animal attack	Poor environment at the campsite	Unfavorable environment	Envirnmental factor
Heavy fog, blizzard, tsunami attack, Thunderstorms, flash floods	Extreme weather and more disasters	Weather and disaster emergencies	
Traffic is blocked and order is chaotic, Lack of management, security crimes	Poor management	Lax security control	management factors
Children play with water and fire at will, Underage adventure activities	Supervisory personnel failed in their duties	Unqualified safety supervision	
Information failure, electric shock, brake failure, gas tank failure, equipment aging and loss of control	Equipment failure	Bad equipment	Equipment factors
Incomplete supporting facilities and lack of protective equipment	Facilities are not perfect, Equipment missing	Not fully equipped	

3.3 Selective encoding

The purpose of selective coding is to discover core categories that can explain most of the research phenomena and are easily related to other data. Based on the ten main categories of spindle coding, multiple factors leading to camping travel safety accidents were further summarized.

3.4 Theoretical saturation test

In order to ensure the scientific rigor of the research, we conducted a theoretical saturation test and subjected the remaining 1/3 of the original data to the same open, axial and selective coding as above, and found the differences and similarities between the two through comparison. The coding results showed that no new theoretical categories and relationships were extracted from the remaining 1/3 of the data. This shows that the four main categories obtained by the above three-level coding in this article have become relatively mature.

4. Results

The triggering factors of camping tourism safety accidents include (1) personnel factors. Specifically, it refers to the relevant entities that cause tourism safety accidents, including the campers themselves and the employees of the camping site. Among them, the factors of campers mainly include the following: poor personal physical fitness, leading to physical discomfort and exhaustion during the camping process; Insufficient preparation, unclear destination route and unfamiliar road conditions; Individual activities or team members who do not know each other; Lack of safety awareness, engaging in dangerous behaviors such as indiscriminate use of fire sources and electrical appliances, and unauthorized entry into restricted areas; Easy to relax vigilance and neglect carelessness, some campers deliberately engage in novel adventure activities in pursuit of excitement; Lack of experience, such as improper use of fire sources leading to fires and carbon monoxide poisoning, indiscriminate consumption of wild food leading to poisoning, unfamiliarity with terrain leading to getting lost and trapped, etc. The factors affecting employees mainly include the low professional level of camping site employees, weak operational skills leading to instrument operation errors, and so on. (2) Environmental factors mainly include adverse environments and sudden disasters. Safety accidents caused by adverse environments include the following situations: sudden attacks or intimidation from ants, bears, lions, and other animals during camping; Camping activities are suspended due to water shortages in special campsites such as deserts; Complex terrains such as cliffs and high mountains are prone to safety accidents such as falls and high-altitude falls, which can cause physical and mental harm to campers. Sudden disasters mainly include high temperature and rainstorm before camping, as well as mountain torrents, fog, snow and other meteorological disasters during camping, which increase the difficulty of rescue. (3) Management factors mainly refer to the factors that lead to camping accidents during various stages of camping activities due to the lack or inadequacy of management by campers and practitioners. These factors include the following: inadequate safety supervision, lax safety management, low medical level, and inadequate treatment. Specifically, the lack of strict safety management before the start of camping activities leads to disorderly order at the campsite, resulting in problems such as overcrowding and public security crimes; There is a lack of camping management personnel or insufficient strength, and there are problems with the setting of safety positions. During the camping process, campers who fall into the water or cliff due to untimely rescue cannot receive timely assistance and can only rely on safety rescue issues such as self-rescue and mutual rescue. The inadequate medical treatment after the accident outbreak is manifested as a shortage of medical supplies, untimely treatment, and low medical level, which can worsen the injuries of campers or result in poor treatment effectiveness and may leave serious sequelae. (4) The equipment factor mainly involves insufficient preparation of equipment related to the camping trip and the poor condition of equipment and facilities. Due to the high autonomy and arbitrariness of camping tourism, most campers choose to purchase equipment themselves, and the quality of equipment varies, posing certain safety hazards. In addition, campers usually choose camping sites based on their actual situation. Some camping sites have certain hardware conditions that are lacking, as well as poor facilities and communication signals that do not cover all areas. Once an emergency occurs, due to inadequate outdoor equipment and poor communication quality, the rescue timing may be delayed, resulting in potential losses. The existence of this phenomenon indicates that there is still significant room for improvement in improving the environmental safety of camping sites.

From the above analysis, it can be seen that there are many factors that induce camping safety accidents, which can be summarized into four core categories. human factors, environmental factors, management factors and equipment factors. Each category covers multiple inducing factors, consisting of 47 factors. The 47 triggering factors referred to by the conceptual category are distributed in various stages of camping. The analysis shows that camping tourism safety accidents have stage characteristics. This article takes the four stages of camping preparation, experience, accident occurrence and rescue as the main line to systematically sort out the formation mechanism of accidents, as shown in Figure 1.

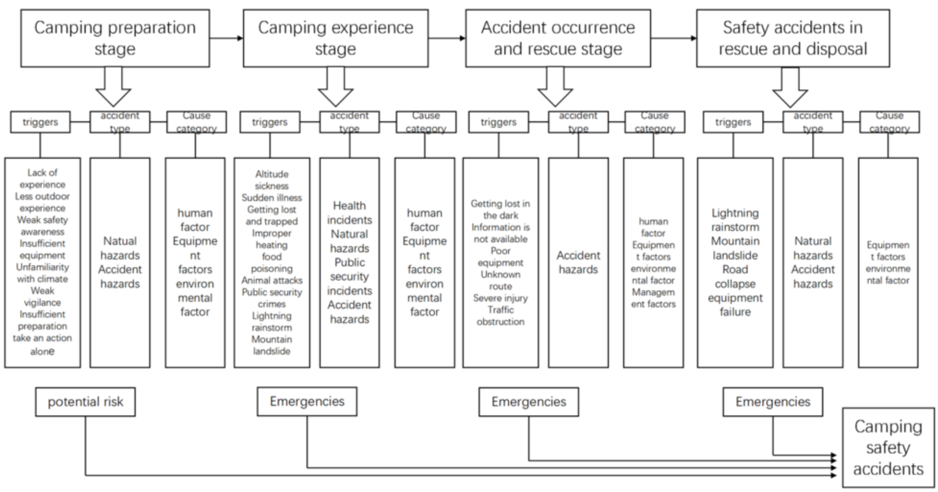

Figure 1. Cause mechanism diagram of tourism safety accidents

5. Conclusion

This article adopts the grounded theory method based on crawlers and natural language processing and uses Nvivo20.0 software to extract 47 categories, 10 main categories and 4 core categories. The study found that accident triggers can be divided into four categories. human factors, environmental factors, management factors and equipment factors.

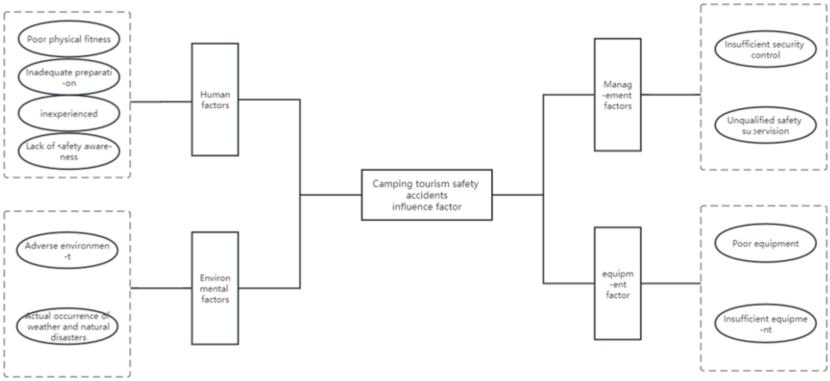

Figure 2. Factors influencing safety accidents in camping tourism

The research conducted on the occurrence and evolution characteristics of camping tourism safety accidents reveals that these incidents unfold in distinct stages. During the preparation stage for camping trips, inadequate preparation can lay the groundwork for potential dangers in the subsequent stages. For instance, failing to take into account all weather conditions thoroughly, neglecting to conduct a comprehensive site assessment, or not bringing along the necessary equipment can all contribute to creating a hazardous situation. Moving on to the camping experience stage, environmental changes, human negligence, and the pre-existing dangers that were not addressed earlier can culminate in a variety of accidents. These may include falls, fires, and other mishaps that can occur due to the dynamic and often unpredictable nature of outdoor environments. Finally, the rescue phase is a critical juncture in managing these safety incidents. Despite its importance, rescue efforts can be hindered or delayed due to a multitude of factors that continue to exert their influence. These factors include poor communication among the rescue team, insufficient equipment, and the inherent difficulties involved in conducting rescues in remote or challenging terrains. These challenges can exacerbate the spread of the accident, and the extent of the losses incurred.

Limitations of this article: While this article aims to investigate and analyze the various elements that contribute to safety incidents within camping tourism, it falls short in several significant aspects. Specifically, the article does not undertake a thorough examination of the hierarchical order and the intricate logical interdependencies among these factors. Consequently, it fails to delineate a clear sequence of importance or causality that might exist between them. Furthermore, the research does not extend to devising comprehensive prevention strategies and management protocols that could be tailored to address these factors based on their identified levels of influence and logical connections. This omission means that while the article provides a broad overview of potential safety issues, it does not offer a structured approach to prioritize and tackle these issues effectively, which would be essential for stakeholders aiming to enhance safety measures in camping tourism environments.

In the future, it would be beneficial to undertake comprehensive research that delves into the intricate web of primary, secondary, and logical relationships among the diverse factors that are pertinent to the safety aspects of camping tourism. This extensive study should aim to identify and analyze the fundamental elements that directly influence safety, as well as the secondary factors that may indirectly affect it. Additionally, the logical interconnections and dependencies between these factors should be scrutinized to gain a deeper understanding of how they collectively contribute to the overall safety environment of camping tourism.

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Diversification and Performance of Pharmaceutical Enterprises – Empirical Analysis Based on China's A-Share Pharmaceutical Listed Companies

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Abstract. Diversification is one of the important strategies in the growth process of enterprises. At present, the academic community has not yet reached a unanimous conclusion on the relationship between diversification and corporate performance. Taking 31 China's A-share pharmaceutical listed companies from 2018 to 2022 as a sample, this paper empirically analyzes the impact of diversification on the performance of pharmaceutical companies. Empirical results show that overall, diversification has a negative impact on the return on equity (ROE) of a company, but it is not significant. However, from the perspective of different views, related diversification leads to a significant decrease in the company's ROE, while unrelated diversification leads to a significant increase in the company's ROE. Using return on assets (ROA) as a substitute variable for ROE to conduct a robustness test on the model, the results remain consistent. This indicates that overall diversified operations have a negative effect on the performance of pharmaceutical companies, but it is not significant. Related diversified operations have a significant negative impact on the performance of pharmaceutical companies, while unrelated diversified operations have a significant positive impact on the performance of pharmaceutical companies. Based on the empirical results, the performance improvement strategies of pharmaceutical manufacturing enterprises are proposed from the perspectives of maintaining moderate diversification and focusing on building core competitiveness. This study enriches the research content of diversification, provides support for the evaluation of the implementation effects of diversified strategies for pharmaceutical companies, and can also provide a basis for how to choose diversified strategies.

Keywords. Pharmaceutical Enterprises, Diversification, Enterprise performance

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1. Introduction

With the continuous development of the world economy, more and more enterprises begin to implement diversification strategies and embark on the road of diversified management. On the one hand, by using the surplus resources accumulated by the existing business, the enterprise can continue to supplement the company's current business, further consolidate the competitiveness of the enterprise, and avoid the desperate risks that may be brought by specialization. On the other hand, the enterprise can also consider investing the remaining resources into the new product industry to avoid the risk of enterprise profitability decline caused by the overall contraction of the industry market in the future [1]. By introducing new business with synergies with the original business value chain activities, the competitive advantage brought by the synergistic effect of "1 + 1> 2" can drive enterprises to quickly win market share in the new market and drive enterprises to achieve growth [2][3]. According to the transaction cost theory, when enterprises provide external products or services through resource integration, internal transactions are often superior to external transactions. When the cost of the external market transaction link involved in the production and operation activities of the enterprise is too high, the enterprise will naturally consider internal self-research to replace the external transaction activities with high costs [4]. When an enterprise conducts diversified operations, due to the low internal transaction cost, the diversified enterprises can adopt the way of lowering the price, making it difficult for competitors to enter the market, to protect the market share and profit margin of the enterprise, and continue to obtain profits to drive the continuous growth of the enterprise scale and value of the enterprise. However, due to the large differences in the industry and operating environment, some enterprises have to invest a lot of resources to implement the diversified operation strategy, and the capital cost pressure is greater, therefore it is difficult to bring more benefits to the enterprises in the short term. At the same time, from the perspective of corporate governance, the separation of ownership and management rights of modern enterprises produces the principal-agent problem and pays more benefits to the shareholders to reduce the resources controlled by the operators, thus reducing the power of the operators. Diversification is in line with the intention of operators to expand enterprise investment without paying dividends to shareholders, and the blind implementation of diversification may lead to the reduction of enterprise performance [5][6].

At present, regarding the relationship between diversification and corporate performance and the research results mainly include diversification premium theory, diversification discount theory, and diversification neutral theory. When it comes to the diversification premium theory, some scholars have found a positive correlation between enterprise diversification and performance through empirical research. For example, taking an empirical study on the relationship between commercial banks' diversification and their performance, Management JOI (2019) and Pisedtasalasai A, Edirisuriya P (2020) found that diversification strategies of commercial banks significantly improved corporate performance [7][8]. Sihite M (2018) took the Indonesian building automation system industry as the research object and found that the implementation of corporate diversification strategies can have a positive impact on corporate performance [9]. Secondly, the diversification discount theory is advocated by most scholars who believe that the diversification is negatively correlated with firm performance. Wu, Brian (2013) analyzed the impact of opportunity costs from the perspective of market demand and found that diversifications have a negative impact on enterprises under the current market environment [10]. Alawattegama k.k (2018) found that diversified operations increase the cost of monitoring activities in enterprises, leading to an increase in overall cost expenses and a negative impact on corporate performance. The negative effect of monitoring functions on corporate performance is more significant [11]. Duho KCT, Onumah J.M, Owodo R.A ,l(2020) conducted a regression analysis on the panel data of 32 banks in Ghana and found that diversified operations reduced profits, profit efficiency and financial stability [12]. The diversification neutrality theory believes diversification itself is neutral, and it mainly affects the business process, governance structure, organizational system and other aspects of the enterprise to affect the value of the enterprise. Some scholars select sample enterprises to carry out empirical research and confirm that diversification has no significant impact on enterprise performance [13][14][15].

To sum up, scholars have not yet formed a unified judgment on the relationship between diversification and enterprise performance. Since 2009, Chinese government has issued opinions on deepening the reform of the medical and health system. The rapid economic development and the stimulation of new medical reform policies have given rise to huge health investment opportunities, and the pharmaceutical industry has shown a wave of diversification. However, there are few empirical studies on the impact of diversification on the performance of pharmaceutical companies. Li XJ, H Xu HF (2011) selected the relevant data from 39 listed enterprises and conducted empirical research on the degree of diversification and the value of pharmaceutical enterprises. The results showed that the enterprise value of listed pharmaceutical manufacturing enterprises increased with the improvement in the degree of diversification [16]. Li Y, Shang Y (2021) analyzed the financial indicators of Jilin Aodong enterprises and concluded that the development of financial business harms enterprise performance [17]. Lu ZY (2023) found that Yunnan Baiyao lacked its core competitiveness and independent innovation ability in its diversified operation, which reduced its financial performance. It can be seen from the above, there is no consensus on the impact of diversified operation on the performance of pharmaceutical enterprises [18]. Based on this, this paper takes China's A-share pharmaceutical listed companies as the research object, analyzes the effect of the implementation of their diversified operation strategy, and empirically analyzes the impact on the performance of pharmaceutical enterprises from the perspectives of overall diversified operation, related diversified operation and non-related diversified operation. The main research content and framework are shown in Figure 1. Through the above research, this paper aims to provide a scientific analysis framework for the research of the relationship between diversification and enterprise performance, and to provide a basis for the formulation of diversification strategies and industry selection of China's Pharmaceutical enterprises.

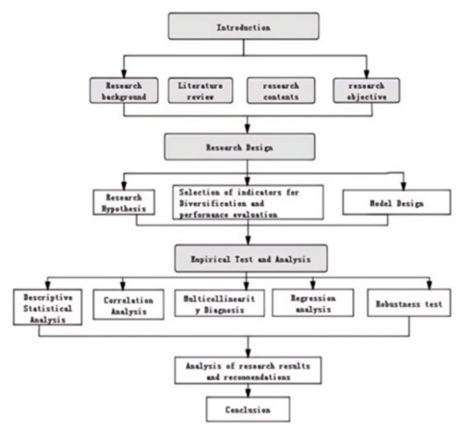

Figure 1 Main research content and framework

2. Research Design

2.1 Research Hypothesis

For the reason of diversification of business risks, most enterprises choose to take the diversification operations which expects to reduce the idle of the remaining resources, maximize their value, and seek greater space for enterprise development. In fact, the effects of diversification implementation vary widely. Some enterprises use a diversification strategy to enter a wider range of markets, expand more customer groups, and improve their performance [19], but it is a reverse case for some enterprises because of the implementation of diversification, which leads to weak cash flow, financial risk increase, and even business distress.

From the perspective of diversification classification, Ansoff (1957) classifies diversification into horizontal diversification, vertical integration, concentric circles, and unrelated diversification [3]. The first three categories are based on the original industries and products to take relevant diversification. Due to the strong correlation, more enterprises tend to carry out such diversification to form the internal market, form the internal economy, and improve the operating efficiency of enterprises, but it may also bring about a negative impact on enterprise performance like dispersed resource allocation, agency costs increase due to excessive expansion caused by blind confidence. Conversely, unrelated diversification refers to entering completely unrelated areas and seeking to provide profitable opportunities for businesses in different industries. Some enterprises make full use of their own surplus resources, use their existing good image to enter new markets, and then find new growth engines to improve corporate performance. Existing literature studies show that with the implementation of a diversification strategy, the performance of pharmaceutical enterprises decreases, indicating that there is a negative correlation, but the difference in the impact of different types of diversification on the performance of pharmaceutical manufacturing enterprises has not been explored. Therefore, the following hypothesis is proposed:

Hypothesis 1: There is a negative correlation between overall diversification and the performance of listed pharmaceutical companies in China.

Hypothesis 2: There is a negative correlation between related diversification and the performance of listed pharmaceutical companies in China.

Hypothesis 3: There is a positive correlation between unrelated diversification and the performance of listed pharmaceutical companies in China.

2.2 Sample Selection and Data Source

This paper selects the research samples of Shanghai and Shenzhen A-share listed companies in the pharmaceutical industry according to the industry classification of China Securities Regulatory Commission, collects the raw data of the sample companies from the CSMAR database, such as return on equity, operating income, total assets, asset-liability ratio, and the shareholding ratio of the largest shareholder during 2018-2022, and determines the performance indicators and relevant variable indicators. The diversification value is calculated based on the percentage of the operating income of each industry in the total income of the enterprise. Based on the principle of integrity and accessibility of corporate financial information, ST and companies with incomplete data are excluded, thus 31 samples of listed pharmaceutical companies are finally selected and SPSS software is used for empirical analysis.

2.3 Research Variables

2.3.1 Explained Variable

Enterprise performance (ROE): measured by return on equity, it is net profit as a percentage of average shareholders' equity. This ratio is not limited by industry, region, and other factors and can reflect the comprehensive efficiency of capital utilization. The higher the ROE, the better the profitability of the owner's equity and the higher the performance of the enterprise.

2.3.2 Explanatory Variable

Considering the accuracy, completeness of the data and the implement ability of the method, the Herfindahl index, which is widely used by scholars to measure corporate diversification, was selected as the explanatory variable. The smaller the index, the higher the degree of diversification of the pharmaceutical company; conversely, the lower the degree of diversification. This method takes into account the operating differences of various industries. Considering the accuracy, completeness of the data and the feasibility of the method, the Herfender Index H, which is widely used by scholars to measure corporate diversification, was selected as the explanatory variable. The smaller the index, the higher the degree of diversification of pharmaceutical company; conversely, the lower the degree of diversification. This method takes into account the operating differences of various industries. The calculation formula is as below:

$$H = \sum_{i=1}^{n} k_i^2 \qquad i=1,2,3\cdots n$$

H: Herfender Index, n: the number of industries in which the enterprise operates, k_i:Revenue by industry as a percentage of total revenue。

In addition, this paper introduces the dummy variable D of diversification. If the enterprise takes related diversification, then D=1; If the firm takes unrelated diversification, D= 0.

2.3.3 Control Variables

Referring to the previous literatures [20][21], the following control variables are selected:

Enterprise size: the specific value is the natural logarithm of total assets. The larger the scale of the enterprise, the more obvious advantages in production, sales, and other links, while providing a larger development platform to attract outstanding talents, all of which may improve the technical barriers of the enterprise, make the enterprise occupy a larger market share, affect the performance to a certain extent.

Asset-liability ratio: the ratio of a company's total liabilities to its total assets. An appropriate asset-liability ratio can provide capital leverage for enterprises, allowing capital to play a greater role in the business process and bring more benefits to the enterprise.

Sales growth rate: the ratio of an enterprise's sales growth in the current year to its total sales in the previous year. The higher sales growth rate means that the enterprise has obvious competitive advantages in the market environment and stable profits.

The shareholding ratio of the largest shareholder: the proportion of the capital contribution of the largest shareholder in the registered capital of the enterprise. The higher the shareholding ratio of the largest shareholder, the higher the shareholding concentration, and the shareholder has greater control and influence in the management decision, thus affecting corporate performance to a certain extent.

The specific research variables are listed in Table 1.

Table 1. Main variable definition and description

variable type	variable symbol	variable name	calculation formula
Explained variable (Enterprise performance)	ROE	return on equity	after-tax profit/net assets
Explanatory variable (Diversification)	H	Herfender Index	Sum of squares of income by industry accounts for total revenue
	D	dummy variable of diversification	related diversification=1; unrelated diversification=0
Control variables	LNASSET	enterprise size	the natural logarithm of total assets
	DEBT	asset-liability ratio	the ratio of a company's total liabilities to its total assets
	STLH	sales growth rate	enterprise's sales growth in the current year to its total sales in the previous year
	SHARE	shareholding ratio of the largest shareholder	the proportion of the capital contribution of the largest shareholder in the registered capital of the enterprise

2.4 Model Design

To further study the relationship between diversification and enterprise performance, this paper constructs the following models:

$$ROE= a+b1H +b2LNASSET +b3DEBT+b4SLTH+b5SHARE+\varepsilon \quad (1)$$

$$ROE= a+b1D +b2LNASSET +b3DEBT+b4SLTH+b5SHARE+\varepsilon \quad (2)$$

$$ROE=a'+b1'HD +b2'LNASSET +b3'DEBT+b4'SLTH+b5'SHARE+\varepsilon \quad (3)$$

$$ROE= a''+b1''HZ +b2''LNASSET +b3''DEBT+b4''SLTH+b5''SHARE+\varepsilon \quad (4)$$

ROE: return on equity, LNASSET: enterprise size, DEBT: asset-liability ratio,
SLTH: sales growth rate, SHARE: shareholding ratio of the largest shareholder,
H: the degree of diversification (HD: the degree of non-relevant operation, HZ: the degree of non-relevant operation), a: the constant term; b: the influence coefficient of each variable on corporate performance.
D: dummy variable of diversification, ε: random error.

3. Empirical Test and Analysis

3.1 Descriptive Statistical Analysis

It can be seen from the descriptive statistics results in Table 2:

(1) Return on equity (ROE): The difference between the maximum value and the minimum value of ROE is more than 90%, indicating that the performance of different enterprises is different and the gap is obvious, and some enterprises have better profits, while some enterprises harvest serious losses.

(2) Herfender Index (H): The mean value, minimum value, maximum value and standard deviation of the Herfindahl index of the sample enterprises are 0.5634, 0.2966, 0.9403, and 0.1651 respectively, indicating that there are differences in the time and degree of diversification among enterprises.

(3) Enterprise size (LNASSET): The mean of enterprises' size is 22.5275, and both the maximum and minimum values are above 20, showing a relatively stable enterprise scale has been formed because the samples selected are listed companies that have been listed for many years.

(4) Asset-liability ratio (DEBT): The mean of asset-liability ratio is 36.17%, the minimum value is 8.66%, and the maximum value is 71.48%. It is generally believed that the reasonable asset-liability ratio is not higher than 50%, indicating that the financial risk of the pharmaceutical industry is not high, but different enterprises vary in the financial risk.

(5) Sales growth rate (SLTH): The mean of sales growth rate is 10.56%, the maximum value is 1.123, and the minimum value is -85.91%, indicating that the gap in business performance between different enterprises is obvious.

(6) Shareholding ratio of the largest shareholder (SHARE): The maximum value of SHARE is 52.28%, the minimum value is 10.79%, and the mean is 29%, indicating that there are slight differences in the internal shareholding ratio of each enterprise. The higher the shareholding ratio of the largest shareholder, the more concentrated the ownership of the company, and at the same time, it has more decision-making power in corporate governance, which can more effectively promote the implementation of corporate strategy and thus affect corporate performance.

Table 2. Descriptive statistics

	ROE	H	D	LNASSET	DEBT	SLTH	SHARE
mean	0.0743	0.5634	0.6129	22.5275	0.3617	0.1056	0.2900
sd	0.1028	0.1651	0.4887	1.1363	0.1707	0.2478	0.0962
min	-0.5313	0.2966	0.0000	20.4196	0.0866	-0.8591	0.1079
max	0.4260	0.9403	1.0000	25.0363	0.7148	1.1232	0.5228

3.2 Correlation Analysis

To explore the relationship between variables, this paper conducts correlation analysis, and the results are shown in Table 3-Table 5.

As Table 3 shows, on the whole, at the 1% level, asset-liability ratio (DEBT) is significantly negatively correlated with corporate performance (ROE), enterprise size (LNSIZE) is significantly positively correlated with corporate performance (ROE), and the shareholding ratio of the largest shareholder (SHARE) is positively correlated with corporate performance (ROE) but not significantly correlated. In addition, neither D, H nor enterprise performance (ROE) pass the significance test. By case, it can be seen from Table 4 and Table 5 that related diversification (HD) and unrelated diversification (HZ) are significantly correlated with enterprise performance (ROE) at 5% and 1% respectively, which preliminarily validates hypothesis 2 and hypothesis 3. Furthermore, related diversification (HD) is not significantly correlated with the proportion of the largest shareholder (SHARE), while unrelated diversification (HZ) is significantly correlated with the proportion of the largest shareholder (SHARE) at 5%, indicating that the impact of the proportion of the largest shareholder on diversification is more significant in listed companies carrying out unrelated diversification.

Table 3. Correlation analysis of overall diversification on enterprise performance

	LNASSET	DEBT	ROE	SLTH	SHARE	D	H
LNSASSET	1						
DEBT	0.257***	1					
ROE	0.215***	-0.312***	1				
SLTH	0.052	-0.057	0.437***	1			
SHARE	0.319***	0.066	0.111	0.088	1		
D	0.133*	0.134*	-0.063	0.043	0.029	1	
H	0.100	-0.116	0.066	0.101	0.113	-0.185**	1

Note：*** indicates significance at the 1% level.; ** indicates significance at the 5% level; * indicates significance at the 10% level.

Table 4. Correlation analysis of related diversification on enterprise performance

	LNASSET	DEBT	ROE	SLTH	SHARE	HD
LNASSET	1					
DEBT	0.438***	1				
ROE	0.120	-0.302***	1			
SLTH	0.040	-0.117	0.549***	1		
SHARE	0.280***	-0.065	0.166	0.072	1	
HD	-0.124	-0.080	-0.232**	-0.099	-0.051	1

Note：*** indicates significance at the 1% level.; ** indicates significance at the 5% level; * indicates significance at the 10% level.

Table 5. Correlation analysis of unrelated diversification on enterprise performance

	LNASSET	DEBT	ROE	SLTH	SHARE	HZ
LNASSET	1					
DEBT	-0.246*	1				
ROE	0.473***	-0.324**	1			
SLTH	0.060	0.041	0.259**	1		
SHARE	0.389***	0.324**	0.019	0.108	1	
HZ	0.495***	-0.127	0.503***	0.349***	0.318**	1

Note: *** indicates significance at the 1% level.; ** indicates significance at the 5% level; * indicates significance at the 10% level.

3.3 Multicollinearity Diagnosis

To ensure the accuracy of regression results, this paper uses variance inflation factor VIF to test whether there is multidisciplinary between variables. The results in Table 6 show that the variance inflation factor VIF among the non-explained variables in each model is no more than 2.It is generally considered that the variance inflation factor VIF ≤10, and the selected variables can be further analyzed for regression.

Table 6. Multicollinearity diagnosis results

	VIF (1)	VIF (2)	VIF (3)	VIF (4)
LNASSET	1.201	1.202	1.422	1.68
DEBT	1.098	1.089	1.328	1.382
SLTLH	1.02	1.016	1.036	1.166
SHARE	1.127	1.12	1.141	1.564
H	1.047			
D		1.032		
HD			1.027	
HZ				1.575

3.4 Regression analysis

The four models constructed in this paper are further analyzed by multiple regression, and the results are shown in Table 7. As can be seen from Table 7, model 1 and model 2 do not pass the significance test. In Model 3, correlated diversification (HD) is significantly negatively correlated with enterprise performance (ROE) at 5% level, while in Model 4, unrelated diversification (HZ) is significantly positively correlated with enterprise performance (ROE) at 5% level.

Table 7. Regression analysis result

Model	ROE (1)	ROE (2)	ROE (3)	ROE (4)
Constant	-0.441*** (-3.184)	-0.314*** (-3.698)	-0.285 (-1.511)	-0.595*** (-2.398)
LNASSET	0.026*** (4.018)	0.020*** (4.980)	0.021** (2.373)	0.030*** (2.517)
DEBT	-0.223*** (-5.363)	-0.189*** (-7.430)	-0.211*** (-3.908)	-0.093 (-1.173)
SLTH	0.168*** (6.084)	0.124*** (7.339)	0.221*** (5.930)	0.052 (0.182)

SHARE	0.013 (0.176)	-0.065 (-1.422)	0.043 (0.429)	-0.164 (-1.424)
H	-0.030 (-0.717)			
D		-0.013 (-1.516)		
HD			-0.141** (-2.294)	
HZ				0.152** (2.488)
R-squared	0.353	0.471	0.444	0.407

Note: *** indicates significance at the 1% level.; ** indicates significance at the 5% level; * indicates significance at the 10% level.

3.5 Robustness test

Return on total asset (ROA) and return on equity (ROE) complement each other, which can reflect the efficiency of asset utilization. To ensure the accuracy of the empirical results, this paper selected return on assets (ROA) as a substitute variable for the explained variable to test the robustness of the model. As shown in Table 8,,there is no significant correlation between Herfindahl index (H) in model 1 and enterprise performance (ROA), and the coefficient of diversification dummy variable (D) in model 2 is negative, but it does not pass the significance test, which once again verifies that there is no significant relationship between overall diversification and enterprise performance. The Herfindahl index (H) of model 3 and model 4 are marked as negative and positive and are significant at 5% and 10% levels respectively. This is consistent with the previous regression results, showing that the models (1)-(4) and empirical results constructed previously are robust.

Table 8. Robustness test results

Model	ROA (1)	ROA (2)	ROA (3)	ROA (4)
Constant	-0.305*** (-3.559)	-0.314*** (-3.698)	-0.222** (-2.115)	-0.373** (-2.064)
LNASSET	0.020*** (4.837)	0.020*** (4.980)	0.016*** (3.293)	0.021** (2.444)
DEBT	-0.194*** (-7.567)	-0.189*** (-7.430)	-0.178*** (-5.926)	-0.129** (-2.230)
SLTH	0.123*** (7.237)	0.124*** (7.339)	0.166*** (8.004)	0.043 (0.127)
SHARE	-0.062 (-1.350)	-0.065 (-1.422)	-0.031 (-0.554)	-0.172* (-2.049)
H	-0.011 (-0.472)			
D		-0.013 (-1.156)		
HD			-0.068** (-1.989)	
HZ				0.094* (2.080)

Note: *** indicates significance at the 1% level.; ** indicates significance at the 5% level; * indicates significance at the 10% level.

Based on the above empirical analysis, conclusions can be drawn as follows:

(1) Herfindahl index (H) in model 1 is not significantly correlated with firm performance (ROE). Meanwhile, the multivariate dummy variable (D) in Model 2 is not significantly correlated with firm performance (ROE). The robustness test is consistent with the above conclusion. It shows that the overall diversification is not correlated with the performance of pharmaceutical manufacturing enterprises, and hypothesis 1 is rejected.

(2) In model 3, the related diversification (HD) is robust with a regression coefficient of -0.141 and a p value <0.05. The higher the degree of related diversification, the lower the performance of pharmaceutical manufacturing enterprises, which verifies hypothesis 2.

(3) In Model 4, the regression coefficient of unrelated diversification (HZ) is 0.152, which is significantly correlated with enterprise performance and is robust. It shows that the performance of pharmaceutical manufacturing enterprises increases with the increase of the degree of unrelated diversification and verifies hypothesis 3.

3.6 Analysis of research results and recommendations

3.6.1 There is no correlation between the overall diversification and the performance of pharmaceutical manufacturing enterprises.

Overall, diversification has no significant effect on the performance of pharmaceutical enterprises. pharmaceutical manufacturing enterprises should fully develop the main business, increase investment in technological innovation, management innovation, marketing innovation, and other aspects to form a competitive advantage, and then improve the resource support for moderate diversification based on core competitiveness.

3.6.2 Related diversification has a significant negative impact on the performance of pharmaceutical manufacturing enterprises.

Related diversification harms the performance improvement of pharmaceutical manufacturing enterprises. Pharmaceutical-related industries have high administrative entry barriers, strong monopoly power, and large entry costs for enterprises to carry out related diversified operations, and it is difficult to form a new growth engine in the short term. Therefore, pharmaceutical manufacturing enterprises should be cautious about the extension of upstream and downstream industries in the industrial chain and should not blindly expand and exacerbate business risks.

3.6.3 Unrelated diversification has a significant positive effect on the performance of pharmaceutical enterprises.

Unrelated diversification can promote performance improvement for pharmaceutical enterprises probably because the enterprise makes full use of its surplus resources and uses the good image of the enterprise to enter new markets of other industries to reap brand expansion and find new growth points. When pharmaceutical manufacturing enterprises carry out diversified business strategies, they should fully consider the industry and product according to their own conditions, and the time to enter.

4. Conclusion

Based on calculating the diversification degree of listed pharmaceutical enterprises with Herfindahl index, this paper empirically analyzes its relationship with the performance of pharmaceutical companies with SPSS software. The research results show that, on the whole, the implementation of a diversified management strategy of pharmaceutical companies has no significant impact on their performance. However, related diversification has a significant negative effect on the performance of pharmaceutical enterprises, while unrelated diversification has a significant positive effect on the performance of pharmaceutical enterprises. This provides insights for enterprise development direction on whether pharmaceutical enterprises should implement diversified business strategy and provides a reference for formulating guidance policies related to high-quality development of the pharmaceutical industry. This research has made some progress in the diversification of business, pharmaceutical industry and enterprise performance, but there are still some limitations. First of all, due to time and resource constraints, we only selected 31 China's A-share pharmaceutical listed companies, with A relatively small sample size, which may have affected the universality of the results. Secondly, in this study, relatively few variables were selected in enterprise performance measurement indicators and influencing factors, and the analysis framework does not fully cover all relevant factors such as risk level and external environment, leading to the neglect of some potential variables. In addition, in the specific classification of the diversified operations of pharmaceutical enterprises, it is also necessary to conduct qualitative analysis of the data, especially in the definition and judgment of related diversified businesses, which is easy to be affected by personal subjective factors, which will also have a certain impact on the research results. With the development of diversified management theory, it is expected that future studies can consider increasing the sample size, adopt more stringent data collection and analysis methods, and explore a more comprehensive analytical framework to further verify and expand the findings of this study, so as to provide more favorable guidance for the improvement of the competitiveness of pharmaceutical enterprises.

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Pricing, Capacity and Estimated Wait Times Decisions in the Ride-Hailing

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Abstract. In recent years, the ride-hailing platform enables the passengers to request a ride from a private vehicle driven by a non-commercially licensed driver and provides them the information of estimated wait times (EWT). These EWT announcements significantly affect the service experience. However, it is unclear whether the drivers or the platform is more appropriate to determine the EWT in the ride-hailing service for gaining more profit for the platform and drivers. In this pursuit, the present study envisaged the development of two models, i.e., the platform set EWT (Model P) and drivers set EWT (Model D) by combining the decisions about capacity and price. We formulated the model as a leader-follower game and obtained Stackelberg equilibrium solutions. Our results show that the platform should pay attention to the capacity cost. The high-capacity cost aggravates the cost burden of the platform in Model (P); therefore, the platform should entitle more autonomy to the drivers for decreasing the total cost. If the platform sets a shorter EWT than the drivers, Model (P) can be considered as a more favorable choice for both players. When the EWT decision of the platform is moderately longer than the EWT decision of drivers, the platform entitles drivers to determine the EWT, which generates a win-win situation.

Keywords. Sharing economy, ride-hailing service; estimated wait times; pricing strategy; capacity strategy

1. Introduction

In recent years, the "sharing economy" has emerged as an efficient way to utilize the surplus resources and transform the consumption of the consumers, i.e., from the exclusive ownership and consumption of resources to that of shared use and consumption [1]. A number of new service business models have emerged. Some widely known examples include accommodation (e.g., Airbnb, Roomorama), ride sharing (e.g., Uber, Lyft), and car sharing (e.g., RelayRides, Zipcar).

A peer to peer (P2P) sharing service platform generally connects the individual service provider and the customer. The convenience of the ride-hailing service appears to make it more appealing than the current alternative transportation modes [2]. However,

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some passengers cancel orders due to the long waiting time for the allocation of order or pick-up [3]. Passengers argue that they tend to choose the ride-hailing service on the basis of the feedback of the wait times, in order to reduce the uncertainty of service availability [4]. In comparison between the taxi service and ride-hailing service, passengers mention that uncertain taxi wait times reduce the taxi service quality and highlight the important role of feedback of wait times of ride-hailing service.

As these estimated wait times (EWT) announcements are widely used to inform passengers about the anticipated ride time, a major question arises: in order to gain more profit for the platform and drivers, who should determine the estimated wait times appropriately, the platform or drivers? The platform takes advantage of information from bigdata to provide precise estimation of the wait times. In reality, the platform plays the major part in providing the estimated wait times. It is also responsible for the delay of the ride. Though the advances in the information technology provide an accurate prediction, drivers, who work as independent contractors, have a better knowledge of themselves and their condition of the working day. Thus, whether the drivers or the platform remains appropriate to make the EWT decision seems ambiguous.

In the present study, we compared the impacts of different EWT decision makers on the performance in the ride-hailing service, and obtained appropriate EWT decision makers to gain more profit for the platform and drivers. We considered a ride-hailing platform connecting independent drivers and passengers, where the drivers were homogeneous. We presented two cases, i.e., the platform sets EWT (Model P) and drivers set EWT (Model D), combined with the integration of capacity and pricing decisions.

Our results show that the relationship between the platform's profits in both models intimately relates to the difference of the optimal EWT decisions and the capacity cost. Our analysis suggests that the platform should choose Model (D) for more profit when optimal EWT decisions get close to each other, else Model (P) could be more favorable. The drivers' strategy depends on the difference between the arrival rates in both models, which is related to the price sensitive factor and the time sensitive factor. Players in the business should take account of riders' characteristics when they make decisions.

The manuscript is organized as follows. In Sections 2, we reviewed the related literature related to the present study. In Section 3, we developed the mathematical model in detail and obtained the Stackelberg equilibrium analysis. We started our analysis with models, i.e., EWT was determined by the platform (Model P) or drivers (Model D). We examined the performance of both models and analyzed the sensitivity of optimal decisions to some parameters. In Section 4, we compared Model (D) with Model (P) with respect to the performance. In Section 5, we present the conclusion with a discussion of limitations of the study and directions for future research.

2. Literature Review

The present study considers three different research streams: operations management of taxi service such as price mechanism, pricing strategy of ride-hailing service, and the ride-hailing service considering the wait times.

Several researchers investigated the pricing problem in the taxi market by taking into account the vacancy rate [5] and considering the nonlinear price mechanism [6]. A small number of papers studied the customer-search problem in the taxi market [7-8]. We adhered to this stream and made comparable assumptions.

Our research focuses on the pricing decision of ride-hailing service (e.g., [9-10]). [11] suggested that the dynamic pricing could guarantee a high service experience during rush hours. [12] developed a two-period model to investigate the dynamic pricing in two nearby zones and argued that dynamic pricing might increase the platform's profit and be even useful in the area where service supply is sufficient. From an extensive review on the research of the ride-hailing service, we refer readers to the report of [13]. Based on the above literature, we studied the price strategy of ride-hailing service. However, we also explored the impact of EWT decision on the price decision.

Many studies focused on the ride-hailing service related to the wait times. [14] investigated the emerging market equilibria in pooled and non-pooled systems considering the wait times. Additionally, several researchers took into account the impact of delay sensitivity on the demand [1,15]. [16] employed the reinforcement learning-based methods to study the optimal delayed matching for ride-hailing service and provided a solution to overcome the curse of dimensionality and sparse reward issues. In contrast to the above studies, we tried to understand that who (drivers or the platform) was more appropriate to determine the EWT.

3. Model

We considered a ride-hailing service market consisting of multiple part-time drivers and a platform that serves impatient and time sensitive heterogeneous passengers. The arrival rate of passengers depends on the price p and estimated wait times w , i.e., $d_i(p_i,w_i)=\Lambda-\alpha p_i-\beta w_i$, ($i=P,D$), where Λ is the demand, α and β are coefficients of price sensitivity and the estimated wait times sensitivity, respectively. Note that we assume that the platform decides the EWT and bears the tardiness cost in Model (P). In contrast to Model (P), the platform sends the order to several online drivers that are entitled to determine which customers to offer their service to in Model (D). The subscript P and D denote Model (P) and Model (D).

3.1 Model P

In Model P, the platform determines the capacity μ_p of ridesharing, as well as the estimated wait time w_P. The price per ride p_P is determined by the price multiplier ϕ_P set by the drivers and the reference price p_r set by the platform, so that $p_P=\phi_P p_r$. It should be noted that p_r is assumed as an exogenous variable.

Drivers The drivers' costs include the cost c_d for fuel and maintenance in each ride and the commission charged by the platform θ . Thus, the optimization problem of drivers is given by $Max \quad \Pi_d^P=((1-\theta)\phi_P p_r-c_d)d_P$.

Platform The platform aims to realize the maximum profit, which can be expressed as $Max \quad \Pi_p^P=(\theta\phi_P p_r-ke^{-(\mu_P-d_P)w_P})d_P-c_\mu\mu_P$, where k represents the tardiness cost, once the realized wait times exceeds EWT. Similar to [17], we assume $1-e^{-(\mu_P-d_P)w_P}\geq s$ is held. Note that s is the required service level.

3.2 Model D

In Model D, the platform should determine the capacity of ridesharing μ_D. Drivers decide the price multiplier ϕ_D, and the estimated wait times w_D simultaneously.

The profit function of both the drivers and the platform is similar to those in Model P. We only change the tardiness cost from the platform's profit function to the drivers' profit function. Thus, the optimization problem of drivers is

$$Max \quad \Pi_d^D = ((1-\theta)\phi_D p_r - c_d - ke^{(\mu_D - d_D)w_D})d_D, \tag{1}$$

subject to

$$1 - e^{-(\mu_D - d_D)w_D} \geq s. \tag{2}$$

Similar to Model P, constraint (7) restrains the service level.

The optimization problem of the platform is derived as

$$Max \ \Pi_p^D = \theta\phi_D p_r d_D - c_\mu \mu_D, \tag{3}$$

3.3 Optimal Solution

Several cases of the taxi market equilibrium problem were described as a Stackelberg game. It considers that the leader is the regulator and the taxi firm is the follower. Since the ride-hailing service resembles the taxi service, we also formulated the problem as a leader-follower game and employed backward induction to obtain the Stackelberg equilibrium solutions. In Model P, the leader is the platform, while the leader in Model D is the driver.

- **Model P**

Drivers' strategy: We first present the drivers' best response to the platform's decisions, as shown in the following proposition.

Lemma 1. Given w_P, the drivers' profit is concave in ϕ_P, and the optimal price multiplier ϕ_P^* is given by $\phi_P^* = \dfrac{\Lambda - \beta w_P}{2\alpha p_r} + \dfrac{c}{2p_r}$. Moreover, the optimal price p_P^* can be expressed as $p_P^* = \dfrac{\Lambda - \beta w_P}{2\alpha} + \dfrac{c}{2}$, where $c = \dfrac{c_d}{1-\theta}$.

The proof of this lemma as well as all the other proofs in this manuscript are given in the appendix.

From Lemma 1, we find that in order to achieve non-negative profit of drivers ($\phi_P \in [\dfrac{c}{p_r}, \dfrac{\Lambda - \beta w_P}{\alpha p_r}]$), EWT should not be greater than $\dfrac{\Lambda - \alpha c}{\beta}$.

Platform's strategy: The platform determines the capacity of ride-hailing service μ_P and the estimated waiting time w_P.

Proposition 1 indicates that the platform cannot earn a positive profit, unless w_P falls on the feasible interval. Note that we assume $d_P(c, \frac{\ln \vartheta}{\mu_P}) = \Lambda - \alpha c - \frac{\beta \ln \vartheta}{\mu_P} \geq 0$, i.e., there is positive demand to provide the service when the smallest reasonable price, c, and the shortest EWT, $\frac{\ln \vartheta}{\mu_P}$, satisfy the Constrain (2). If this assumption is not satisfied, neither the platform nor drivers can gain a positive profit.

- **Model D**

In contrast to Model (P), we assume that the drivers have a better knowledge of the shortest possible ride time T_{wD}^L in Model D, that is, $T_{wD}^L \leq T_{wD}^U$, where T_{wD}^U is the upper bound of EWT, so that drivers could gain positive profit. Otherwise, the problem will become nontrivial. Thus, EWT should be within $[T_{wD}^L, T_{wD}^U)$.

From Proposition 3, we find that the optimal EWT of Model (D) is the shortest possible ride time provided by drivers. In order to avoid the tardiness costs, drivers provide the appropriate shortest possible ride time according to their own situation.

4. Results of Comparison

The difference between the optimal arrival rates is given by $\Delta d = d_P^* - d_D^* = \frac{-\beta \Delta w + \alpha \Delta C}{2}$. Under the condition of $w_P^* \geq w_D^*$, if and only if drivers offer a much shorter EWT, Model (D) attracts more passengers.

The difference of the optimal capacity in both models is derived as $\Delta \mu = \mu_P^* - \mu_D^* = \ln \vartheta (\frac{1}{w_P^*} - \frac{1}{w_D^*}) + (d_P^* - d_D^*) = -\frac{\ln \vartheta}{w_P^* w_D^*} \Delta w + \Delta d$. When the platform offers a shorter EWT, Model (P) needs more capacity. If drivers provide a short EWT, but if it is similar to EWT offered by the platform, the platform will still set a higher capacity in Model (P). In contrast, if the drivers could provide a much shorter EWT, the platform in Model (D) needs more capacity.

Proposition 1

(1) Drivers prefer Model (P) when $\Delta w \in (-\infty, -\frac{\alpha}{\beta} \Delta C]$;

(2) Platform prefers Model (P) when $\Delta T \in (-\infty, \Delta w_1)$ and $\Delta T \in (\Delta w_2, +\infty)$.

Proposition 1 indicates that the platform and drivers make a consistent decision in two scenarios: (i) the optimal EWT is much shorter in Model (P) than in Model (D); (ii) the optimal EWT is moderately higher in Model (P) than in Model (D). In the first scenario, both players favor Model (P), in which the EWT decision is made by the platform. In the other scenario, they prefer Model (D) in which drivers have more autonomy to set the EWT.

5. Conclusion and Future Research

In the present study, we observed that a ride-hailing market consisted of two independent players- the drivers and a platform that make decisions about the price multiplier, the estimated wait times and the capacity. We compared the demand, capacity and model selection of both players. Comparing Model (P) with Model (D), we specifically address under what conditions the platform determines the EWT more appropriately. Interestingly, the results indicate that the platform and drivers make a consistent decision in two scenarios: (i) the optimal EWT is much shorter in Model (P) than in Model (D); (ii) the optimal EWT is moderately higher in Model (P) than in Model (D). In the first scenario, both players favor Model (P), in which the EWT decision is made by the platform; while in the other scenario they prefer Model (D), in which drivers have more autonomy to set the EWT. The results emphasize the importance of the gap of the optimal EWT. Hence, players in the ride-hailing service should be concerned about the difference in the optimal EWT decisions.

Several extensions to our model are worth further investigation. First, our model and results are considering a sole one ride-hailing service platform. While, there always exist more than one platform in the ride-hailing service market in practice, such as Uber and Lyft. Since riders and drivers can choose one or more service platforms, it would be meaningful to investigate the decisions made by players in the competition setting and examine the interaction between multiple platforms. Second, an empirical study of the effect of EWT decision on the riders' arrival rate, the service experience, as well as the profitability of the platform and drivers needs a further investigation.

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Bionic Furniture Design Based on Digital Quantification Research: Application of Semiotics and Semantics

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Abstract. This study aims to explore the application of semiotics and semantics in bionic furniture design, incorporating digital quantitative research methods to uncover consumers' needs and preferences. By utilising user preference surveys, market analysis data, and user feedback, the study reveals key insights into bionic furniture design. It was found that semiotics enhances the cultural depth and aesthetic value of designs by drawing on natural symbols, while semantics aids designers in better understanding users' cognitive and emotional responses, thus optimising the functionality and experience of bionic furniture. The results demonstrate that comfort, design style, and functional requirements in bionic furniture design are closely linked to consumers' purchase intentions. Through digital quantitative analysis, this study offers an innovative theoretical framework and practical guidance for future bionic furniture design, helping designers create products that align more closely with market demands.

Keywords. Digital Quantification, Bionic Furniture Design, Symbolic Design, Semantic Design

1. Introduction

Semiotics and semantics, as crucial theoretical tools for studying symbol systems and the generation of meaning, hold great potential in design, particularly in bionic design [1]. By interpreting and applying natural symbols, semiotics enables designers to create works with deeper cultural and emotional resonance [2]. Semantics, which examines the meaningful interactions between users and design objects, helps guide designers to better understand user needs, thus optimising functionality and enhancing the user experience [3].

Through digital quantitative research methods, designers can more accurately capture and analyse user preferences, market demands, and other relevant data, providing strong support for design decisions [4]. By integrating semiotic and semantic theory with digital quantitative research methods, innovative design solutions can be developed that better meet user needs in bionic furniture design.

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1.1. Research Questions and Objectives

The primary aim of this study is to explore the systematic application of semiotics and semantics in bionic furniture design, with the goal of enhancing the cultural depth, aesthetic value, and overall user experience. The key objective of this research is to propose an innovative approach to bionic furniture design by integrating semiotics and semantics with digital quantification research methods. This will provide a systematic theoretical framework and practical tools for designers. The findings aim to offer a fresh perspective on bionic furniture design, enabling designers to create products that embody cultural significance, aesthetic appeal, and user-centric functionality.

1.2. Research Innovation

This study represents a novel intersection of semiotics, semantics, and bionic design, which has been relatively underexplored in the context of bionic furniture. By combining theory and practice, it proposes an innovative design methodology. Whereas most previous design studies have relied primarily on qualitative analysis, this research introduces digital quantitative methods to gain a more precise understanding of user needs and market trends through big data analysis, thus providing solid data-driven support for design decisions. Additionally, by applying semiotics and semantics, this study not only focusses on the functional aspects of bionic furniture but also on enhancing its cultural significance and the emotional experience of users. This approach opens up a new developmental direction for bionic furniture design.

2. Literature Review

In this research, semiotics, semantics, bionic design, and digital quantification methods form the core theoretical foundation. These theories and approaches not only offer fresh perspectives and tools for innovation in bionic furniture design but also demonstrate their unique value and potential for practical application.

2.1. Semiotics and Design

Semiotics, the study of symbolic systems and meaning making, is rooted in the linguistic theories of Ferdinand de Saussure and the philosophical ideas of Charles Saunders Peirce [5]. Saussure introduced the relationship between the "signifier" (the form of a sign) and the "signified" (the concept it represents), emphasising the dual structure in which the signifier acts as the carrier of meaning. Designers use elements such as form, colour, and material not only to create functional objects but also to imbue them with cultural significance and emotional resonance. By employing semiotic principles, designers can craft products that go beyond functionality, creating deeper connections with users through symbolic representation [6].

2.2. Semantics and Design

Semantics is concerned with the meaning of language and symbolic systems, focusing on how meaning is generated and understood in context [7]. Key concepts in semantics include lexical meaning, syntactic structure, context, and implied meaning. While semiotics emphasises the structure of signs, semantics is more focused on how meanings−particularly linguistic ones−are interpreted and conveyed[8]. In design, semantics plays a crucial role in how users interact with design objects. Design objects are more than just physical entities; they communicate through their form, material, and function, resonating with users' cognitive and emotional responses. By applying semantic principles, designers can predict and understand how users will interpret and engage with their designs, allowing them to optimise both functionality and user experience to meet expectations more effectively [9].

2.3. Bionic Furniture Design

Bionic design, which emerged in the early 20th century, draws inspiration from nature's forms, structures, and functions to apply them in human design and technological innovation[10]. The core principle of bionic design is to mimic the efficiency, sustainability, and intelligence of natural systems, aiming to create products and technologies that are more environmentally friendly and effective. In furniture design, bionic design takes cues from nature to develop furniture that is not only aesthetically pleasing but also functional [11]. This can involve mimicking natural forms, materials, and structural efficiencies. For example, furniture can be designed with lightweight, high-strength properties by emulating plant growth structures or incorporate surface materials with self-cleaning properties modelled after animal skins. The goal is to enhance both the appearance and the underlying structure and function of the furniture, creating pieces that offer both beauty and utility.

2.4. Digital Quantitative Research Methods

Digital quantification research is a data-driven approach that uncovers design patterns and user needs through statistical analysis and algorithmic models. Large-scale user research and behavioural data analysis can reveal latent user needs and preferences, providing designers with focused direction [12]. Market data and trend analysis models also help predict future design trends and consumer behaviours, forming a foundation for strategic design decisions. Additionally, quantitative evaluation of user experiences helps identify and rectify issues within the design, leading to improved user satisfaction and increased market competitiveness.

In the context of bionic furniture design, digital quantitative research methods allow designers to gauge user acceptance of bionic elements and understand how different design features influence user emotions and perception. By integrating digital quantitative research with semiotics and semantics, designers can create furniture that not only meets market demands but also maintains strong aesthetic and cultural values.

3. Research Method

This study aims to explore the application of semiotics and semantics in bionic furniture design through quantitative research. The research methodology consists of four key steps: research design, selection of research subjects, questionnaire design and implementation, and data processing.

3.1. Research Design

A research framework for bionic furniture design was constructed based on the theories of semiotics and semantics. The literature review provided the foundation for the study and helped define key variables and assumptions. Questionnaires were developed to gather data on user preferences and needs related to bionic furniture design, covering aspects such as users' perception, aesthetic preferences, and functional requirements. After collecting the questionnaire data, statistical methods such as descriptive statistics and multiple regression analysis were employed to uncover the relationship between user preferences and design elements.

To ensure the validity and representativeness of the data, the study selected consumers interested in furniture design and actual purchasing needs. The sample included participants from various age groups, genders, occupational backgrounds, and cultural contexts. A total of 498 valid questionnaires were collected, ensuring the reliability and scientific rigour of the data analysis.

3.2. Questionnaire Design and Implementation

This study utilised a questionnaire survey method, divided into four main sections. The first section collected basic demographic information about the respondents, such as gender, age, education, and income level. The second section assessed respondents' understanding and preferences regarding bionic furniture design, including evaluations of key design elements like form, material, and color. The third section focused on functional requirements, investigating respondents' needs and expectations concerning practicality, comfort, and functional diversity in bionic furniture. The questionnaire used a five-point Likert scale, with responses ranging from "strongly agree" to "strongly disagree," corresponding to scores of 5, 4, 3, 2, and 1, respectively. The specific questionnaire questions are detailed in Table 1 and Table 2.

Table 1. The questionnaire design for assessing perception and preferences regarding bionic furniture design

The questionnaire design for assessing perception and preferences regarding bionic furniture design
Q2-1: I am very familiar with bionic design.
Q2-2: I like the design style of bionic furniture.
Q2-3: Bionic design influences my furniture purchasing decisions.
Q2-4: I like the shape design of bionic furniture (e.g., mimicking the forms of animals or plants).
Q2-5: I appreciate the material design of bionic furniture (e.g., using natural or biomimetic materials).
Q2-6: I like the colour design of bionic furniture (e.g., incorporating natural tones).
Q2-7: I appreciate the functional design of bionic furniture (e.g., multi-functional features).
Q2-8: I enjoy the comfort of bionic furniture (e.g., in terms of seating or tactile experience).
Q2-9: I like the incorporation of natural elements (e.g., animals or plants) in bionic furniture.

Table 2. Questionnaire design for functional needs and expectations of bionic furniture design

Questionnaire design for functional needs and expectations of bionic furniture design
Q3-1: I am very satisfied with the performance of bionic furniture.
Q3-2: I believe bionic furniture provides a high level of comfort.
Q3-3: Bionic furniture makes me feel happy and joyful.
Q3-4: I find bionic furniture to be highly practical.
Q3-5: I think bionic furniture is aesthetically pleasing.
Q3-6: I believe bionic furniture offers me emotional comfort.
Q3-7: I prefer bionic furniture to be unique.
Q3-8: I feel safe and secure when using bionic furniture.
Q3-9: Bionic furniture meets my emotional needs.
Q3-10: If such a bionic furniture design exists, I would recommend it to friends and family.

4. Data Analysis and Results

4.1. Descriptive Statistics

In this study, 498 participants from various regions of China were surveyed. Descriptive statistics reveal that 36.75% of the participants were male, while 57.23% were female. In terms of age, the largest group was "20 to 30 years old," accounting for 68.88% of the participants, while the "over 60 years old" category had the lowest representation at 0.00%. Regarding educational background, "undergraduate" was the most common level of education, making up 53.21% of respondents, while "doctoral" was the least common, at 2.81%. In terms of income, the majority (69.08%) reported earning between 50,000 and 100,000 yuan annually, with only 7.03% earning more than 100,000 yuan.

4.2. Descriptive Statistics

The second section of the questionnaire focusses on participants' perception and preferences regarding bionic furniture design, including their opinions on aspects such as form, material, and colour, as detailed in Table 3. For question 2-8, "I like the comfort design of bionic furniture (e.g., the feeling of sitting and touching)," the average score was the highest at 4.03. In contrast, for question 2-6, "I like the colour design of bionic furniture (e.g., the use of natural colours)," the average score was the lowest at 2.84.

The third section of the questionnaire focusses on consumers' functional requirements and expectations for bionic furniture design, as shown in Table 4. Question 3-2, "I believe bionic furniture will provide a high level of comfort," had the highest mean value of 4.03. In contrast, question 3-5, "I find bionic furniture very beautiful," had the lowest mean value at 2.49.

Table 3. Descriptive statistics on consumers' perception and preferences regarding bionic furniture design

Question	N	Mean	Std. Deviation
Q2-1	498	3.24	1.192
Q2-2	498	3.79	1.262
Q2-3	498	3.78	1.181
Q2-4	498	3.08	1.243
Q2-5	498	3.00	1.200
Q2-6	498	2.84	1.332
Q2-7	498	3.07	1.233
Q2-8	498	4.03	1.167
Q2-9	498	3.81	1.154

Table 4. Descriptive statistics on functional requirements and expectations for bionic furniture design

Question	N	Mean	Std. Deviation
Q3-1	498	3.12	1.160
Q3-2	498	4.03	1.175
Q3-3	498	3.55	1.155
Q3-4	498	2.99	1.209
Q3-5	498	2.49	1.256
Q3-6	498	3.68	1.095
Q3-7	498	3.60	1.129
Q3-8	498	3.62	1.198
Q3-9	498	3.66	1.092
Q3-10	498	3.21	1.252

Based on the top three highest average scores from the second section of the questionnaire, a correlation analysis was conducted with the consumer expectations from the third section. The analysis utilised Pearson's chi-square test (X^2), degrees of freedom (*df*), and significance analysis (*p*) in SPSS software. Pearson's chi-square test examines the independence or association between two categorical variables by comparing the observed frequencies with the expected frequencies, determining if there is a statistically significant association between the variables. In this study, the test helps identify the relationship between consumers' perception and preference for bionic furniture and their functional needs and expectations for its design.

Degrees of freedom represent the independent pieces of information in a statistical model that are used to calculate the test statistic. They indicate how much of the data can vary without impacting the model's outcomes, providing further clarity on the chi-square test results and ensuring the conclusions' reliability and validity.

Significance analysis calculates *p*-values to determine whether the statistical results are significant. The p-value reflects the probability of observing the given result (or a more extreme one) if the null hypothesis is true. Generally, a *p*-value of less than 0.05 ($p < 0.05$) indicates a significant association.

As shown in Table 5, the chi-square statistics for most of the questions reveal a high level of significance ($p < 0.05$), indicating a significant association between "perception and preference for bionic furniture design features (comfort, Q2-8)" and "consumer functional requirements and expectations for bionic furniture design." This suggests that the comfort aspect of bionic furniture design has a significant influence on consumers' functional needs and expectations.

As shown in Table 6, the chi-square test results for "consumer perception and preference for bionic furniture design features (design style, Q2-2)" and "functional requirements and expectations for bionic furniture design (Q3-1 to Q3-10)" indicate that all chi-square statistics were statistically significant ($p < 0.05$). This suggests that the "design style" aspect of bionic furniture has a significant impact on consumers' functional needs and expectations. Therefore, when designing bionic furniture, the choice of design style plays a crucial role in enhancing consumer satisfaction and purchase intention.

Table 5. Analysis of the correlation between consumers' perception and preference (comfort) for bionic furniture design characteristics and their functional requirements and expectations for bionic furniture design.

Question	X^2	*df*	*p*
Q3-1	.289	4	.000
Q3-2	.255	4	.000
Q3-3	.310	4	.000
Q3-4	.293	4	.000
Q3-5	.244	4	.000
Q3-6	.255	4	.000
Q3-7	.234	4	.000
Q3-8	.197	4	.000
Q3-9	.224	4	.000
Q3-10	.125	4	.005

Table 6. Correlation analysis between consumer perception and preference (design style) for bionic furniture design features and functional requirements and expectations for bionic furniture design.

Question	X^2	*df*	*p*
Q3-1	.193	4	.000
Q3-2	.212	4	.000
Q3-3	.294	4	.000
Q3-4	.170	4	.000
Q3-5	.120	4	.001
Q3-6	.283	4	.000
Q3-7	.305	4	.000
Q3-8	.255	4	.000
Q3-9	.224	4	.000
Q3-10	.178	4	.000

As shown in Table 7, the chi-square test results for "Consumers' perception and preference for bionic furniture design features (influence on purchase, Q2-3)" and "functional requirements and expectations for bionic furniture design (Q3-1 to Q3-10)" reveal that all chi-square statistics were statistically significant ($p < 0.05$). This indicates that the bionic design of furniture significantly influences consumers' functional requirements and expectations. Moreover, bionic design impacts consumers' purchasing decisions. Therefore, when designing furniture, incorporating bionic elements is an important guiding factor, and designers should focus on this aspect to enhance consumer satisfaction and overall user experience.

Table 7. Correlation analysis of "bionic furniture design characteristics (influence on purchase)" and "functional requirements and expectations for bionic furniture design."

Question	X^2	*df*	*p*
Q3-1	.156	4	.000
Q3-2	.233	4	.000
Q3-3	.267	4	.000
Q3-4	.137	4	.002
Q3-5	.113	4	.001
Q3-6	.321	4	.000
Q3-7	.258	4	.000
Q3-8	.232	4	.000
Q3-9	.228	4	.000
Q3-10	.154	4	.001

4.3. Linear Regression Analysis

The primary goal of linear regression is to identify which factors significantly influence consumer expectations, providing valuable insights for product design. The results help researchers understand and explain how consumer perceptions and preferences affect their expectations.

The model summary (Table 8) shows that, although the R-squared values are relatively low (all below 0.2), the influence of all independent variables on consumer expectations is statistically significant. This suggests that these variables can explain consumer expectations for bionic furniture design to some extent. The significance tests (p-values) in the ANOVA table (Table 9) and the coefficients table (Table 10) are all below 0.05, indicating that the variables of comfort, design style, and influence on purchase have a significant impact on consumer expectations. The scatter plot in Figure 1 demonstrates a positive relationship between consumer perceptions and preferences and consumer expectations, further validating the regression model.

Table 8. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Comfort	.1826[a]	.0405	.0385	1.1499
Design Style	.2134[a]	.0517	.0497	1.1431
Influence on Purchase	.1999[a]	.0467	.0449	1.1461

a. Predictors: Comfort, Design Style, Influence on Purchase

Table 9. ANOVA[a]

Model		Sum of Squares	*df*	Mean Square	F	Sig.
Comfort	Regression	26.435	1	26.4357	21.3667	.0413[b]
	Residual	658.058	496	1.3266		
	Total	684.493	497			
Design Style	Regression	34.1816	1	34.1816	27.5357	.005[b]
	Residual	650.3118	496	1.3112		
	Total	684.4934	497			
Influence on Purchase	Regression	30.5661	1	30.5661	24.8195	.0079[b]
	Residual	653.9274	496	1.3183		
	Total	684.4935	497			

a. Dependent Variable: Consumer Expectations
b. Predictors: Comfort, Design Style, Influence on Purchase

Table 10. Coefficients[a] (a. Dependent Variable: Consumer Expectations)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.673	.173		15.527	.000

Comfort	.1712	.0441	1738	3.9843	.0413
Design Style	.1957	.0405	2134	4.9076	.005
Influence on Purchase	.1953	.0434	1999	4.5867	.0079

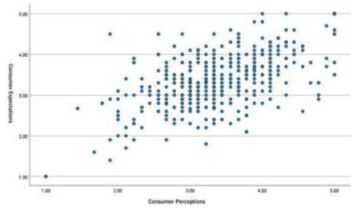

Figure 1. Scatter plot of consumer expectations against consumer perceptions.

5. Results Discussion

Based on the analysis of data from 498 respondents, the results show that consumers have varying preferences for different design elements of bionic furniture. Comfort, such as the sitting and tactile experience, received the highest evaluation, with an average score of 4.03. This indicates that consumers place a high value on the comfort of furniture, aligning with the core principle of biomimetic design, which aims to optimise the user experience by mimicking natural forms and functions. However, colour design received the lowest recognition, with an average score of 2.84. This suggests that the use of natural colours may not fully satisfy the aesthetic preferences of modern consumers. Designers may need to strike a balance between traditional natural elements and contemporary fashion colours to better appeal to consumer tastes.

In terms of functional requirements, comfort remains the top priority, with an average score of 4.03, reaffirming the critical role of comfort in bionic furniture design. On the other hand, aesthetics received a lower score of 2.49, indicating that there is room for improvement in the visual appeal of bionic furniture currently available. This may be due to the fact that some designs prioritise functionality over visual aesthetics. Additionally, consumers rated safety, uniqueness, and emotional needs highly, showing that they not only expect practical functionality but also psychological comfort from bionic furniture. This suggests that future designs should emphasise emotional engagement, utilising bionic elements to create a deeper emotional connection with users.

The data analysis in this study demonstrates the significant impact of semiotics and semantics in bionic furniture design. The chi-square test results indicate a statistically significant relationship between the comfort and design style in bionic furniture and consumers' functional needs and expectations. This suggests that the cultural and emotional messages conveyed through natural forms and symbols have a direct influence on consumer preferences. For instance, consumers showed a high level of acceptance for natural elements in bionic furniture, such as designs imitating the forms of animals and plants (Q2-9, with an average score of 3.81). This validates the importance of semiotics in bionic design, where natural symbols enhance the cultural and aesthetic value of furniture by conveying specific cultural and emotional meanings.

6. Research Value and Insights

By integrating semiotics and semantics into bionic furniture design and applying digital quantitative research methods, this study underscores the pivotal role of bionic design in meeting user needs and enhancing cultural connotation and aesthetic value. The use of digital quantification provides robust data to support design decisions by revealing consumer preferences for bionic furniture.

Through linear regression analysis, the study identified comfort, design style, and purchase influence as key factors affecting consumer expectations for bionic furniture design, with statistically significant relationships between these factors. This suggests that combining semiotics, semantics, and digital analysis enables designers to better address consumers' functional needs while enhancing the market competitiveness of products.

The findings suggest that future bionic furniture design should further explore comfort and emotional resonance, using semiotics and semantics to better understand and incorporate natural symbols, creating designs with rich cultural meaning and visual appeal. Additionally, colour and aesthetic choices should align with modern trends to increase consumers' desire to purchase. By continuously refining symbolic communication and emotional feedback in the design process, bionic furniture will have greater market potential and user appeal.

In conclusion, this study provides a new perspective on bionic furniture design by combining semiotics, semantics, and digital quantification methods, laying a strong foundation for future developments in the field.

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Water Resource Capacity Using EFDC Model and Big Data Technology: A Case Study of Dongjiang Lake, Chenzhou

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Abstract. Based on field monitoring results, this study employed the environmental fluid dynamics code (EFDC) model to examine the water resource capacity and hydrodynamic water quality of Dongjiang Lake and establish the two-dimensional hydrodynamic water quality model in line with the actual condition of Dongjiang Lake. From the attenuation coefficients of various pollutants in different control units of Dongjiang Lake basin as described in the Research Report on Environmental Quality, the Pollutant Discharge and Environmental Capacity of Zixing in 2013, and the average water quality at actual monitoring points in 2016, statistics of the pollutant storage volume and environment capacity utilization in 2023 were employed in this study. The results indicated that the theoretical discharge of pollutants in Zixing City comprised the discharge of pollutants from upstream counties and the discharge of pollutants in Zixing district. In Zixing, a surplus of 25% COD, 17% ammonia nitrogen and 54% TP was observed, but TN exceeded 105% of the capacity. Further, certain measures were suggested to maintain the water quality, including adherence to the scientific and technological innovation, improving the mechanism, and enhancing the inclusive and sustainable utilization of water resource in the whole region. Moreover, the local government should vigorously advocate social inclusiveness and comprehensively enhance the coupling coordination level of water resource system and strengthen the policy suggestions on the establishment of coupling coordination capability of water resource systems among provinces, cities and counties.

Keywords. Water resource capacity, EFDC model, big data, Dongjiang Lake basic (in Chenzhou)

1. Introduction

The crisis of water resources is one of the major risks for economic and social development all over the world [1-2]. Based on the data from the China Water Resources Bulletin (2020), the utilization rate of water resources development in China's basins was 17.8%, the re-utilization rate of industrial water was approximately

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62%, the leakage rate of urban water supply network was approximately 20% and the utilization coefficient of irrigation water was approximately 0.45 in 2020 [3]. Moreover, some key problems such as quality-induced water shortage, potential safety risk of drinking water source, deterioration of water environment quality and damages to water eco-environment have not been fundamentally solved [4-6].

Chengzhou City, Hunan Province, China, possesses abundant water resources. Dongjiang Lake serves as the core water resource in this part and occupies 4719 km^2 of total area. The water area in Chengzhou covers 160 km^2, with annual water storage of 81.2×10^8 m^3. Accordingly, Chengzhou is an important strategic water source in the Hunan Province. Chenzhou undertakes the pilot task of building a national sustainable development agenda innovation demonstration zone with the theme of 'Sustainable Utilization of Water Resources and Green Development'. It is a vivid practice of implementing a new vision for the development and President Xi's ecological civilization thought, which can provide Chenzhou's experience, Hunan model and Chinese scheme for solving major social contradiction in the new era, thereby achieving the development task in the new era and implementing 2030 sustainable development agenda by the United Nations. Dongjiang Lake reservoir in Chenzhou has a total storage capacity of 81.2×10^8 m^3, with an average annual inflow of 44.8×10^8 m^3. The storage capacity of Dongjiang Lake equals to half of the volume of Dongting Lake. At present, the first and the second phases of Dongjiang Water Diversion Project in Chenzhou has been fully completed, which can satisfy water demand by more than 1 million urban residents along the route. Southern Water Company, Hunan University and Hunan Architectural Design Institute have organized the implementation of Chang-Zhu-Tan-Heng-Chen Pipeline Direct Drinking Water Project, which overcomes the problem of clean drinking water for more than 15 million residents along the river. However, there exists quite acute contradiction between the economic development in Dongjiang Lake and the protection of eco-environment. Accordingly, it is necessary to establish a coupling coordination model between the utilization development of water resources from Dongjiang Lake and the balanced development of ecological environment. A key link is to scientifically and accurately measure water capacity of the Dongjiang Lake. The core in the calculation of water resources capacity is to establish the measurement model of pollution load and the change of receiving water body, so as to express the state variables and important environment processes. This can affect the transport of pollutants or water quality factors. Accordingly, the implementation effect of management technology or program measures can be evaluated.

2. Related Works

The Environmental Fluid Dynamic Code (EFDC) water model was first developed by John Hamrick et al. from Virginia Institute of Marine Science, the College of William and Mary, is mainly used for establishing the 3D mathematical model of surface water quality [7-9]. EFDC adopts Fortran for programming, in which the hydrodynamic modulus is similar to ECOM 3D model. Water quality change is investigated based on the CE-QUAL-ICM model, which considers the behaviors on cement-water interface simultaneously on the basis of hydrodynamic model. However, concurrent consideration of the behavior at the mud water interface can make it possible to simulate the migration and transformation of multiple pollutants [10-12]. By combining the mathematical method with the water environment chemistry and hydraulics, EFDC can more effectively reveal the changes of water environment, chemical and ecological elements based on hydrodynamic and water quality mathematical mode [13-14]. Currently, EFDC has been extensively applied in hydrodynamic and water quality simulations, and achieved favorable results [15-16]. Compared with similar models, EFDC model possesses a lot of advantages. EFDC model, with open-source codes, can be convenient for research and secondary development. The boundary process is quite flexible. With common file formats, EFDC can be rapidly combined with different models. EFDC also shows favorable coupling performance and can be used in coupling patterns with many models. Using the complete pre- and post-processing software EFDC-Explorer, EFDC is featured by high visualization degree, showing great convenience in dealing with network and image files. Owing to the high computation efficiency, EFDC model presents extensive applications all over the world. Some Chinese scholars employed EFDC model for the spatial and temporal distribution characteristics of Tangcun Reservoir, and the hydrodynamic optimization adjustment scheme for Tianjing Lake, Taicang. EFDC was employed to understand the effect of monsoon on water using 14 different schemes during the implementation period of Caizi Lake water transport project. Further, it was used to decipher the spatial/temporal patterns of water quality under 3 different scenes in Five Connected Lakes to propose certain corresponding solutions and precautionary measures [17-20]. Fan et al. employed the EFDC model for investigating the hydrodynamic water quality features and the driving factors [21]. Zhao et al. analyzed the comprehensive performance of ecological service values in the wetland around Dianchi Lake [22]. Based on EFDC model, some other scholars evaluated the risks of hazardous substances in four great lakes of China, and hydrodynamic behavior and algal processes of Miyun Reservoir, and also simulated hydrodynamic characteristics of the Three Gorges Reservoir after impounding [23-25]. In order to account the sudden rapid increase of chlorophyll and turbidity while the external load level showed no significant change, Zhao et al. conducted the simulation on the response to pollution load reduction of the Changtanfeng Reservoir in high and low water years [26-27]. Tang et al. examined the limitation factors for algae growth in the Taihu Lake and highlighted the effects of external nutrients on the water quality [28]. Chen et al. established the 3D eutrophication model of the Danjiangkou Reservoir [29]. Zeng et al. predicted the concentrations of nitrogen and phosphorous in water under 13 scenarios for long-distance inter-basin water transfer projects based on EFDC, and also measured and evaluated the eutrophication risk [30]. The core in water resource capacity calculation in EFDC model is to establish the measurement model of pollution load and the change of receiving water quality. Accordingly, the state variables that affect the transport states of pollutants or water quality factor and important environmental process can be expressed, so as to evaluate the management technology or the implementation effect of measures. By means of monitoring data analysis and status survey, it was determined that the main excessive pollutants in the region were mainly COD, NH3-N, and TN and TP in combination with the economic structure in Dongjiang Lake and Chenzhou City, which were then selected as the predictive factors in the subsequent study.

3. Methodology

3.1 Functional modules of the EFDC model

In this study, using the EFDC model, the environment capacity of Dongjiang Lake was calculated and analyzed. EFDC model mainly includes the following functional modulus: hydrodynamics, temperature and heat transfer, material transport, sediment transport, water quality and eutrophication, toxic matter pollution and transport, and Lagrange particle tracking. These 7 modules are relatively independent and also coupled with each other, forming a complete EFDC model, as shown in Figure 1.

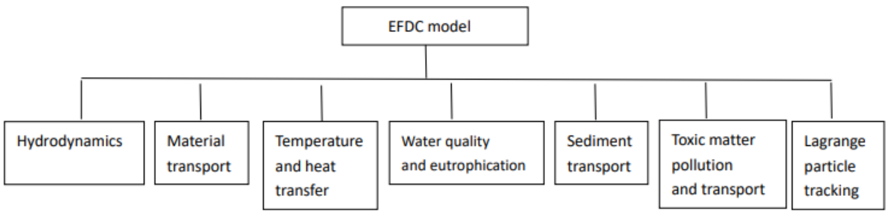

Figure 1 Architecture of the EFDC Model

Compared with similar models, EFDC model possesses a lot of advantages. EFDC model, with open-source codes, can be convenient for research and secondary development. The boundary process is quite flexible. With common file formats, EFDC can be rapidly combined with different models. EFDC also shows favorable coupling performance and can be used in coupling patter with many models. With complete pre- and post-processing software EFDC-Explorer, EFDC is featured by high visualization degree, showing great convenience in dealing with network and image files. Owing to high computation efficiency, EFDC model currently shows extensive applications all over the world. Some Chinese scholars employed EFDC model for the spatial and temporal distribution characteristics of Tangcun Reservoir, hydrodynamic optimization adjustment scheme for Tianjing Lake, Taicang, the effect of monsoon on water using 14 different schemes during the implementation period of Caizi Lake water transport project, and spatial/temporal patterns of water quality under 3 different scenes in Five Connected Lakes and proposed some corresponding solutions and precautionary measures. Zeng et al. predicted the concentrations of nitrogen and phosphorous in water under 13 scenarios for long-distance inter-basin water transfer projects based on EFDC, and also measured and evaluated the eutrophication risk. The core in water resource capacity calculation in EFDC model is to establish the measurement model of pollution load and the change of receiving water quality. Therefore, state variables that affect the transmission status of pollutants or water quality factors and important environmental processes can be expressed to evaluate the implementation effectiveness of management techniques or measures. By means of monitoring data analysis and status survey, it can be determined that the main excessive pollutants in the region are mainly COD, NH3-N, TN and TP in combination with the economic structure in Dongjiang Lake and Chenzhou City, which were then selected as the predictive factors in the subsequent study.

3.2 Water quality model

Based on preliminary analysis results of the water body characteristics in Dongjiang Lake basin, Chenzhou, this study adopted EFDC model for achieving a comprehensive measure of the water resource capacity in Dongjiang Lake.

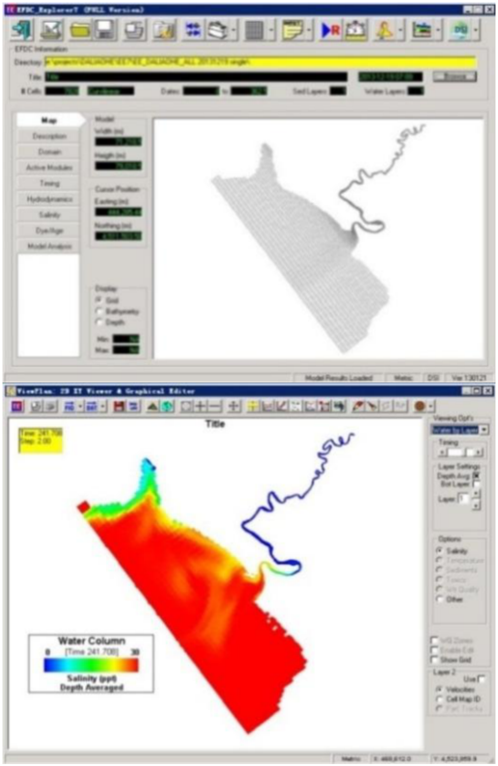

Figure 2 EFDC Software Running Interface

In terms of hydrodynamic calculation, EFDC model uses Mellor-Yamada-2.5-order mode, and solves the problems with process splitting method. The whole solving process can be divided into internal mode and external mode, respectively. Specifically, the solution of 2D model and 3D models act as external mode and internal mode, respectively. Next, the internal mode can be split into horizontal convective diffusion (to be solved in explicit formula) and vertical diffusion (to be solved in implied format).

According to the requirements in project task and the obtained data, the region (N25°36'~ N26°0' and E113°18'~E113°33') was modeled. Based on the water characteristics in the region, calculation was performed with the use of 3D hydrodynamic model. The plane was meshed with curved orthogonal network, and more intensively meshed in the key region. The simulated reservoir that covered a simulation area of 155.3 km^2 was divided into 2410 grids. Figure 3 displays the meshed calculation area in Dongjiang Lake and the elevation map on the bottom.

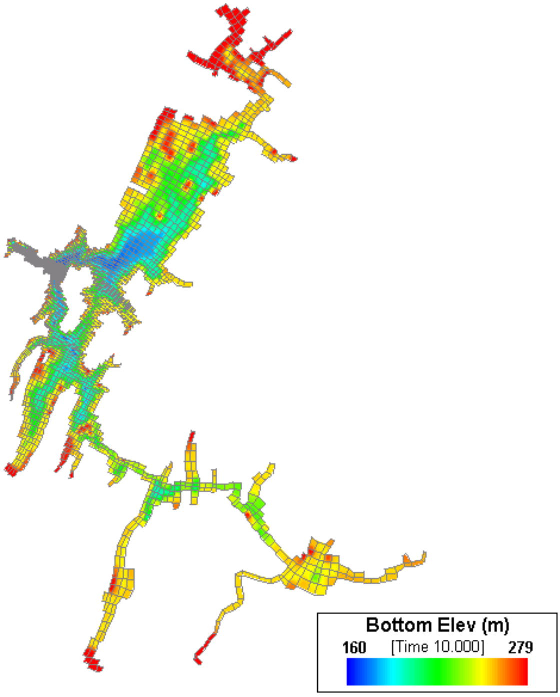

Figure 3 Calculation area and elevation map of Dongjiang Lake

Table 1 lists the designed hydrological conditions calculated by the water resource capacity and multi-year average flow rates of various tributaries. Without multi-year average flow rate, the hydrological conditions were simulated based on the flow rate at a multi-year average assurance rate of 50% of the various rivers joining the Dongjiang Lake.

Table 1 Designed hydrological conditions

Name of inflowing rivers	Designed hydrological flow/ (m3/s)	Designed inflow load/ (t/d)
Chushui River	12	100
Zheshui RIver	21	100
Oujiang River & Qishui River	24.8	100
Inflowing river on the southern side	3	100
Inflowng river on the northern side	4.5	100

From results of the attenuation coefficients of various pollutants in different control units of the Dongjiang Lake as described in Research Report on Environmental Quality, Pollutant Discharge and Environmental Capacity of Zixing (2013), the background load of the Dongjiang Lake and the comprehensive attenuation coefficients corresponding to various pollution indexes were calculated, as listed in Table 2. The average water quality values at the real monitoring points in the Dongjiang Lake in the year 2016 were set as the background concentrations. The mean concentration of TN was 1.0 mg/L. For the calculation of water environment capacity, the II-type water standard 0.5 mg/L was set.

Table 2 Comprehensive attention coefficients of different pollutants

Serial number	Control index	Background concentration (mg/L)	Target concentration (mg/L)	Comprehensive attenuation coefficient (1/d)
1	COD	15	20	0.01
2	NH_3-N	0.24	1.0	0.001
3	TN	0.5(1.0)	1.0	0.001
4	TP	0.039	0.2	0.0005

3.3 Water quality of inflowing rivers

Based on DEM data and drainage map of Dongjiang Lake, 244 catchment units were divided using the ArcGIS and ArcSWAT software. This division was convenient for the statistics of spatial points, where pollutants were accompanied into the receiving water body. Specifically, the Oijiang River, Zheshui River, Qishui River and Chushui River consisted of 62, 41, 21 and 10 catchment units, respectively, and the catchment nodes were also set, as shown in Figure 4.

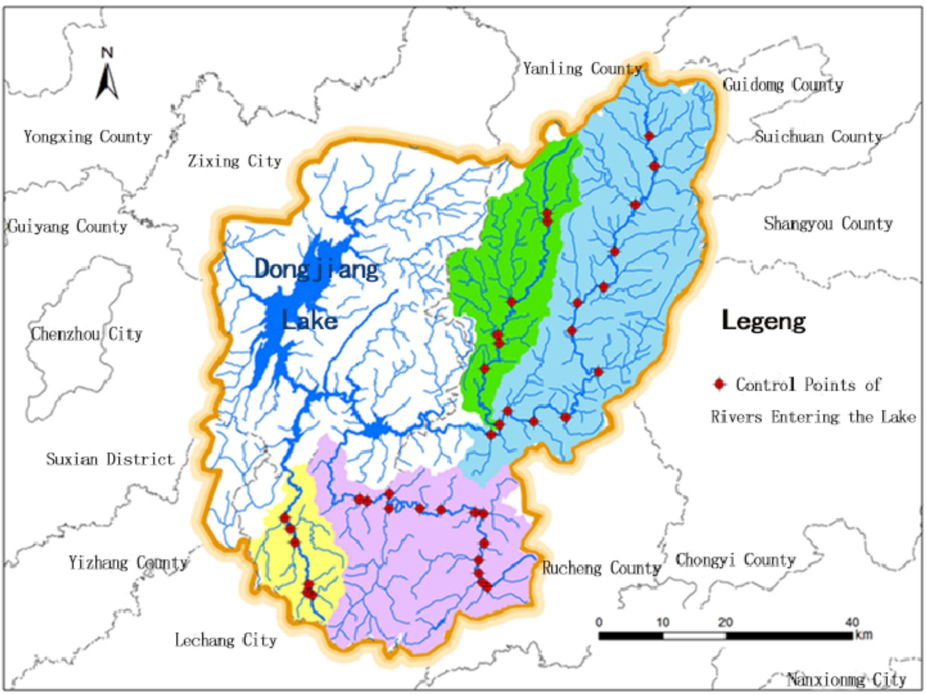

Figure 4 Schematic representation of the catchment units and control points of rivers flowing into the Dongjiang Lake

Based on the segment-end control model of 1D convective displacement model, the calculation equation of environment capacity of the river within unit time can be written as:

$$M=[Cs-Coexp(-kL/u)]exp(kL/2u) Qr$$

where, M denotes the environment capacity in unit time; C_S denotes the segment-end concentration of the pollutant, with a unit of mg/L; Co denotes the concentration of pollutants at the starting section, with a unit of mg/L; k denotes the comprehensive self-purification coefficient of pollutant, with a unit of 1/s (it should be noted that the value of k is always expressed by 1/d and converted into 1/s in calculation); L denotes the length of river segment (for a river segment of L, the self-purification length of pollutant generally equals to L/2); u denotes the average flow rate under the designed flow, with a unit of m/s; or denotes the designed flow. The model parameters included the target of water quality Cs, initial concentration Co, average flow velocity at the design flow rate u (m/s); design flow rate Qr, degradation coefficient k, flow 'or'; and the flow rate u were determined.

The average water quality at the actual monitoring points in Dongjiang Lake in 2016 was set as the background concentration. Table 3 lists various pollution control indexes, target concentrations, background concentrations and the attenuation of pollutants.

Table 3 Comprehensive attenuation coefficients of different pollutants

Main parameter	Control index	Chushui River	Zheshui River	Oujiang River	Qishui River
Target concentration (mg/L)	COD	20	20 (15)	20 (15)	20
	NH_3-N	1	1	1	1
	TN	—	—	—	—
	TP	0.2	0.2 (0.1)	0.2 (0.1)	0.2
Background concentration (mg/L)	COD	15	15	15	15
	NH_3-N	0.34	0.4	0.5	0.3
	TN	—	—	—	—
	TP	0.05	0.016	0.054	0.018
Comprehensive attenuation coefficient	COD	0.23	0.23	0.23	0.23
	NH_3-N	0.1	0.1	0.1	0.1
	TN	—	—	—	—
	TP	0.02	0.02	0.02	0.02

4. Results and Discussion

4.1 Water environment capacity

According to above hydrological conditions, the responses of the water quality of control section in the mixture region to unit loads of various inflowing rivers (including the inflows from the southern side, Chushui River, Zheshui River, Oujiang River, Qishui River and the northern side) were calculated with EFDC model. Tables 4~7 list the calculation results of the water environment capacity of various pollutants in Dongjiang Lake. The environment capacity was calculated by completely linear optimization, which can be regarded as the unique maximum environment capacity (the allowable pollutant absorption capacity) under above-described hydrological conditions. The total capacity distribution was performed according to the designed hydrological conditions and the related formulas. The results show that only one of the schemes satisfied the water quality standards during the distribution of water environment capacity. The total capacity distribution was sometimes far smaller than the environment capacity. The water environment capacities of COD, NH3-N, TN and TP in Dongjiang Lake were 16369.46 t/a, 1712.77t/a, 1070.94 t/a and 344.84 t/a, respectively.

Table 4 Calculated water environmental capacity of COD

Sewage draining outlet	Inflow from the southern side	Inflow from Chushui River	Inflow from Zheshui River	Inflow from Oujiang River and Qishui River	Inflow from the southern side	Sum
Designed hydrological condition (m^3/s)	3	12	21	24.8	4.5	65.3
Environment capacity (t/a)	4436.43	2651.48	2063.68	2174.89	5043.00	16369.46
Total capacity distribution (t/a)	263.09	1052.36	1841.64	2174.89	394.64	5726.62

Table 5 Calculated water environment capacity of NH_3-N

Sewage draining outlet	Inflow from the southern side	Inflow from Chushui River	Inflow from Zheshui River	Inflow from Oujiang River and Qishui River	Inflow from the southern side	Sum
Designed hydrological condition (m^3/s)	3	12	21	24.8	4.5	65.3
Environment capacity (t/a)	104.02	299.60	516.48	621.14	171.54	1712.77
Total capacity distribution (t/a)	73.78	295.13	516.48	609.94	110.67	1606.00

Table 6 Calculated water environment capacity of TN

Sewage draining outlet	Inflow from the southern side	Inflow from Chushui River	Inflow from Zheshui River	Inflow from Oujiang River and Qishui River	Inflow from the southern side	Sum
Designed hydrological condition (m^3/s)	3	12	21	24.8	4.5	65.3
Environment capacity (t/a)	50.17	193.34	337.78	403.49	86.15	1070.94
Total capacity distribution (t/a)	48.25	193.01	337.78	398.90	72.38	1050.32

Table 7 Calculated water environment capacity of TP

Sewage draining outlet	Inflow from the southern side	Inflow from Chushui River	Inflow from Zheshui River	Inflow from Oujiang River and Qishui River	Inflow from the southern side	Sum
Designed hydrological condition (m^3/s)	3	12	21	24.8	4.5	65.3
Environment capacity (t/a)	16.16	62.26	108.76	129.92	27.74	344.84
Total capacity distribution (t/a)	15.54	62.15	108.76	128.44	23.31	338.20

4.2 Water environment capacities of inflowing rivers

Table 8 lists the calculation results of the water environment capacity of Chushui River, Zheshui River, Oujiang River and Qishui River, in which the environment capacity was calculated by completely linear optimization of mathematical model. The result was regarded as the maximum environment capacity for each river (*i.e.*, the allowable pollution). For Chushui River and Qijiang River, the results of the total capacity distributions were calculated, based on the proportion of catchment runoff distribution at each node of the river. On calculating the determined allocation results, it was found that in addition to the principle of water resource contribution, Zheshui River and Oujiang River considered the principle of minimizing GDP contribution and governance costs (the smaller the proportion of reduction or relocation of current pollution sources, the less investment). The environmental capacity of Zheshui River and Oujiang River was calculated based on the capacity allocation ratio determined by three principles with the same weight.

Table 8 Summary of water environment capacity and water system (Unit: t/a)

		Chushui River	Zheshui River	Oujiang River	Qishui River
COD	Environment capacity	477.95	1912.48	4071.15	754.02
	Total capacity distribution	382.96	873.06	743.82	57.34
NH_3-N	Environment capacity	21.71	73.02	159.18	36.09
	Total capacity distribution	19.94	42.88	77.55	8.97
TP	Environment capacity	3.69	11.83	25.83	7.02
	Total capacity distribution	3.61	11.47	15.72	1.82
TN	Environment capacity	193.34	337.78	403.49	93.33
	Total capacity distribution	193.01	337.78	398.90	92.27

Table 9 lists the calculation results of environment capacity of the Dongjiang Lake, Qishui River, Oushui River, Zheshui River and Chushui river using EFDC model and 1D steady-state water quality mode. Accordingly, water environment capacity of Dongjiang Lake was also obtained. Specifically, the calculated water environment capacities of COD, NH_3-N, TN and TP were found to be 24127.4 t/a, 2029.9 t/a, 2125.9 t/a and 396.7 t/a, respectively. For Zixing, the calculated water environment capacities of COD, NH_3-N, TN and TP were found to be 16369.4 t/a, 1712.8 t/a, 1970.9 t/a and 344.8 t/a, respectively. For Rucheng, the calculated water environment capacities of COD, NH_3-N, TN and TP were observed to be 5007.7 t/a, 197.2 t/a, 787.6 t/a and 31.9 t/a, respectively. For Guidong, the calculated water environment capacities of COD, NH3-N, TN and TP were 2207.9 t/a, 92.8 t/a, 240.3 t/a and 14.6 t/a, respectively. For Yizhang, the calculated water environment capacities of COD, NH_3-N, TN and TP were 542.4t/a, 27.1 t/a, 27.1 t/a and 5.4 t/a, respectively.

Table 9 Summary of water environment capacities of different districts and cities in Dongjiang Lake Basin

County/ City	Water system	Environment capacity (t/a)				Total capacity distribution (t/a)			
		COD	NH_3-N	TN	TP	COD	NH_3-N	TN	TP
Guidong	Oujiang River	1799.79	71.32	191.55	11.88	605.35	55.89	189.37	11.33
	Qishui River	408.12	21.50	48.77	4.55	29.96	4.69	48.21	0.95
		2207.91	92.82	240.32	16.43	635.31	60.58	237.59	12.28
Rucheng	Oujiang River	2271.37	87.86	211.94	13.94	138.46	21.65	209.53	4.39
	Qishui River	345.90	14.59	44.56	2.47	27.38	4.28	44.05	0.87
	Zheshui River	1912.48	73.02	337.78	11.83	873.06	42.88	337.78	11.47
	Chushui River	477.95	21.71	193.34	3.69	382.96	19.94	193.01	3.61
		5007.70	197.19	787.62	31.94	1421.86	88.75	784.37	20.34
Yizhang	Changce River	542.42	27.12	27.12	5.42	542.42	27.12	27.12	5.42
Zixing	Dongjiang Lake	16369.4	1712.8	1070.9	344.8	5726.6	1606.0	1050.3	338.2

4.3 Calculation of allowable discharge into the lake

The environment capacity adopts a fully linear optimization method in mathematics, which equals to the maximum environment capacity of each river, *i.e*., the allowed discharge amount. In case of the Dongjiang Lake, the allowable discharge amounts of COD, NH_3-N, TN and TP were observed to be 16369.46 t/a, 1712.77t/a, 1070.94 t/a, and 344.84 t/a, respectively. For Rucheng, the allowable discharge amounts of COD, NH_3-N, TN and TP were 5007.7 t/a, 197.2 t/a, 787.6 t/a, and 31.9 t/a, respectively. For Guidong, the allowable discharge amounts of COD, NH_3-N, TN and TP were 2207.9 t/a, 92.8 t/a, 240.3 t/a, and 14.6 t/a, respectively. For Yizhang, the allowable discharge amounts of COD, NH_3-N, TN and TP were 542.4 t/a, 27.1 t/a, 27.1 t/a, and 5.4 t/a, respectively.

Table 10 lists the statistics of the discharge amounts of pollutants into the lake and the utilization of environment capacities by the year 2030. The theoretical discharge amount of pollutants in Zixing included the discharge of pollutants from the upstream counties and the area under administration. It can be observed that COD, ammonia nitrogen and TP exhibited the surplus of 25%, 17% and 54%, but the discharge of TN exceeded the capacity by 105%. The discharge amount of COD, ammonia nitrogen, TP and TN from the upstream counties into the lake far exceeded the environment capacity.

In terms of the required reduction of COD, Guidong ranked the first, followed by Yizhang. In terms of the required reduction of ammonia nitrogen, Rucheng ranked the first, followed by Guidong and Yizhang. In terms of the required reduction of TN, Guidong ranked the first, followed by Zixing, Rucheng and Yizhang. In terms of the required reduction of TP, Rucheng ranked the first, followed by Guidong and Yizhang.

Table 10 Comparison of Pollutant and Water Environment Capacity in the Dongjiang Lake Basin by 2030 (Unit: t/a)

	COD t				**NH_3-N t**			
	Zixing	Rucheng	Guidong	Yizhang	Zixing	Rucheng	Guidong	Yizhang
Allowable discharge amount	16369.4	5007.7	2207.91	542.42	1712.8	197.19	92.82	27.12
Actual discharge amount	12274.52	4806.55	3521.07	557.53	1426.31	641.46	459.63	73.74
Required discharge amount	—	—	1313.16	15.11	—	444.27	366.81	46.62
Utilization rate	74.98%	95.98%	159.48%	102.79%	83.27%	325.30%	495.18%	271.90%
	TN t				**TP t**			
	Zixing	Rucheng	Guidong	Yizhang	Zixing	Rucheng	Guidong	Yizhang
Allowable discharge amount	1070.94	787.62	240.32	27.12	344.8	31.94	16.43	5.42
Actual discharge amount	2190.89	967.38	695.95	108.68	157.47	64.9	45.51	7.03
Required discharge amount	1119.95	179.76	455.63	81.56	—	32.96	29.08	1.61
Utilization rate	204.58%	122.82%	289.59%	400.74%	45.67%	203.19%	276.99%	129.70%

Note: Discharge loads from other inflowing tributaries were considered in the calculation for Dongjiang Lake

In Zixing, although the discharge of COD, ammonia nitrogen and TP did not far exceed the environment capacity of Dongjiang Lake, serious local water pollution was observed. In particular, at the inlet of Xining River and Pingshi, some indexes on local sections of inflowing river, such as the discharge sections of Dongping, Chukou and Yanzi exceeded the standard values. It may possibly create a serious risk for the requirement on I-class water quality of state-controlled sections.

In this study, the environmental conditions of the Dongjiang Lake basin were monitored from 2015 to 2022. A favorable water quality was observed by analyzing the monitoring data of the Pingshi bottom, Right fork of the lake water flow, Wharf, and Qingjiang Dalong section, which overall exceeded the II-class water quality standard. However, the concentration of cadmium, arsenic, lead and cooper in the sediment were higher than the background values of the soil. The heavy metal pollution brought about inflowing rivers also showed some potential risks. Thus, the water eco-environment of the Dongjiang Lake still faces many serious problems. In this study, we analyzed the monitoring data and current situation investigation of water resources and environment in the Dongjiang Lake Basin. Further, by using the EFDC model we comprehensively studied the accounting problem of the water environment capacity in Dongjiang Lake. From the calculation results, the allowable discharge amounts of COD, NH_3-N, TN and TP were found to be 16369.46 t/a, 1712.77 t/a, 1070.94 t/a, and 344.84 t/a, respectively. The discharge of pollutants into the lake and the utilization of environment capacities in 2030 were also predicted in this study. The theoretical discharge included the discharge amounts of pollutants from both upstream counties and the area under administration, respectively. The discharge amounts of COD, NH_3-N and TP exhibited a surplus of 25%, 17% and 54%, respectively, but the discharge of TN exceeded the capacity by 105%.

5. Policy suggestions

In this study, based on the calculated water environment capacity of Dongjiang Lake, the allowable, theoretical and required discharge amounts of COD, NH3-N, TN and TP for various counties and cities along Dongjiang Lake were calculated. In order to achieve a fair water-quality target, the government should firmly adhere to the concept of ecological civilization, focus on the problems of low water utilization efficiency and heavy metal pollution, further govern the sub-standard segments in the control units, accelerate the implementation of eco-environment protection project in Dongjiang Lake, and control the discharge load of upstream pollutants. Meanwhile, it is suggested to accelerate the implementation of the government policies for agricultural non-point pollution, domestic sewage and industrial pollution in the reservoir, which can further reduce the discharge of pollutants.

5.1 Insisting scientific and technological innovations and enhancing the level of sustainable utilization level of water resource inclusiveness in the whole region

First, it is suggested to increase the investment in technical research and application of high-efficiency utilization of the water resources. By fully drawing advanced scientific and innovative resources all over the world, the government can build a scientific and technological innovation community for the sustainable utilization of water resource in Dongjiang Lake by integrating the related good-quality resource in this region. It is suggested to actively encourage enterprises, schools and research institutes to apply for patents on water resource technology and equipment, guide all the entities to participate in this area, deepen the integration between production and education, and focus on technology research and development regarding comprehensive water-saving. Further, there is a need for development and utilization of unconventional water resource and ecological environment management of rivers and lakes, effectively promote the transformation and application of scientific and technique achievements, and constantly exploit the development potential of water resource endowment.

Second, The Chenzhou City should adopt a "government industry university research cooperation" approach to accelerate the key core technology research and development of inclusive and sustainable water resources utilization and promote the landing and transformation of scientific and technological achievements. By relying on Asia-Europe Water Resource Research and Utilization Center, multi-dimensional intelligent monitoring system, ecological big-data, and information service centers, the deep lakes of Dongjiang Lake should be constructed, so as to create a highland for the gathering of talents of water resource development and a platform for the transformation of achievements of Dongjiang Lake.

Third, it is suggested to strengthen the management and governance of water consumption volume and intensity of traditional high-water-consumption industries and enterprises and key water-consuming units. There is a need to develop novel water-saving facilities and devices and enhance the utilization rate of the water resource. Water utilization standards for both industrial and agricultural enterprises should be strictly formulated, and both promotion and publicity of water-saving technologies should be strengthened, so as to coordinate the construction of water-saving cities. The government should also pay attention to emission reduction and recycling and reduce water footprint of industrial and agricultural unit output value and per capita water consumption. By sieving the construction of national sustainable agenda innovation demonstration zone in Chenzhou as an opportunity, the government should enhance policy incentive and reward/punishment policies, force traditional high water/power-consumption enterprises to constantly improve production facilities and equipment, guide the enterprises to raise water utilization efficiency in production, reduce sewage treatment and discharge, and increase both the recycling rate and comprehensive utilization rate.

5.2 Vigorously advocating the social inclusion and enhancing the coupling coordinate level of the water resource system

The government should focus on the improvement of people's livelihood, address the problems of inadequate and unbalanced water supply and water use for residents, and strengthen the construction of water resource infrastructure in urban and rural areas along the Dongjiang Lake. Further, it should reduce both leakage and loss of water resource and strive to promote the equalization of basic public services and improve the system and mechanism of real-time monitoring of drinking water sources. It is also suggested to vigorously develop the primary industry, promote urban-rural integrated development, strive to raise per capita disposable income of farmers, and promote the high-quality economic development and social coordinated development in both urban and rural areas.

The government should also actively explore the two-mountain conversion mechanism and continue strengthening the inclusive policies of coupling coordination of water resource system with the economy, society, environment, scientific and technological innovation system. Further, there is a need to promote the inclusive co-construction and sharing of ecological environment and explore the establishment of the water right trading mechanism with ecological value. It is also suggested to vigorously implement the two-mountain conversion mechanism, which includes the ecological compensation, evaluation and trading of ecological products, and the protective development of green resources. Additionally, there is a need to form a combination of water resource protection and utilization system, and achieve the organic unity of ecological, social and ecological benefits.

5.3 Strengthening the coupling coordination capacity of inter-province, inter-city and inter-county water resource system

The government should establish and improve the standard system of water environment quality, conservation and intensive use of water resources, and pollutant discharge and recycling in Dongjiang Lake basin. It should set the protection red line of water eco-protection, strengthen the construction of management system and capability in the basin, and build the ecological environment barrier of water resource in the Dongjiang Lake. The government should stand at the height of strategic water resource of Hunan Province, plan the special rectification of the chemical pollution and sewage inlets of key drinking water source in Dongjiang Lake, and enhance the comprehensive treatment capability of water resource, ecology and environment.

In view of inclusive utilization and sustainable development of water resource in the Dongjiang Lake basin, Chenzhou, it is suggested to promote formulation of cross-boundary section assessment compensation agreements and ecological compensation mechanisms with Guangdong Province, Hengyang City and Xiangtan City. This can form a cross-province and cross-city ecological compensation system with vertical connection and horizontal coordination.

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Research on Cross-Border Merger and Acquisition of Logistics Enterprises Based on Synergies: A Case Study of SF Holding's Merger and Acquisition of Kerry Logistics

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Abstracts. In recent years, the growth rate of mergers and acquisitions among enterprises in the capital market has gradually slowed down, but it still has a high degree of activity. Mergers and acquisitions for the purpose of asset reorganization and industry integration are still frequent. Mergers and acquisitions have gradually become one of the important ways for the rapid growth and development of Chinese enterprises. With the rise of e-commerce, China's express delivery industry has entered a golden period of development, but at the same time of rapid development, it also faces the problem of low level of internationalization. In the environment of increasingly fierce competition in the domestic market, the express delivery industry has turned its eyes to the international market, intending to carry out cross-border business in the form of mergers and acquisitions and open up international logistics channels. As an important case of cross-border merger and acquisition of international logistics companies in China's express industry, the cross-border merger and acquisition of Kerry Logistics by SF Holding has attracted wide attention. This paper adopts case study method and literature study method to analyze the realization of SF Express 'cross-border merger and acquisition of Kerry Logistics from the perspectives of financial synergy, management synergy and operational synergy. In addition, it provides a reference scheme for other domestic enterprises to deal with the potential risks in the process of cross-border mergers and acquisitions.

Key words. SF Express Holdings; Kerry Logistics; Cross-border mergers and acquisitions; synergies

1.Introduction

With the acceleration of globalization and the diversification of residents' needs, cross-border e-commerce has risen rapidly, accounting for 5.7% of China's trade in goods in 2023, with exports as high as 1.83 trillion yuan, becoming a key driver of

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export growth [1]. [1]In terms of policies, the Outline for Building a strong Country with Quality promotes the development of multimodal transport, smart logistics and supply chain in the field of logistics [2], and the state encourages the internationalization of the express delivery industry to build an efficient logistics system. [2]In this context, logistics enterprises have accelerated digital transformation, improved green operation capabilities, and expanded into the international market through mergers and acquisitions [2].[2]

Despite the dominance of express delivery leaders in cross-border logistics, Chinese express delivery companies are still actively building global networks through mergers and acquisitions. In September 2021, SF Holding successfully acquired Kerry Logistics. This paper takes this as an example to study the synergies of the merger and acquisition, explore whether it meets expectations, and how these effects perform in the logistics industry, so as to provide experience for other logistics enterprises in cross-border mergers and acquisitions.

In order to solve practical problems, this paper uses literature research and case analysis to deeply explore the synergies of SF Express's merger and acquisition of Kerry Logistics. At present, cross-border M&A studies mostly focus on other industries, and there are few case studies on private logistics M&A, especially from the perspective of synergies. Therefore, this paper chooses this case to enrich the research on cross-border M&A of express logistics enterprises in theory and provide guidance for cross-border M&A of domestic private enterprises in practice. In recent years, domestic logistics mergers and acquisitions are frequent, and competition is fierce, but there is still room for integration in cold chain, integrated logistics and other fields. The research of this paper has the adaptability of The Times and provides reference for cross-border mergers and acquisitions of logistics enterprises in China and helps the future mergers and acquisitions activities.

2. Literature review

Driven by multiple factors such as market expansion, resource integration, cost saving and technology acquisition, cross-border M&A aims to enhance the global competitiveness of logistics enterprises [3]. [3]In the context of smart logistics, M&A can help enterprises acquire advanced technologies and international market resources and accelerate business globalization. Synergy is the key to the success of M&A, which is reflected in the improvement of operational efficiency, cost saving and increase of market share [3].[3]

In order to understand the effect of cross-border M&A more comprehensively, it is necessary to deeply analyze its synergistic performance in actual operation. Synergy is one of the key indicators of the success of cross-border M&A, which is mainly reflected in the improvement of operational efficiency, cost saving and increase of market share [3]. [3]Cross-border M&A can enhance the competitiveness of enterprises in the international market by integrating global resources. However, studies have found that M&A can not always bring the expected synergies, especially in financial performance. For example, YTO Express after M&A has not shown significant financial synergies but has decreased profitability in the short term due to the increase in management expenses [4].[4]

In general, although the existing literature provides a certain theoretical basis for cross-border mergers and acquisitions of logistics enterprises, there are still gaps in the research of private logistics enterprises. This paper aims to further explore the synergistic performance and influencing factors of cross-border mergers and acquisitions of logistics enterprises by analyzing the case of SF Express Holding's merger and acquisition of Kerry Logistics, so as to provide reference for the practice of cross-border mergers and acquisitions.

3. Research methods and case description

3.1. Research Methods

First, literature research method. This paper reviews the research results of cross-border M&A theories at home and abroad, and collects the existing literature on the motivation, synergy and practical effects of cross-border M&A. Then, by analyzing the performance of synergies in practice, especially the lack of financial synergies, it further reveals the challenges faced by cross-border mergers and acquisitions in practice. Through literature research, we can identify the research gaps in the field of cross-border mergers and acquisitions of private logistics enterprises, and on this basis, conduct research on SF Holding's merger and acquisition of Kerry Logistics.

The second is case analysis method. Taking the cross-border merger of Kerry Logistics by SF Holding as a case study, this paper analyzes the realization of synergies in three dimensions of operation, management and finance before and after the merger by referring to the quarterly and annual reports disclosed by SF Holding on its official website and Jichao News Network, and draws targeted research conclusions and case Revelations, aiming to provide inspiration and reference for the logistics and express industry.

3.2. Description of case study

SF Holdings originated in Shunde, Guangdong Province. Initially, it mainly dealt with express deliveries between the Pearl River Delta and Hong Kong, and gradually evolved into one of the top comprehensive express logistics service providers in China. Since 2009, SF has been strategically positioning itself in the international market and established a presence in Singapore in 2010 to accelerate its international expansion[5][6]. Kerry International Logistics, founded in 1981, entered the Chinese mainland in 2001. Its business spans across 59 countries and regions, covering international freight transportation, cross-border e-commerce, etc. It possesses a complete logistics distribution system and is a globally leading container depot operator[6]. On February 10, 2021, SF announced the acquisition of 51.5% equity of Kerry Logistics at 14.6 billion yuan. Previously, the scale of SF's international express delivery business was relatively small, and it urgently required cross-border mergers and acquisitions to obtain strategic resources and maintain its competitive edge in the international market[7].[20]

4. Synergy analysis of SF Holding's cross-border merger and acquisition of Kerry Logistics

In recent years, the synergy of cross-border mergers and acquisitions has become a hot issue for domestic scholars, including the synergy of management, operation and finance. Luling He and Yingxiang Tong all evaluated the M&A performance of Hanwei Electronics and Alibaba from these three aspects. Based on the above scholars' views, this paper also evaluates the M&A performance of SF Holding through the three aspects of M&A synergies [8].[8]

4.1. Analysis of operating synergies

As the core of M&A, operating synergies aim to improve operating efficiency, optimize resource allocation, achieve economies of scale and efficient concentration of capital, and help enterprises take advantage in the market [9]. [9]Kerry Logistics, as the world's leading third-party logistics provider, will expand its overseas network and increase its international share through the acquisition by SF Express. The synergy effect of merger and acquisition is the basis of performance improvement, so the change of financial performance becomes the key to measure the effectiveness. [8]This section makes an in-depth analysis of SF Express 'revenue structure, profit and growth ability after the acquisition of Kerry Logistics, and comprehensively analyzes the operating synergies.

4.1.1. Analysis of operating synergies from the perspective of revenue composition

The detailed regional distribution of SF Holding's revenue before and after its acquisition of Kerry Logistics is shown in Table 1. During the period from 2021 to 2022, SF Holding's revenue in Hong Kong, Macao, Taiwan and overseas and its proportion show an increasing trend. Especially in 2022, the growth trend is particularly significant. Despite the volatility of the international market in 2023, its international logistics revenue is still far above the pre-merger level. [5]As can be seen from Table 2, compared with YTO and STO, SF Express's overseas business continues to take the lead in the past five years. Especially after the acquisition of Kerry Logistics at the end of 2021, SF Express has experienced multiple growth for two consecutive years.

Table 1. Regional distribution of SF Express holding income before and after the merger (unit: 100 million yuan)

Indicators	2019	2020	2021	2022	2023
Mainland revenue	1073.9	1473.8	1860.1	2046.2	2235.1
Take up a proportion of	95.72%	95.72%	89.78%	76.50%	86.49%
Income from H K, MAC and TW	24.3	29.5	47.7	89.9	91.3
percentage	2.13%	1.91%	2.31%	3.36%	3.54%
Overseas income	11.2	14.1	129.0	484.7	257.6
percentage	1.00%	0.92%	6.22%	18.12%	9.97%
Other non-logistics businesses	12.94	22.4	35.0	54.1	-
Account for	1.15%	1.46%	1.68%	2.02%	-

Table 2. Comparison of overseas income of SF Express, YTO and Shentong from 2019-2023 (Unit: 100 million yuan)

Indicators	2019	2020	2021	2022	2023
Sf Express	35.13	43.6	176.7	574.6	349.35
Sto Express	28.34	38.87	50.21	45.58	36.93
Yunda	0.08	0.01	0.02	0.05	0.09

4.1.2. Analysis of operating synergies based on profitability

The average gross profit margin of SF Holding and the industry before and after the merger is shown in Table 3. From the horizontal comparison, until the year when SF Holding completed the cross-border merger of Kerry Logistics, its gross profit margin of sales showed a downward trend, which was consistent with the change direction of the overall sales gross profit margin of the industry [10]. [10]From the vertical comparison, after the completion of the merger in 2021, the gross profit margin of SF Holding still showed a downward trend, and the gross profit margin began to increase in 2022, indicating that the cost control measures of SF Holding played a positive role. Therefore, from the perspective of sales gross margin index, SF Holding's profitability has improved since 2022, and operating synergies have been realized.

Table 3. Average Gross profit margin of SF Holding and Industry from 2019 to 2023 (unit: %)

Items	2019	2020	2021	2022	2023
Sf Holding	17.42	16.35	12.37	12.49	12.82
Industry average	5.67	4.93	4.07	4.17	4.29

The average net profit rate on sales of SF Holding and the industry before and after the merger is shown in Table 4 below. By horizontal comparison, the net profit rate on sales of SF Holding is above the industry average before and after the merger, and the trend is consistent with the industry as a whole, showing a strong industry correlation [11]. [11]In the year of merger and acquisition, the net profit rate of SF Holdings fell to the lowest level in history due to the increased investment in network construction. However, since 2022, thanks to the expansion of supply chain and international business, the net profit margin on sales has gradually recovered, and increased by 124.1% year-on-year in 2022. [12]With the deepening of business integration, SF Express's profitability has returned to the pre-merger level, and operational synergies have emerged.

Table 4. Average net profit rate on sales of SF Holding and the industry from 2019-2023 (unit: %)

Items	2019	2020	2021	2022	2023
Sf Holding	5.01	4.50	1.89	2.62	3.06
Industry average	1.94	1.64	1.48	1.51	1.61

The average net profit rate on sales of SF Holding and the industry before and after the merger is shown in Table 5 below. After the acquisition of Kerry Logistics by SF Holding, the change of ROE was contrary to the industry trend and dropped sharply in the initial stage, mainly due to the increase in the proportion of economic express delivery but the imbalance of cost and benefit [11], and the increase in investment in hardware and software technology and supply chain construction after the acquisition [12]. [11][12]However, with the advancement of integration, ROE gradually approaches the industry average, profitability has improved since 2022, and operating synergies have begun to show.

Table 5. Average Return on equity of SF Holding and Industry from 2019 to 2023 (unit: %)

Project	2019	2020	2021	2022	2023
Sf Holding	5.01	4.50	1.89	2.62	3.06
Industry average	1.94	1.64	1.48	1.51	1.61

The average net interest rate on total assets of SF Holding and the industry before and after the merger is shown in Table 6 below. The net interest rate of SF Holding's total assets changed in the opposite direction of the industry before and after the merger, but it rebounded from 2021 and approached the industry. This change is mainly due to the improvement of net profit. On the one hand, it is due to the improvement of income quality and the good results of lean resource planning and cost control measures; on the other hand, it is due to the integration of resources after the acquisition of Kerry Logistics, which increases the overall profit of the company. [8]Therefore, in terms of the change of net interest rate on total assets, with the deepening of integration after the completion of the merger, profitability will improve from 2022, and operating synergies will emerge. Whether it can be sustained in the future remains to be seen.

Table 6. Average net interest rate on total Assets of SF Holding and Industry from 2019 to 2023 (unit: %)

Items	2019	2020	2021	2022	2023
Sf Holding	6.85	6.81	2.44	3.28	3.61
Industry average	3.99	3.19	3.47	3.32	2.96

4.1.3. Business synergies analysis based on growth ability

The growth rate of SF Holding and the industry's total profit before and after the merger is shown in Table 7 below. After the acquisition of Kerry Logistics by SF Holding, the growth rate of net profit fluctuated greatly, resulting in negative growth in 2021 due to the price war. However, the following year, thanks to Kerry Logistics' international freight business, SF Express 'net profit jumped from 3.919 billion to 7.03 billion, with a growth rate as high as 78.7%, far exceeding the industry average [13]. [13]This shows that the merger and acquisition significantly improved SF Express's growth ability and market competitiveness and achieved the expected operational synergies.

Table 7. Average net profit growth rate of SF Holding and Industry from 2019 to 2023 (unit: %)

Items	2019	2020	2021	2022	2023
Sf Holding	26.00	23.24	-43.46	78.70	12.96
Industry average	3.28	4.61	27.50	14.01	-0.50

4.2. Analysis of management synergies

Management synergy refers to the redistribution of efficient management methods to inefficient companies after M&A to improve overall management efficiency and capability, reduce costs, and achieve management synergy. [15]From the perspective of talent management and cost control, this paper discusses the management synergy effect after SF Express's acquisition of Kerry Logistics.

4.2.1. Analysis of management synergies based on talent management

Human resources are the cornerstone of a company, reflecting the level of knowledge and skills within the organization. The merger between SF Holding and Kerry Logistics aims to expand international business and requires an international perspective team to assist. Kerry Logistics has an international team, which brings advantages to its international operations. However, SF has abundant experience in domestic management but lacks international talent reserves, with only one senior executive having overseas background in 2021. After the merger, Kerry Logistics maintains its independent brand operation, not only solidifying its customer base but also helping SF leverage its talent advantage to accelerate its internationalization. This integration combines SF's domestic management experience with Kerry's international team advantage, injecting new momentum into the company's development.[9]

4.2.2. Analysis of management synergy effect based on expense control perspective

Improving management efficiency can enable enterprises to allocate resources more reasonably, strengthen the optimization and control of costs, and thus reduce expenses. In this section, sales expense ratio and administrative expense ratio are selected as key indicators to evaluate the effectiveness of cost control [14].[14]

The administrative expense ratio and selling expense ratio of SF Holding before and after the merger are shown in Table 8 below.

Table 8. Indicators of SF Holding's expense control level from 2019 to 2023 (unit: %)

Indicators	2020	2021	2022	2023
Sf Holding	8.66	8.29	7.40	7.71
Industry average	1.46	1.37	1.04	1.16

As can be seen from Table 9, SF Holding has significantly reduced its selling expense ratio since the year of acquisition, dropping to 1.04% in 2022, a decrease of 0.42% compared with 2020. This change benefited from SF Express's precise marketing strategy, which effectively reduced sales expenses and achieved remarkable results in cost control. At the same time, SF Express took advantage of Kerry Logistics' global supply chain nodes and brand advantages, and after internal integration, its business covered the whole country to further control sales costs [15].[15]

After the merger and acquisition, the proportion of SF Express 'administrative expenses also decreased significantly, which was mainly attributed to Kerry Logistics' international operation management experience and expertise, which improved management efficiency and execution. Since 2021, SF Express has streamlined and optimized its organizational structure, closely aligned with business development, and continued to reduce the ratio of selling expenses and administrative expenses [16].[16]

In general, M&A has a positive impact on SF's reduction of sales expense ratio, enhanced management cost control ability, and achieved management synergies

4.3. Analysis of financial synergies

Financial synergy reflects the financial ability of an enterprise, which is mainly enhanced by opening up the circulation of resources, especially solvency. This section will analyze the solvency of SF Holding before and after M&A and discuss the specific effects of M&A on financial synergy.[3]

4.3.1. Analysis of financial synergy effect based on short-term solvency

Table 9 shows the comparison between SF Holding's current ratio and the industry average before and after the merger. Sf's current ratio continues to be lower than the industry average, hovering around 1.3, indicating that its short-term solvency is reasonable, but there are still financial risks. Sf Express has adopted diversified financing and preferred short-term financing products in the long run, which has effectively alleviated short-term funding pressure and reduced financing costs. In the year of merger and acquisition, SF Express maintained a stable liquidity ratio, and its current assets and liabilities increased simultaneously. In the following year, current liabilities increased by 2.18%, while current assets decreased by 3.65%, resulting in a decrease in the current ratio, and current liabilities accounted for 65.52% of the total liabilities. By the end of 2023, SF Express's current ratio recovered and approached the pre-merger level. On the whole, the current asset turnover of SF Express fluctuates after the acquisition, and the financial synergy effect is not significant.

Table 9. Average current ratio of SF Holding to the industry from 2019-2023

Items	2019	2020	2021	2022	2023
Sf Holding	1.38	1.24	1.24	1.17	1.23
Industry average	1.39	1.40	1.38	1.36	1.29

Table 10 shows the comparison between SF Holdings and the industry average quick ratio before and after the merger. The quick ratio of SF Express is always higher than the industry average and is greater than 1, which reflects its strength in financial risk management [17]. [17]In the year of the acquisition of Kerry Logistics, the quick ratio increased slightly, but it declined in the following year due to the growth of current liabilities, which aggravated the debt pressure. By 2023, SF Express's quick ratio had recovered to its pre-merger level. Therefore, from the point of view of the quick ratio, SF Express has not been significantly improved by M&A, and the financial synergy effect is not significant.

Table 10. Average quick ratio of SF Holding to industry from 2019-2023 (unit: times)

Items	2019	2020	2021	2022	2023
Sf Holding	1.36	1.21	1.24	1.14	1.20
Industry average	0.85	0.85	0.83	0.84	0.79

4.3.2. Analysis of financial synergies based on long-term solvency

Table 11 shows the comparison between SF Holding's asset-liability ratio and the industry average before and after the merger. Sf Express's asset-liability ratio fluctuates greatly before and after the merger and is higher than the industry average. Before 2019, SF Express was heavily indebted due to the asset-heavy direct operation model, and its debt-to-asset ratio climbed. After 2019, its long-term debt ratio increased to 65 percent, reducing capital risk. However, after the acquisition of Kerry Logistics, SF Express's long-term and short-term borrowings increased due to its heavy use of cash. At the same time, SF Express announced A non-public offering plan to raise no more than 22 billion yuan, and its wholly owned subsidiaries also issued no more than 20 billion yuan of debt financing products, with a total financing scale of more than 40 billion yuan, and the debt pressure increased. In addition, since 2021, SF Express has adopted the new leasing criteria, increasing the right to use assets and leasing liabilities. [8]Therefore, the financial risk of SF Express increased after the merger, the long-term debt repayment ability did not improve, and this part of the financial synergy was not realized.

Table 11. Average asset-liability ratio of SF Holding and industry from 2019-2023

Projects	2019	2020	2021	2022	2023
Sf Express Holdings	54.08	48.94	53.35	54.67	53.37
Industry average	48.64	49.75	51.46	50.83	51.35

Table 12 shows the comparison between SF Holding and the industry average equity ratio before and after the merger. Sf's equity ratio has always been lower than the industry average, indicating that its financial structure is sound, and its long-term solvency is strong. In the year of the acquisition of Kerry Logistics, SF Express's equity ratio increased by 18.75 percent year-on-year, reaching the highest in five years in 2022, which is consistent with the analysis of asset-liability ratio. Sf Express debt level rose due to merger and acquisition financing. But by the end of 2023, the equity ratio had declined. Therefore, the equity ratio of SF Express increased after the merger, and the long-term debt repayment ability did not improve, and this part of the financial synergy was not realized.

Table 12. SF Holding and industry average equity ratio 2019-2023

Project	2019	2020	2021	2022	2023
Sf Holding	1.18	0.96	1.14	1.21	1.14
Industry average	2.22	2.40	2.57	2.61	2.66

4.4. Suggestions on improving synergies of SF Holding's cross-border acquisition of Kerry Logistics

4.4.1. Optimize capital structure and reduce capital cost

Sf Holding's asset-liability ratio is high due to the asset-heavy mode, and ultra-short financing products frequently affect the stability of capital structure. Therefore, SF Express needs to study debt financing methods, optimize capital structure, reduce costs and ensure steady development based on the actual situation [18]. [18]It is suggested that SF Express should issue long-term debt instead of short-term debt, extend the maturity time of debt, and reduce the refinancing risk and the impact of interest rate fluctuations. At the same time, it is suggested to take advantage of the low-interest rate environment, raise funds through bonds or long-term loans, stabilize the cost of capital, and reduce taxes by using the debt interest tax shield effect [19]. [19]In recent years, the state supports the express delivery industry, and commercial banks also support express loans. Sf Express can take this opportunity to optimize its financing structure.

4.4.2. Diversify payment methods to rationalize financial risks

In the cross-border merger and acquisition, SF Holding acquired 51.5% shares of Kerry Logistics for HK $17.555 billion in cash, which resulted in the decline of the enterprise's long-term and short-term solvency, and the financial synergy was not obvious. [18]Given that the transaction has been completed and the payment method cannot be changed, SF Express needs to develop diversified payment strategies according to its own situation to promote financial synergies and reduce financial risks. In addition, the announcement of Kerry Logistics shows that SF International Holdings (Thailand) has offered to buy 73.18% of the outstanding shares of Kerry Express (Thailand), with a total value of about 1.404 billion yuan. If the acquisition is successful, SF Express will hold 100% of the shares of Kerry Express (Thailand) [20]. [20]Therefore, SF Express should balance long-term and short-term liabilities in the follow-up financing, use the good reputation of both parties to reduce borrowing costs, reduce financial pressure, and keep the ratio of liabilities to assets within a reasonable range.

5. Conclusion

Based on the theory of synergy effect, this paper takes SF Logistics as the research object and analyzes the management, operation and financial synergy effect of its acquisition of Kerry Logistics. The research results show that SF Express has achieved good synergies in both operation and management, which are embodied in the growth of operating income, the improvement of profitability, the expansion of international operation talents and the improvement of the overall quality of employees. However, the financial synergies are not obvious, mainly due to the adoption of full cash payment in M&A, which increases the debt burden and affects the solvency.

Overall, SF's acquisition of Kerry Logistics has achieved remarkable results, promoting SF's entry into the Southeast Asian market and increasing international and supply chain business revenue. However, the merger also brings problems and risks that need to be addressed by both sides. Sf Express and the companies that plan to conduct cross-border mergers and acquisitions should pay close attention to the influence of complex factors such as culture, policy and environment, as well as possible differences in the integration process, and properly handle them to avoid financial and internal control challenges to SF Express. The success of the merger is largely due to the competitive advantages of both parties in their original business areas, and has laid a solid foundation for SF Express's internationalization strategy

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Question of AITO Marketing Strategy Analysis

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Abstract. With the improvement of people's awareness of environmental protection, low-carbon environmental protection, energy saving and emission reduction, green travel and so on have become a new way of life. In recent years, the new energy vehicle market gradually emerged, each big factory began to invest in the competition in the field of new energy, the competition is gradually white-hot, domestic brands BYD, Geely and other quickly force to occupy the main market, and Huawei and Xiaomi and other digital manufacturers also joined this track. This paper mainly focuses on the research perspective of Huawei and Cyrus, discusses why it can become a rising star and a dark horse in the field of new energy, analyzes the advantages and disadvantages, and compares the differences with other brands from the perspective of marketing. This paper is committed to answering the main marketing strategies of AITOs success, providing strategic reference for other brands, summarizing the defects and loopholes in marketing planning, and providing new ideas and new methods for the new generation of AITO.

Keywords. New energy, intelligent driving, AITO, Marketing mix

1.Introduction

1.1. Research Background

The new energy vehicle industry refers to the automobile industry with electric vehicles, hybrid electric vehicles and fuel cell vehicles as the main products and involving key technologies such as electric motors, batteries and electronic control systems. AITO is a high-end intelligent car brand, jointly launched by Huawei and Seres, dedicated to integrating intelligent technology into the automotive field, bringing a new driving experience to users. AITO is committed to integrating intelligent technology into every aspect of car design, manufacturing, and usage through technological innovation, enhancing the driving experience and convenience for users. As shown in Figure 1, China's auto sales in 2024 surged in March after a fall." It is expected that in 2024, the global sales volume of new energy vehicles will exceed 20 million units, and China will contribute for 60 percent of the global sales volume." Zhang said China has further become a" bellwether " of the global new energy vehicle industry. At the same time, China's new energy vehicle enterprises occupy an important market position, and the

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position of the new energy vehicle industry chain is further enhanced. China is accelerating as the center of the global automotive supply chain.[1]

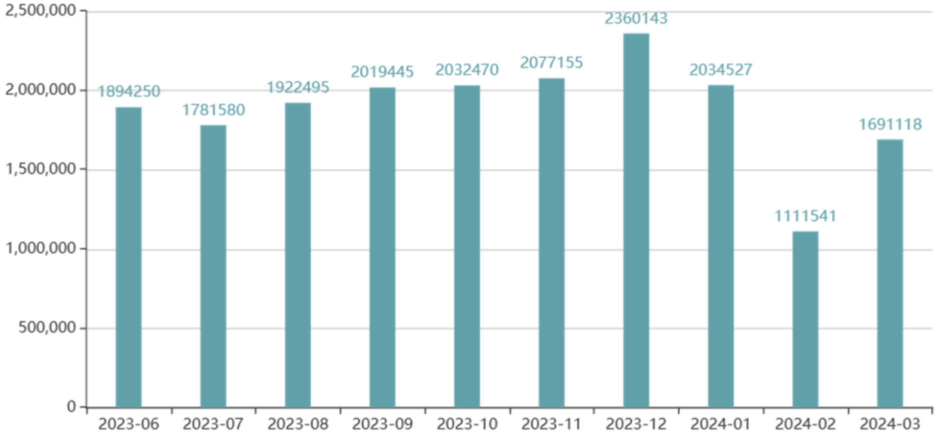

Figure 1 Trend Chart of China's Automobile Sales

The development of new energy automobile industry background mainly includes the following aspects: globally, governments to cope with the serious challenges of greenhouse gas emissions and improve the utilization efficiency of energy, have adopted a series of forward-looking policy measures to support the development of new energy vehicles, such as car subsidies, purchase tax shall be exempted, charging infrastructure, etc. , to ensure the convenient use of new energy vehicles. At the same time, the new energy vehicle industry is experiencing unprecedented technological innovation. Many traditional automobile enterprises invest in the field of new energy vehicles for technological innovation and product upgrading to adapt to the market changes, in the production process, which will improve the image of consumers and improve the long-term development of new energy vehicles.[2] International competition: New energy vehicles have become the focus of competition in the global automobile industry. Enterprises from all countries are actively layout the new energy market and compete for technological advantages and market share.

1.2. Research method, purpose, and significance

Article using case study method to help AITO build and strengthen its unique brand image. Through planning research, we can ensure that the brand conveys clear, consistent and unique values, thus enhancing consumers' recognition and memory of the brand. Research can help AITO to define its market positioning and target audience. Through in-depth market research and analysis, we can understand the needs, preferences and behavior patterns of target consumers, and provide targeted marketing strategies and solutions for the brand. By putting forward effective marketing strategies, it can better consolidate its market position and expand its market share in the competition of the new energy market. Marketing planning research can provide guidance and support for the development of the brand. Through an in-depth understanding of the market and consumers, brands can more accurately grasp the market trends and consumer needs, so as to develop marketing strategies that are more in line with the market reality and consumer expectations. An effective marketing planning scheme can help ask people to improve marketing efficiency and reduce marketing costs. Through clear marketing goals and plans, brands can carry out more targeted marketing activities to reduce unnecessary waste and costs.

1.3. Literature review

No matter from the perspective of energy security, environmental pollution or the transformation and development of the automobile industry, vigorously developing new energy vehicles is an inevitable trend of the automobile industry. With the rapid growth of sales of new energy vehicles, the improvement of charging infrastructure and the improvement of users' purchase intentions, pure electric vehicles and hybrid electric vehicles will have broad market potential. However, although FAW Pentium new energy vehicles started early in the industry, the market share is declining, and the survival and development of the Pentium brand is facing a severe test. Zhang Pengfei (2023) takes FAW Pentium new energy vehicles as the research object and uses the relevant theories of enterprise strategy management to study its development strategy. The SWOT analysis method is used to make a systematic analysis of the advantages, disadvantages, opportunities and threats of new energy vehicles. Combined with the development trend of the industry and the company's mission and vision of the company, the conclusion that FAW Pentium new energy vehicles should adopt WO strategy in the development is drawn, and the comprehensive strategy combining integration strategy and diversified management strategy is put forward. [3]

The Kotler behavioral choice model was proposed by Philip Kotler. This model emphasizes that consumer purchasing behavior is not only influenced by marketing stimuli such as product, price, place, and promotion, but also by external stimuli such as social, political, economic, cultural, and technological factors. Specifically, the Kotler behavioral choice model suggests that different consumers may exhibit different purchasing behaviors when faced with the same marketing and external stimuli. This is because factors such as their living environments, upbringing, life views, and values can all affect their purchasing decisions. Moreover, the model indicates that the consumer's purchasing decision is a complete and continuous process, involving not only pre-purchase information gathering and evaluation but also post-purchase experience feedback. This feedback influences future purchasing behaviors, creating a closed-loop decision-making process. In summary, the Kotler behavioral choice model provides a perspective for understanding consumer purchasing behavior. It highlights the impact of marketing stimuli and the external environment on consumer decision-making and points out the proactivity and differences among consumers during the purchasing process.[4]

2. Analysis of the marketing environment for AITO

2.1. Macroenvironmental analysis of AITO

2.1.1. Policy environment analysis

As the global community places increasing emphasis on environmental protection and sustainable development, governments worldwide have introduced policies to encourage the development of new energy vehicles (NEVs). Askey Auto, as a participant in the NEV sector, has benefited from these policies and gained more market opportunities. In 2001, China established a major science and technology project for electric vehicles, with the expert team creatively proposing the overall research and development framework of "three verticals and three horizontals," which became the fundamental pillars supporting the development of China's NEV industry. Throughout the NEV development process, we have fully leveraged the advantages of the new national system, fostering a collaborative effort among government, industry, academia, and research institutions to propel China's NEVs from inception to maturity, adhering to the dedication and perseverance of "ten years to hone a sword" in pursuing breakthroughs in key core technologies.

2.1.2. Economic environment analysis

With the development of the economy and the improvement of people's living standards, consumer demand for automobiles is increasing. According to data recently released by the China Association of Automobile Manufacturers, China's monthly car production in November set a new historical high, and the monthly production and sales of new energy vehicles exceeded 1 million for the first time. Deputy Secretary-General Chen Shihua stated that the market share of new energy vehicles has been over 30% for seven consecutive months, showing a stable and gradually increasing trend. After the pandemic, the daily production of Chinese passenger cars has steadily increased, stabilizing at around 30,000 units per day. As shown in Figure 2, It is expected that in 2023, China's automobile production and sales will reach a new high of 30 million units. Regarding the reasons for the rapid growth in production and sales in November, the China Association of Automobile Manufacturers believes that on one hand, it is influenced by the year-end carryover effect, and on the other hand, it is related to the low base of the same period last year. At the same time, with the rise in energy prices and the scarcity of traditional energy sources, the economic advantages of new energy vehicles are gradually becoming more prominent. AITO, with its efficient energy use and low maintenance costs, has won the favor of consumers. In addition, as consumers' awareness of environmental protection and energy conservation deepens, the market demand for new energy vehicles will further expand, providing a broad market space for the development of AITO.

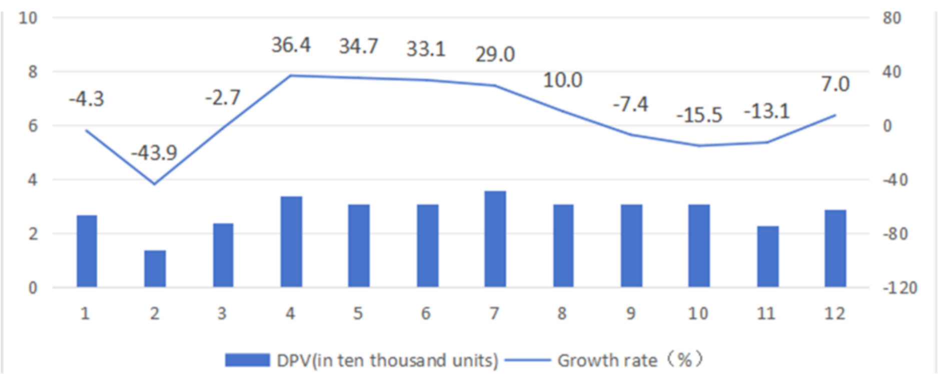

Figure 2 Year-on-Year Growth Rate and Daily Production of Sedans

2.2. Microenvironment analysis of AITO

2.2.1. Customer analysis

The customer personas of AITO primarily consist of middle-aged and young individuals with a certain level of economic strength and social status. As shown in Figure 3, according to FANS survey data, the vast majority of owners who purchased the AITO M9 are middle-aged and young individuals aged 30 or over. These customers prioritize quality and performance when purchasing vehicles, and they also have high expectations for vehicle comfort and intelligence. Simultaneously, male customers account for 87% of the market, while female customers make up approximately 13%, which is a high proportion compared to vehicles of the same class. In addition, regarding family size, approximately 68% of families have three or more members, indicating that most AITO owners consider family factors when making purchases to better accommodate the travel needs of family members.

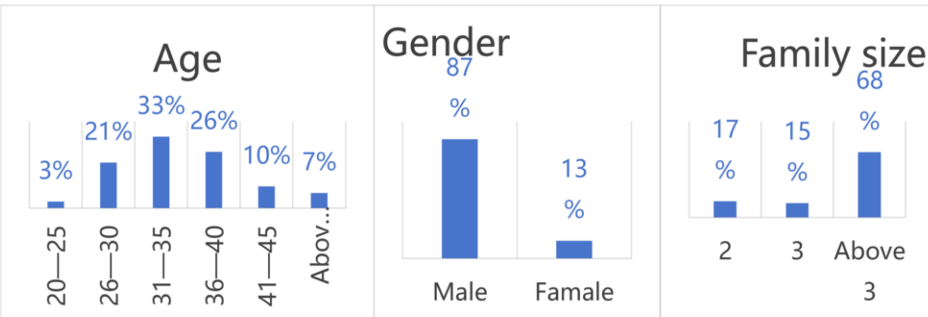

Figure 3 User Personas of AITO

3. Analysis of the current situation of AITO marketing strategy

3.1. Product strategy

3.1.1. Product mix

Product mix strategy is an economic strategy that involves how a company plans and combines its different products in terms of pricing relationships, functional characteristics, market positioning, and other factors. As shown in Figure 4, the main purpose of this strategy is to promote the sales volume of various products simultaneously by flexibly adjusting these relationships between different products, thereby achieving the company's value-added goals. AITO's product portfolio reflects the pursuit of intelligent, luxury experiences and diverse choices. For example, M9, as the first flagship SUV of Hongmeng Zhixing, shows the strength of Huawei intelligent vehicle full-stack technology solution. Equipped with Huawei's top ten intelligent car black technology, including a full ten-screen Hongmeng cockpit, HUAWEI ADS 2.0 advanced intelligent driver assistance system, providing users with superior luxury and intelligent experience.

3.2. Price strategy

3.2.1. Lipid-free pricing strategy

Lipid-free pricing strategy is a pricing strategy in marketing that involves setting a relatively high price for a new product or service when it first enters the market, in order to quickly recover costs and maximize profits as much as possible. This strategy is typically applicable to products that are innovative, unique, or have a low-price elasticity of demand. As shown in Figure 5, M7 and M9 respectively occupy the top spot on the sales charts for mid-large and large SUVs. Cost is the sum of expenses generated by an enterprise in the process of production, management and marketing. It is the starting point and an important part of the product price, and it is the main factor constituting the price.[5] Due to the high development cost and configuration of AITO, it is necessary to increase the initial pricing to recover part of the cost.

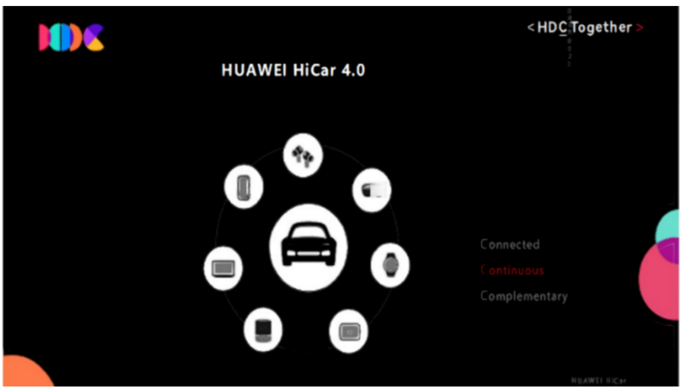

Figure 4 Huawei smartphone and vehicle connectivity

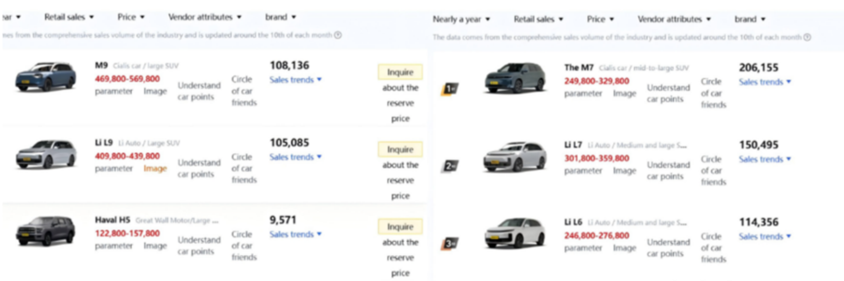

Figure 5 Comparison of Price and Sales Volume between AITO and Competitive Brands

Therefore, AITO relies on its market-leading technology to adopt the skimming pricing strategy for all three of its models and makes high profits in a short period of time. Since the ultimate goal of a company is to make money, an important step is to gain market share.[6]

4. Existing Problem

4.1. Product line single

The problem of a single AITO product line is mainly reflected in the relatively small number of models and the lack of sufficient diversity and flexibility to adapt to the needs and preferences of different consumer groups. This problem may bring the following challenges: Due to the relatively single product line, there are only M5, M7 and M9 models, which are difficult to cover all market segments, which leads to the loss of competitive advantage in some areas. This solidified brand image could limit AITO's ability to expand into new markets or attract new consumers in the future. What's more, a single product line also means that AITO lacks sufficient resilience in the face of market changes. Once a market segment shrinks or competition intensifies, it will be difficult to compensate for the loss with other alternatives, which poses a threat to the stability and sustainability of its overall performance.

4.2. Low brand awareness

As a new energy vehicle brand jointly created by Huawei and Cyrus, AITO's brand positioning focuses on intelligent technology and innovation. Question aims to transform Huawei's outstanding strength in frontier fields such as communication and artificial intelligence into competitive advantages in the automotive field and is committed to building new energy vehicles with highly intelligent and interconnected characteristics. However, compared with Xiaomi, BYD, Ideal and other brands that have a certain market influence, AITO's brand recognition is still in the growth stage.

4.3. Pricing strategy cannot meet customer needs

At present, new energy vehicles are developing rapidly. However, in terms of customer demand, some AITO marketers still have the problem that the analysis of customer demand is not comprehensive enough, leading to the fact that customer demand cannot be accurately and systematically analyzed, which increases the difficulty of customer relationship management. However, the survey found that some sales staff did not well analyze customers' consumption demand, consumer psychology, consumption characteristics, purchase intention and still used the traditional fuel vehicle marketing method to publicize the boundary new energy vehicles. On the basis of customer demand analysis is not comprehensive, only using low elastic pricing sales way is difficult to attract customers willing to buy new energy vehicles, can even lead to customers of new energy vehicles safety factor, performance, quality, which will directly affect the boundary market penetration speed, and affect the market share.[7]

5. Suggestions

5.1. Rich product line

5.1.1. In-depth market research

Understand the needs and preferences of different consumer groups, as well as market trends and competitive trends. According to the research results, the product positioning is clear, and the market segments to enter, such as urban commuting, family travel, cross-country adventure, etc. According to the market positioning, to launch more different types of models, such as cars, SUV, MPV, sports cars, etc., in order to meet the needs of different consumers. Under the same model, a variety of configurations and variations are provided to meet consumers' personalized and differentiated needs.

5.1.2. Strengthen technology research and development, and enrich technical routes

Continuous innovation to meet consumer needs: With the increasingly fierce competition in the new energy vehicle market, consumers have increasingly stringent requirements on products. In this context, AITO must maintain continuous innovation and launch new products that are highly competitive in line with market demand and demand. In the process of product design and development, AITO should always put user experience and user needs in the first place, and constantly optimize the product design and functional configuration through in-depth study of consumers 'usage habits and preferences, to ensure that the product can truly meet consumers' expectations.

5.2. Improve brand awareness

AITO should increase its brand publicity, carry out brand promotion through various online and offline channels, and enhance its brand awareness and reputation. At the same time, through joint marketing, cross-border cooperation with partners and other ways, broaden the scope of brand influence and enhance the brand influence. In terms of marketing strategy, AITO can significantly invite influential opinion leaders or industry experts to conduct in-depth experience and evaluation of products, and release objective and positive product evaluation and use feelings, which can significantly improve the brand awareness and reputation. At the same time, AITO should maintain a high degree of sensitivity and response to negative feedback and complaints, actively deal with and provide satisfactory solutions, show the brand's respect and care for users, so as to maintain a good brand image.

5.3. Increase marketing and publicity efforts

Increasing the marketing and publicity of new energy vehicles will help people achieve sales targets. First, in order to speed up the listing of new energy vehicles and expand the scope of new energy vehicles to occupy the market, we should actively launch preferential subsidy policies for the purchase of new energy vehicles, in order to stimulate customers' desire to buy. In the process of promoting new energy vehicles, we can take the current preferential car purchase policy and the advantages of new energy vehicles provided by the state as the main publicity content, and take green environmental protection and light as the highlight of the publicity.[8] Second, can draw lessons from the electricity industry preferential activities, strengthen the analysis of diversified customer demand, actively cater to the customer's consumption trend and consumption concept, through the shopping festival invited famous anchor to promote new energy vehicles, introduce their driving experience, to attract more customers recognized and buy ask new energy vehicles. In addition, it is also necessary to establish a customer feedback and evaluation mechanism for promotion effect, so that enterprises can more accurately understand the effectiveness of marketing activities, and timely improve the activities in each link according to the feedback information, so as to promote the formation of competitive advantages of new energy vehicles.[9] Finally, we can learn from the promotion method of Xiaomi Auto, and invite auto bloggers from the short video platform to evaluate all aspects of AITO experience, so as to increase the promotion efforts.

5.4. Develop a more reasonable pricing strategy

When analyzing the basic performance and cost of vehicles, enterprises need to fully consider the price of the same type of competitive brands and traditional fuel vehicles. Some flexible pricing strategies can be adopted, such as launching solutions adapted to young people, such as new energy vehicle battery rental solutions, to highlight the higher cost performance of products and meet the needs of different consumer groups.[10]

Fully consider the production cost, identify the target customer group, understand their purchasing ability, purchasing behavior, and demand and preferences for the product. Analyze the price sensitivity and consumption power of different customer groups in order to develop differentiated pricing strategies for different customer groups. Analyze competitors' product quality, price, cost and production status, as well as their marketing strategies and marketing portfolio strategies. Understand the raw material supply and resource status of the product to take these factors into account in pricing. With the help of big data and artificial intelligence technology, the company conducts in-depth analysis of market trends, consumer behavior and competitor dynamics, so as to provide strong support for the formulation of pricing strategies.

6. Conclusion

As a new rising new energy vehicle brand, AITO is facing both opportunities and challenges in the current fierce market competition environment. From the perspective of industry background and company background, AITO needs to establish and strengthen brand image in the competitive market, clarify market positioning and target audience, and increase market share; in terms of marketing strategy, AITO has implemented a series of product, price, channel and promotion strategies. However, there are still some obvious problems, such as a single product line, fuzzy brand positioning, insufficient product promotion and user interaction, and slow market penetration. These problems restrict the market performance and development potential of AITO to some extent. To solve these problems, this paper presents a series of countermeasures and suggestions. First, AITO needs to enrich its product line and launch more products that meet market demand through in-depth market research and technical research and development; second, define market positioning and strengthen brand building to enhance brand image and popularity, strengthen user interaction and marketing efforts, and enhance contact with users through online and offline activities to improve user satisfaction and loyalty. In addition, the IQ should develop a more reasonable pricing strategy to occupy more market share, which is also the key to improving the competitiveness of the AITO market.

In general, AITO needs to constantly optimise its marketing strategy. Through the implementation of a series of measures, AITO is expected to stand out in the fierce market competition, achieve their own marketing effect, and then realize the long-term development of the brand.

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Research on Inventory Optimization of A Company

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Abstract. With the continuous development of the market economy, the competition among enterprises is becoming more and more intense. New enterprises pay more and more attention to inventory management and try to establish a set of scientific and strict inventory management methods in order to reduce the waste of funds and control the inventory cost within the minimum, so as to increase the economic benefits of the enterprise. Company A belongs to the retail enterprise, which has high requirements in inventory management as well as funds. This paper adopts the relevant theories and methods of inventory management, and on this basis draws on the research results in inventory management at home and abroad, analyzes the current inventory management situation of Company A, analyzes the problems and reasons it faces, and improves it. On the basis of determining the optimal inventory management objectives, it puts forward the measures for Company A to carry out inventory management optimization: (1) ABC classification method, classifying the types of goods, determining the classification procedure of goods, and optimizing the inventory of various items; (2) perfecting the method of demand forecasting, optimizing the process of demand forecasting, and guaranteeing the implementation of demand forecasting; (3) optimizing the inventory order model, determining a reasonable safety inventory, improve the management mechanism of slow-moving products. The research of this thesis has certain reference value for the inventory management of Company A, and also provides certain reference for the inventory management of other enterprises.

Keywords. Inventory management; ABC classification; inventory optimization; demand forecasting

1. Introduction

1.1 Background of the study

With the development of economic globalization, enterprises are facing an increasingly competitive environment. How to carry out effective inventory management, reduce logistics costs, and improve enterprise competitiveness has become the core issue of

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enterprise management. At present, China's enterprises generally have the problem of excess inventory, resulting in a large amount of capital backlog, increasing the operating costs of enterprises. Therefore, how to optimize inventory management from the perspective of reducing logistics costs, to achieve the effective allocation of resources, is an important issue facing enterprises. Inventory management costs account for as much as 20%-30% of enterprise supply chain costs, so it is necessary to focus on the cooperation between key node enterprises in the supply chain and establish an integrated management mechanism. Inventory management is the core issue in enterprise supply chain management, through inventory management optimization, it can get more attention from manufacturers, retailers, wholesalers and suppliers, and improve the utilization efficiency of cash flow [1].

Based on the actual situation of Company A, this study will examine the various aspects of its inventory management, such as procurement, production, sales, etc., analyze the impact of different aspects on inventory management, and find out the key factors affecting inventory management. Based on this, this study will analyze how these key factors affect the logistics cost from the perspective of logistics cost and propose corresponding optimization strategies for inventory management. The optimization strategy of this study will be based on the aspects of reducing the occupation of fixed assets, reducing the backlog of inventory, and improving the efficiency of capital utilization, etc., which seeks to reduce the logistics cost of enterprises and optimize the inventory management level of Company A[2] .

1.2. Methodology, purpose and significance of the study

With the rapid development of the economy, the inventory management problem has become a decisive factor in the development of enterprises, so reducing inventory management costs and optimizing the inventory management of enterprises can increase the competitiveness of enterprises in the market and improve the operation of enterprises. The importance of this paper is as follows:

(1) Deal with Company A's difficulties in inventory management. From several perspectives, such as inventory ordering mode, ABC classification management, and demand forecasting, we can realize the refinement and scientificization of Company A's inventory management, and effectively deal with the current problems of Company A's stagnant inventory, inefficient turnover, and serious capital occupation, in order to further improve Company A's inventory management level [3] .

(2) Ensure the effective implementation of inventory management in Company A. Company A should forecast demand based on Company A's sales, use inventory models, ABC classification management, and other methods to reduce the proportion of Company A's inventory, and optimize and implement Company A's inventory management program over a longer period of time to enhance Company A's economic interests.

(3) Reduce Company A's inventory management costs. Aiming at the common characteristics of the retail industry, taking Company A as an example, we propose a set of practical inventory management optimization methods to reduce Company A's inventory management costs, improve the effectiveness of the company's resource allocation and inventory management, and continuously optimize and innovate so as to improve the efficiency of Company A's supply chain operation.

1.3. Literature review

Literature shows that there are problems in corporate inventory management such as lack of staff capacity, poor inventory turnover, and long inventory cycles, which can arise from the external environment or from within the company. In the process of research on enterprise inventory, there exists a relatively complete set of theoretical analysis methods, such as gray model method, moving average method, exponential smoothing method, network analysis method, system dynamics, hierarchical analysis and so on. At present, scholars at home and abroad have conducted a lot of research on the optimal problem of inventory management, but the inventory management research for large-scale retail industry is relatively small, lack of systematic analysis, and the retail industry enterprises themselves are diversified types of products, so the problem of inventory management often occurs. Based on this, this paper selects Company A, a large retail supermarket, to study the optimization of its inventory management, and analyzes the problems and their causes in the process of inventory management of Company A, and improves the inventory management of Company A. We hope that it can be of some reference significance for Company A's inventory management. [4] .

2. Relevant theoretical foundations

Inventory management, also known as stock management, is a management activity that manages the quantity and condition of goods in logistics. The goal of inventory management is to support the production, maintenance, operation and customer service of the organization. The main tasks of inventory management are to ensure the quality of materials, to meet the needs of users, and to minimize costs by making administrative savings wherever possible. The goal of inventory management is to achieve reasonable control of inventory quantities, reduce capital tied up, improve logistics efficiency, and ensure the accuracy and security of inventory [5] .

Demand forecasting is through the relevant survey data, detailed analysis and study of the proposed project's products in the future changes in market demand, to grasp the internal law of demand, accurately assess and judge the direction of its development, so as to ensure that the construction project put into operation after the product is the right way, the variety of products to meet the market demand, and at the same time is also the most competitive. Demand forecasting for engineering construction projects is a prerequisite and premise for feasibility studies. It is divided into two parts: domestic and international. Demand forecasting is based on market research data. The market research to be carried out is focused on the complexity of the product to be developed and the characteristics of the project.

The Economic Order Quantity (EOQ) model, a common inventory management model, also known as the Entire Lot Interval Quantity (ELOQ) model, is the most common way most companies minimize ordering and inventory costs. The model assumes that demand is stable and that suppliers can provide the required quantity of goods at any time. When the quantity of goods ordered is large enough, the ordering and transportation costs can be reduced, thus lowering the total cost of ownership. On the other hand, if the quantity of goods ordered is too small, it can lead to an increase in inventory costs. Therefore, the objective of the economic order lot model is to find an optimal order quantity that minimizes the total cost. [5].

Material classification method is also often called ABC classification method, or Pareto analysis method, which is more applied in cost management and belongs to one of the classification methods of inventory management. Material classification method is based on the percentage of cost of different items, divided into A, B and C categories, for different types of items, to determine different management methods, to realize the management of multiple varieties and items, to strengthen cost control. The ABC classification enables control of the main item types. Through the way of cost control, the main and secondary items are separated in different ways, the main contradiction of inventory cost control is explored, and the work of data collection, processing, and category classification is done.

3. Status of inventory management in Company A

3.1.A Company profile

Company A was established in 2021 and is located in Yuhua District, Shijiazhuang, it is a retail-oriented enterprise with a wide range of product categories and a wide age range of customers, but most of the customers are older middle-aged and elderly groups, this age group has higher purchasing power and stronger spending power. This paper will investigate the inventory situation of Company A, identify its inventory problems and propose solutions for it[6] .

3.2.A Company A's inventory procurement status

3.2.1. Order forms

Company A has two types of ordering, direct and indirect.

Direct ordering: Company A contacts its suppliers directly to purchase the goods it needs. Because Company A has enough market share to negotiate with suppliers, direct purchases usually result in better prices and better-quality goods.

Indirect ordering: Purchasing goods through agents or distributors. Company A uses indirect ordering because it does not have enough purchasing experience and resources for certain products. The advantages of indirect purchasing are that information about suppliers and commodities can be obtained more easily and the purchasing process is simpler.

3.2.2. Order operation

Company A firstly conducts market research to understand the specific information on prices and varieties in the market, and to understand the market development trend and consumer demand. The second step is to select suitable commodities and orders according to the market demand and its own positioning and develop a reasonable commodity planning program. The second step is to choose suitable suppliers to ensure a long-term stable source of goods, high-quality goods, and provide flexible ordering methods.

Then comes the process of ordering, acceptance, and selling on the shelves. Finally, there is inventory management, which adjusts inventory in a timely manner according to sales and market demand in order to maintain a reasonable level of inventory and avoid excess or shortage.

3.2.3 Need to consider inventory procurement

Factors to be considered in inventory purchasing include demand factor, purchasing factor, production factor, inventory factor, procurement lead time, seasonal factor and random factor. The seven influencing factors of inventory are a very important part of business management, which directly affects the operational efficiency and customer service level of company A. The company must fully consider these factors when purchasing to ensure the stable operation and development of the company[7] .

3.3.A Current status of inventory management in the company

3.3.1 Basic status of stockpile management

Company A has a head office warehouse and small warehouses in each store and has a warehouse management system that allows it to inventory its warehouses at any time. Inquire about inventory, locations, and product sales. Because Company A sells a wide variety of products, there are many types of products sold. Quantities also vary widely. At present, what Company A can do is to manage the products by simple categorization, and the most scientific method has not yet been introduced. In addition, due to the different characteristics of the products, the amount of inventory has increased, making inventory management very difficult. Although Company A has realized the necessity of scientific classification of inventory and has classified it according to the actual situation of the company, carried out reasonable inventory control, and introduced the strategy of regular ordering, it is still not able to manage the inventory of various products correctly. Once a month, Company A places a bulk merchandise orders. Before placing the order, the company leaders and the head of the purchasing department will forecast the demand based on the actual situation of the company, and at the same time summarize and replenish the work properly to prevent the situation of out-of-stock.

3.3.2 Status of inventory process management

Inventory management in Company A includes inbound management, outbound management and inventory management, and there is an inextricable relationship between the three. In the process of warehousing, acceptance of goods and counting of quantities are carried out, while warehousing involves sales documents and picking up of goods. In order to better find the optimal solution to match Company A's inventory management, it is necessary to have a deeper understanding of Company A's inventory, so it is necessary to have a deeper understanding of the process of warehousing and inventory counting of inventory management[8] .

If the enterprise can't well articulate the link between goods in, goods out and inventory, it will be easy to have discrepancies between accounts and reality. Strengthen inventory management to prevent over- or under-inventory. From 2020 to 2023, Company A's inventory amounted to more than 3 million dollars, and the inventory fund occupation was more serious.

4. A company's inventory management problems and cause analysis

4.1. Inventory management problems in one company

4.1.1 High rate of capital employed in inventory

Collect and organize the inventory data of Company A and analyze its data from 2020 to 2023, as shown in Table 4-1:

Table 4-1: Collecting and organizing Company A's inventory data and analyzing it from 2020 to 2023

timing	Amount on hand (in millions of dollars)	Sales (million dollars)	Percentage of funds
2020	442.06	864.76	51.12%
2021	487.36	912.28	53.42%
2022	339.76	605.41	56.12%
2023	382.23	667.54	57.26%

From Table 4-1, it can be seen that from 2020 to 2023, Company A's inventory fund ratio keeps increasing from 51.12% to 57.26%, which is an increase of 6.14%. From these data, the inventory amount and sales amount show a continuous decreasing trend from 2020 to 2023, with a slight increase in 2023. The increase in the proportion of inventory funds has caused Company A to occupy huge funds, resulting in a huge waste of resources and increasing the difficulty of Company A's inventory management.

In recent years, due to the impact of the epidemic, Company A's inventory and sales have been on a downward trend, but the percentage of inventory funds has been increasing, which is related to the great impact of the epidemic on logistics. At the same time, due to the impact of the epidemic on the economy, the purchasing power of consumers has declined accordingly, leading to an increase in inventory and management costs, which increases the company's capital utilization, reduces the flow of funds, and increases the pressure on the company's sales, which is particularly unfavorable to the future development of Company A[9] .

4.1.2. Failure to process slow-moving sales in a timely manner

Company A categorizes its inventory based on customer needs and preferences. Despite Company A's extensive analysis of customer demand, there are still some products that Company A is unable to sell. Effective management of excess inventory is not only related to the effectiveness of the company's inventory management, but also the excess inventory will increase the cost of Company A. A large part of the reason for Company A's excess inventory is the lack of accurate analysis and prediction of customers' demand, and the lack of reasonable assessment of customers' purchasing power, which leads to insufficient purchasing power of the customers, resulting in a large amount of excess inventory. In addition, people's consumption preference has changed a lot under the drive of new media such as "fast hand" and "douban". Coupled with Company A's negligence in inventory management, which led to problems in product sales, some products were about to expire, some had already expired, some had a short shelf life, and some were seasonal products, which could easily lead to slow sales due to expiration, out-of-season, and irrational inventory management[10] .

4.1.3. Low inventory turnover rate

The level of inventory turnover is directly related to the short-term solvency of Company A, which in turn affects the company's management. Therefore, by increasing the inventory turnover ratio of Company A, it can strengthen the capital investment of the enterprise and reasonably release and consume the inventory of Company A, so as to improve the operation management of the enterprise and accelerate the capital turnover. From 2020 to 2023, Company A's inventory turnover days are increasing, the average inventory and sales volume are decreasing, and the corresponding inventory turnover ratio is getting lower and lower, which means that Company A's inventory cost is getting higher and higher, and the corresponding management difficulty is getting higher and higher, resulting in a serious capital utilization and a serious surplus of merchandise inventory.

4.1.4. Inaccurate demand forecasts

Company A's demand forecasts are inaccurate due to internal and external circumstances. Including external factors and internal factors. Among them, external factors will have a direct impact on consumers, such as the rise of short videos makes consumers no longer only pay attention to the service and intelligence of the product, but pay more attention to the celebrity effect and Netflix bandwagon, which exacerbates the fluctuation of consumer demand. The internal factor is the manager's prediction and attention to demand. Due to the limited knowledge and ability of managers, there is a bias in the prediction of demand.

4.2.A Analysis of the causes of inventory management problems in the company

4.2.1. Analysis of internal causes

(1) Inventory control

Company A has some problems in inventory control, such as inventory overhang, inventory shortage, and irrational inventory structure, resulting in low inventory turnover and high inventory losses.

(2) Inadequate information systems

Company A's information system has deficiencies, such as the lack of effective inventory management software and inaccurate data in the information system, resulting in inefficient inventory management.

(3) Lack of internal oversight

Company A's internal oversight system still has many deficiencies, such as the lack of an effective internal audit oversight mechanism and unclear responsibilities, resulting in chaotic inventory management and serious waste[11] .

4.2.2. Analysis of external causes

(1) Market changes

Company A's inventory management faces severe tests due to the uncertainty of the market environment and increased competition. For example, sales forecasts are subject to deviation due to changes in market demand, which affects the company's inventory control.

(2) Changes in policies and regulations

For example, changes in tax policy and environmental regulations may increase the cost of inventory or restrict inventory sales.

(3) Supply chain issues

The instability of the supply chain can cause difficulties in managing Company A's inventory. For example, untimely deliveries or inconsistent quality from suppliers can result in inventory shortages or backlogs.

5. A company's inventory management optimization measures

5.1. Optimization objectives

In order to ensure the long-term development of Company A, the company should keep the inventory management level within a reasonable range, reduce the inventory cost, improve the efficiency of inventory management, establish a scientific inventory management optimization mechanism, shorten the management cycle, improve the overall level of inventory management, and achieve the profit target[12] .

5.2. Introduction of ABC classification management methodology

The ABC classification method is a commonly used inventory management method that categorizes inventory items according to their quantity and value so as to determine different management methods and control measures. Its main purpose is to improve the efficiency and effectiveness of inventory management, thus making better use of limited resources[13] .

(1) Breakdown of commodity procurement types

Generally speaking, category A materials account for 60%-80% of the total inventory, belonging to the company's more important material content. category B materials account for 20%-30% of the total inventory, belonging to the company's general concern for the material. category C materials generally account for 5%-15% of the total inventory, accounting for 60%-80% of the consumed quantity, belonging to the high-value inventory commodities that can be increased at any time.

However, the traditional ABC classification method is complicated to categorize goods, so we need to classify the company's goods with the help of purchasing difficulty and the value of goods. Purchasing difficulty is denoted by X, Y and Z. The results are shown in Table 5-1:

Table 5-1 ABC classification of Company A's products.

form	subcategories	Volume ratio (%)	Annual cost of sales (%)
A	AX/AY	50-70	5-10
B	BX/BY	20-30	15-20
C		5-10	60-80

(2) Clarify the steps of commodity classification

Based on the difficulty of purchasing Company A's products and the value of the goods, the following steps are performed based on determining the categories, subcategories, volume ratios, and annual cost of goods sold ratios:

The first step is to categorize the basic data for all of Company A's products based on sales volume and cost.

The second step is to account for each program individually based on the proportion of selling expenses to total costs.

The third step is to calculate the cumulative proportional probability of all items.

The fourth step is to classify them according to the ABC classification.

In the fifth step, based on the difficulty of purchasing and the value of the commodity, the three different commodities A, B, and C are categorized for a second time, i.e., X, Y, and Z delineation, resulting in a commodity subcategory.

The sixth step is to combine the cost of goods sold and the difficulty of purchasing various types of goods, further categorize the combination of goods, resulting in AX, AY, BX, BY four major categories, to focus on their control, and develop a targeted inventory management strategy.

(3) Optimize inventory strategies for different items

Table 5-2 Product Management Strategies for Company A under the ABC Category

form	A	B	C
subcategories	AX/AY	BX/BY	
Percentage of annual cost of sales	lower (one's head)	intermediate	your (honorific)
Order Quantity	more	more	fewer
Ordering frequency	Each order point	Month/time	fewer
counting frequency	Month/time	Month/time	Quarter/time
safety stock	your (honorific)	intermediate	lower (one's head)

Class A commodities: the quantity accounts for about 50-70%, the annual cost of goods sold accounts for about 5-10%, the cost is low, the inventory is large, the value is high, and it plays a key role in Company A's inventory management, which should be highly valued by Company A. For Class A commodities, adjust the order quantity in real time according to the actual demand, ensure the safety stock, and do the inventory and maintenance of the commodities on a regular basis.

Category B goods: the quantity accounts for about 20-30%, and the annual cost of goods sold accounts for about 15-20%. The importance of Category B goods is slightly lower than that of Category A goods, so it is only necessary to ensure that the order quantity of Category B goods conforms to the requirement of safety stock. Category B goods are generally subject to a monthly inventory by means of regular ordering, which enables proper control of the inventory.

Category C commodities: about 5-10% of the quantity and 60-80% of the annual cost of goods sold, high economic value of the commodity, low profit, so the order quantity is small, the frequency is low, and the order is usually completed quarterly [14] .

5.3 Improvement of demand forecasting methods

(1) Determination of forecasting objectives: Firstly, the forecasting objectives of Company A are determined on the basis of product categorization. In order to ensure unnecessary resource consumption and waste, ABC classification method is adopted for Company A. Demand forecasting for AB goods, shorten the forecasting cycle as much as possible, improve the forecasting accuracy, and determine the corresponding goods safety stock by combining with the demand.

(2) Constructing forecasting model: Strengthen information sharing and improve communication mechanism by analyzing and organizing relevant historical data and information. This includes analyzing Company A's annual sales plan, financial statements, annual sales reports, inventory tables, etc. Analyze Company A's inventory management demand forecasting basic data to clarify customer demand trends. Collect the actual sales situation and inventory level to choose the appropriate demand forecasting method.

(3) Review the forecast results: the demand forecasting process involves many factors, which will lead to errors in the forecast results and the actual existence of errors, further affecting the company's decision-making, which may result in significant economic losses, so it is necessary to minimize the probability of error.

(4) Determine the forecast value: Combined with the results of the demand forecast approved by the audit, prepare a demand forecast report and submit the forecast value of the report results to the company's management personnel to carry out audits in a timely manner, and send the results of the report approved by the audit to the relevant departments in a timely manner, as a reference and a basis for the management of the inventory of the other departments[15].

(5) Ensuring the implementation of demand forecasting: Both qualitative and quantitative forecasting are required for Company A's inventory demand forecast. Qualitative forecasting means that the forecaster relies on professionals and experts who are familiar with business knowledge, experience, and comprehensive analytical skills, and uses his or her own experience and judgmental skills to determine the nature and extent of the future development of an event on the basis of existing historical data and intuitive materials, and after that, integrates the views of all parties in a certain manner as a way of predicting the future development. Quantitative forecasting is the use of past information or variables that influence factors to predict future needs. It is a kind of prediction and forecasting of future development and changing conditions based on the more complete historical statistical information that is already available, and through some kind of mathematical and scientific processing and organizing, so as to show the regular relationship between the relevant variables. Methods such as historical analogy, group opinion method and time series method are mainly used to carry out the forecasting of data.

Since the smoothing index method is simpler and more accurate, the smoothing index a,Eq. is constructed:

Next period's forecast = actual demand value *α + (1-α) * previous period's forecast value

Suppose a product of Company A is the object of study and its inventory management demand is forecasted using the smoothing index method. Assuming that the forecast value of the goods in February is 210 and the actual sales volume is 200, set α to 0.3, and based on this, calculate the forecast value for March as 200*0.3+(1-0.3)*210=207. It is known that the actual demand for March is 216, and based on this, forecast the demand for March as (1-0.3)207+216*0.3=209.7.

Demand forecasting for Company A's products needs to be carried out in conjunction with a standardized demand forecasting process and implementation, using a combination of qualitative and quantitative analysis to determine the reasons for changes in demand for certain commodities in the enterprise, and, if necessary, to introduce a system of accountability for inventory management to reduce the cost of inventory management, improve the accuracy of demand forecasting, and enhance the efficiency of Company A's inventory turnover.

5.4. Optimize inventory ordering model

5.4.1 Determine a reasonable safety stock

For Company A's A, B two products, should also establish the economic order lot model, that is, EOQ, which applies to the batch interval procurement, does not allow shortages, that is, the demand for a certain material per unit of time is a constant D, at this time, with the consumption of D per unit of time and decreasing, after a period of time T, when the reserve is reduced to 0, it immediately enters into the order quantity, the inventory increases from 0 to the maximum inventory Q, and then start the next storage cycle, thus forming a multi-cycle storage model. Therefore, inventory management is to minimize inventory costs under the condition of guaranteeing a certain quantity. For different kinds of goods, different inventory management strategies can be adopted.

The low cost, high profit, and high sales volume of category A goods make it suitable to use the regular order method and the temporary purchase method together to maintain the safety of inventory. The sales volume of category B goods is lower than that of category A goods, so only the regular order method can basically satisfy the demand. The sales volume of category C goods is also lower because of its own higher cost, and the quantitative ordering method can be used.

In order to forecast the sales of Company A's merchandise, you need to calculate the standard deviation of demand, average lead time, ordering costs, and inventory costs for Company A's merchandise. Combine this with the economic lot size model to calculate safety stocks, lot sizes, and order points for key items. [10]. For exampleFor Company A's Class A merchandise in 2024, the demand for one product is forecast to be 13,745 units. Assuming a service level of 90% during the inventory cycle, a determined safety factor of 1.8, an average lead time of 20 days in the ordering cycle, a storage cost of $5 per product, and a reorder cost of $200, the calculations are as follows[16] :

Safety stock = standard deviation of requirements * safety factor *√ order lead time = 1.8*15*√20 = 118 units

Reorder point = advance ordering period * average daily demand + safety stock = 20*13745/365+225 = 871 units

Economic order quantity = $\sqrt{}$ (2DS/C) = $\sqrt{}$ (2*13745*200/80) = 262 pcs.

Average stock = safety stock + recurrent stock = 118 + 262/2 = 249 pieces

5.4.2 Improvement of mechanisms for the management of slow-moving goods

The operational strategy at the store level is as follows:

(1) Adjust the display area and copy the sample.

(2) Linkage display, combining slow-selling products with hot-selling products, and driving slow sales through hot sales.

(3) Setting sales targets and strengthening sales promotion.

(4) Enhanced guidance for stores, such as window displays.

The operating strategy at the corporate level is as follows:

(1) Setting sales goals for the store and giving employees reasonable compensation for large orders and high unit price products.

(2) For products with large inventory, promotions are based on their time-to-market and product life cycle.

(3) The company's product and training department can develop FABE and operation guidelines for products, conduct training for stores, and provide help for product specialization.

(4) At the ordering level, when a company cannot accurately predict what will be hot in the market, it can use trial sales, small lots and high frequency to order and distribute uncertain products [17] .

6. Effectiveness of the implementation of inventory management optimisation in company A

Through the optimisation measures of Company A's inventory management, the accuracy of inventory information and demand forecast can be improved, combined with a reasonable inventory level, to help Company A set up a safety stock and improve Company A's inventory management level. Through the optimisation of inventory management, the level of material management can be improved, the inventory management process can be established and perfected, the closeness between Company A's procurement and inventory can be improved, the reasonableness of material procurement can be strengthened, the cost and expense of procurement can be reduced, the reasonableness of inventory management can be improved, and the efficiency of Company A's production and operation can be enhanced. Through half a year's implementation of the programme, Company A's inventory management has achieved the following initial results.

6.1 Shortening of inventory turnover days

From the beginning of the implementation of the optimised inventory management plan in Company A, the comparison of the inventory turnover days before and after the optimisation shows that the inventory turnover days are drastically reduced, which improves the efficiency of the inventory turnover, so the optimisation of the inventory management in Company A can strengthen the inventory management and reduce the inventory cost expenditure.

6.2 Supply and Demand Information Sharing Enhancement

On the basis of Company A's original inventory management, further optimisation and upgrading are carried out to improve the management services of personnel in different links, standardise the management process, improve the accuracy and authenticity of data entry, and improve the efficiency of material flow in Company A's inventory management. In the inventory management system, it is necessary to ensure that the status and process of the entire inventory can be queried, improve the degree of sharing of various information modules, and improve the efficiency of inventory management and supply chain management of Company A. For example, with the inventory management system, it is possible to check the status and process of the entire inventory at any time. For example, with the help of the inventory management system, you can check the status of materials in and out of the warehouse, the quantity of specific goods, inventory information, etc., and reasonably adjust the next procurement plan, with the help of the safety stock, to reduce the abnormal orders and inventory backlogs, stock-outs, and at the same time, reduce the use of funds as well as the unreasonable logistics freight costs. Compared with Company A's original inventory management, the optimized inventory management greatly reduces inventory and procurement costs, reduces the number of labourers, reduces costs, shortens the response time to customers, improves the punctuality and reliability of goods delivery, and brings more competitive advantages to Company A's competition.

6.3 Inventory Turnover Efficiency Improvement

Based on the ABC classification method, we explore the optimisation plan of Company A's inventory management and select BV products in Class A goods and ZX products in Class B goods to start the comparative analysis and compare and analyse before and after the optimisation of inventory management by combining the data of safety stock, inventory turnover rate, average inventory and order quantity. Through the optimisation of inventory management, the inventory turnover ratio has been significantly improved, the corresponding inventory cost has been greatly reduced, the use of inventory funds has been reduced, the operational efficiency of Company A has been improved, and the optimisation of inventory management has achieved very significant results.

7. Research conclusions and outlook

7.1 Conclusions of the study

Inventory management is a very important part of the business process, through the use of effective inventory management system to control inventory materials, to ensure the effective use of enterprise resources. Inventory management occupies a very important position in the business activities of an enterprise and is the embodiment of the core competitiveness of the enterprise. On this basis, this paper proposes a new method, that is, by optimizing the inventory of Company A, it can effectively reduce the inventory cost, improve the inventory turnover rate, enhance customer satisfaction, and then enhance the competitiveness of the enterprise. On this basis, based on the inventory status quo of Company A, the questionnaire survey and data analysis are used to find out the main problems in Company A's inventory management and optimize them. By applying ABC classification method, demand forecasting method and performance evaluation method, the inventory management status quo of Company A is effectively improved, which provides a reliable guarantee for the long-term development of the enterprise.

Based on the theory of inventory management, this paper analyzes the current situation of inventory management in Company A. Combined with the results of the questionnaire survey and data analysis, it analyzes the problems and reasons of inventory management in Company A, proposes corresponding optimization measures, and evaluates the effect of the implementation, and carries out a comparative analysis of the data before and after the optimization. Through the study, the following research results are obtained:

(1) Propose optimization measures for inventory management in Company A. Introduce the ABC classification management method, subdividing the difficulty of commodity procurement, clarifying the steps of commodity classification, and optimizing the inventory strategy for different goods. Improve the demand forecasting method, optimize the demand forecasting process, and ensure the implementation of demand forecasting. Optimize the inventory ordering model, determine a reasonable safety stock, and improve the management system of slow-moving goods.

(2) Propose guarantee measures for optimizing inventory management in Company A. It is necessary to realize regular inventory counting, dynamic statistics of inventory data, continuous employee training and improvement of inventory management system. The strong safeguard measures improve the refinement level of Company A's inventory management and provide a strong guarantee for the optimization of Company A's inventory management program.

(3) Evaluate the effect of inventory management optimization in Company A. Combined with Company A's inventory management optimization plan, it is concluded that Company A has achieved good results through carrying out inventory management optimization, which is reflected in the shortening of inventory turnover days, the reduction of the number of emergency purchases, the enhancement of the sharing of information on supply and demand, and the improvement of the efficiency of inventory turnover. By optimizing Company A's inventory management, Company A's profits and benefits have been greatly improved, and it can also provide reference for other enterprises to optimize their inventory management.

7.2 Shortcomings and prospects of the study

This paper focuses on analyzing and studying the current situation of inventory management in Company A. Although the problems of the company's inventory management are found and solutions are proposed, there are still some shortcomings, such as the limited use of some research methods and the limited use of quantitative analysis methods.

With the progress of the times and the development of science and technology, the methods of inventory management optimization are becoming more and more diversified and effective, and a variety of advanced concepts continue to appear, which can provide better solutions for inventory management optimization. At present, big data technology has made rapid development, and future inventory management research can be based on intelligence and universality, combined with big data technology, analyze the methods of inventory management optimization, and further improve the level of inventory management research.

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The Intervention Effect of "Reminiscence Therapy" on the Self-Esteem of Elderly Individuals with Advanced Age

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Abstract. Purpose: The purpose of this study was to understand the current status of self-worth among elderly individuals (aged 85 and above) in welfare institutions and to explore the effects of reminiscence therapy on their cognitive biases, negative emotions, and interpersonal communication barriers in elderly care. Methods: An 8-month long intervention and questionnaire survey was conducted using the Self-Worth Sense Scale for the senior citizens in the jurisdiction of Shanghai N Welfare Institute and its two community health service centers directly under it. 530 senior citizens were randomly divided into the intervention group and the control group, and the intervention group was provided with recall activities once every two weeks for one hour at a time, and the Social Involvement Scale, Quality of Life Scale and Self-Worth Sense Scale were used to measure the Intervention effect. Results: The total score of self-worth of the elderly was significantly improved through the recall intervention, and the five dimensions of influencing ability, interpersonal relationship, rule quality, psychological quality and physical ability were significantly improved. Conclusion: The effect of “Thinking Back” on the self-worth of institutionalized elderly is positive and effective, and the design of “Thinking Back” intervention activities is operable for the social work practice of institutionalized elderly.

Keywords. elderly individuals; self-esteem; reminiscence therapy

1. Introduction

As the elderly population in our country continues to grow, the pressure of elderly care and retirement is increasing; On the contrary, the situation in our country is characterised by a continuous decrease in family size and a reduction in available resources for family support.[1, 2] Such contradictions have led to a continuous expansion in the demand for elderly care services, especially for the elderly, and the socialized elderly care model has gradually replaced the family elderly care model.[3, 4] As a socialized elderly care mode, the status of institutional elderly care in the national elderly care service system has been constantly changing, from "supplement" to "support", playing an increasingly important role. Although the elderly living in elderly care institutions will receive professional and timely care for their lives and their basic physiological needs will be met, their more advanced needs such as psychological counseling and emotional support cannot be met.

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Many elderly people, especially the elderly, are negative and pessimistic, have low self-esteem, and think they are useless, dragging down the country and their families, and are worthless people.[5, 6] The vulnerable group of elderly people (over 85 years old) has obvious differences from the middle-aged and younger elderly people (60-69 years old) both physically and psychologically. The decline of many psychological functions and changes in mentality seriously affect their quality of life in their later years. Objectively, social workers are required to attach great importance to the special needs of this group.[7] However, at present, the social work field in my country has not yet identified the elderly as a group in need of special services. The professional services for this group are rather scattered and are still in the stage of practical exploration, lacking practical research and theoretical support.

Since the "recall method" was proposed by American psychiatrist Butler in 1963, it has been the focus of researchers at home and abroad. It has been applied in different environments and among different subjects, especially in elderly care institutions and nursing homes, to improve the cognition, emotions, self-esteem and other aspects of the elderly.[8-10] Its role in improving the cognitive, emotional, and mental disorders of the elderly, and improving their mental health and quality of life has been increasingly recognized. The Social Work Department of the Shanghai No. N Social Welfare Institute introduced the "Recall Method" in early 2014. Combining the physical and mental characteristics of the elderly in the institution, the elderly verbally recalled their life milestones to re-establish their own meaning of life, improve their quality of life, and establish their dignity and self-confidence. Based on this, this study intends to explore the role of the "Recall Method" in improving the self-worth of the elderly in the institution and provide empirical data for better improving the quality of life of the elderly.

2. Objects and Methods

2.1 Research subjects

From January to October 2023, young retired elderly people living in the jurisdiction of Shanghai N Welfare House and its two directly affiliated community health service centers were selected as the survey subjects. Inclusion criteria: ① According to the elderly (>85 years old); ② Retirement, according to national regulations, men aged 60, female cadres aged 55, and female workers aged 50 are regarded as retirees, including those who retire early due to loss of labor force and those who are re-employed after retirement, and the location of the retirement unit is in the city; ③ Have certain visual and auditory functions, have mobility, mild dementia, basic understanding and expression ability, no major life events in the recent period, stable physical condition; voluntarily participate in activities, and have appropriate time allocation. Exclusion criteria: ① Those who suffer from severe physical diseases, cognitive disorders, consciousness disorders, mental illnesses, etc. and are difficult to cooperate; ② Those who refuse to participate in the survey.

2.2. Survey Tools

① General information: The survey content includes the gender, age, education level, pre-retirement occupation, physical and mental state of retired elderly people. ② Social involvement scale: The scale adapted by Minihan et al. [11] was used, which includes four dimensions: worry about others' approval, offline social interaction, social investment, and social risk-taking. The Likert 4-point scoring method was used, with scores ranging from 1 to 4 from "strongly disagree" to "strongly agree". All items were scored positively, and the higher the total score, the higher the individual's rejection sensitivity. ③Quality of life scale: the simplified quality of life scale revised by Wang Hongyu et al. [12] was used, which has 12 items and 8 dimensions. Since the number of items in each dimension is different, it is impossible to compare the quality-of-life scores of different dimensions, so the original scores need to be standardized. ④ Self-worth scale: The self-worth scale for the elderly compiled by Zhou Hui et al. [13] was used. It includes five dimensions: influence value, rule value, physiological value, psychological value, and interpersonal value, with a total of 25 items. Each item is assigned a score of 1 to 5 from "completely inconsistent" to "completely consistent", with a full score of 125 points. The higher the score, the stronger the elderly's sense of self-worth.

2.3. Survey Methods

The questionnaire on the sense of self-worth of the elderly was used. The investigators were composed of graduate students, undergraduate students and other members of the research team who had received unified training. The tutor contacted the community health service centers to obtain support and obtain the health records of residents. The elderly who met the inclusion and exclusion criteria were surveyed in a door-to-door manner. The purpose and significance of the study were explained first, and a formal survey was conducted after obtaining the consent of the interviewees. The author mainly surveyed the elderly in the welfare home through questionnaires and interviews. The study employed a formal questionnaire titled "Self-worth of the Elderly," which was designed to measure the self-worth of older adults across five primary dimensions. These dimensions were carefully selected to comprehensively assess the various aspects of self-worth relevant to the elderly population, such as personal achievements, sense of purpose, social connections, physical well-being, and emotional health. The questionnaire items were tailored to capture the nuances of these dimensions and were further refined based on the actual circumstances and characteristics of the research subjects, ensuring that the questions were relevant and easily understood by the elderly participants. To complement the questionnaire, the interview content was also customized according to the specific context and needs of the study population. This approach allowed for a deeper exploration of the respondents' self-perceptions and experiences, providing a richer and more nuanced understanding of their self-worth. In total, 545 questionnaires were distributed among the elderly participants, ensuring a wide and diverse sample to enhance the representativeness of the findings. Out of these, 530 questionnaires were completed and deemed valid, resulting in a high response rate of 97.2%. This impressive response rate underscores the participants' engagement and the effectiveness of the data collection process, contributing to the reliability and robustness of the study's results. The high number of valid responses also indicates the appropriateness of the questionnaire design, and the relevance of the topics covered, which resonated well with the elderly respondents.

2.4. Statistical methods

SPSS Statistics 25.0 was used for data analysis. Quantitative data were analyzed descriptively and expressed as mean ± standard deviation (x ± s). The correlation between self-efficacy, self-worth and social adaptation was analyzed by Pearson correlation analysis. The mediating effect and the moderating effect were analyzed by hierarchical regression analysis. AMOS 23.0 was used to establish a structural equation model for testing. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Basic Information of the Survey Subjects

There were 185 males and 345 females; aged 85-96 (87.5±0.3) years old; 75 people with primary school education or below, 115 people with junior high school education, 131 people with high school education, and 209 people with college education or above; 59 people were managers, 179 professional and technical personnel, 214 office workers, 51 workers, and 29 self-employed merchants before retirement; 87 people had a pension of <3000 yuan, 259 people had a pension of 3000-5000 yuan, 154 people had a pension of >5000-8000 yuan, and 30 people had a pension of >8000 yuan.

3.2. The effect of thinking back

It can be seen from the total score and each dimension score of independent sample T and "sense of self-worth" that there is a significant difference between the intervention group and the control group. The scores of the intervention group increased from pre-intervention to post-intervention, while on the contrary, the scores of the control group showed a downward trend. Among them, the scores of independent sample T are shown in Table 1, and the total score of self-worth and the changes in scores of each dimension are shown in Table 2.

Table 1 Comparison of the effects of recall intervention on independent sample T.

	Before intervention		After intervention		The P values of the specific and summary scores of the five dimensions	
Subjects	Intervention group (n=50)	Control group (n=45)	Intervention group (n=50)	Control group (n=45)	Intervention group (n=50)	Control group (n=45)
Total score	85.9±17.6	86.5±17.3	107.0±8.2	76.7±16.5	0.003	0.012
Influence	15.1±4.8	14.8±3.1	21.0±2.0	13.1±2.8	0.002	0.008
Relationships	20.0±3.3	18.9±5.4	25.1±2.5	16.7±3.9	0.001	0.107

Physiological value	21.2±5.4	22.1±3.2	25.6±2.4	20.2±2.6	0.031	0.07
Rule	15.3±3.0	15.9±1.5	17.8±1.4	14.5±3.5	0.025	0.154
Psychological Value	14.3±3.5	14.8±4.1	17.5±1.6	12.2±3.7	0.021	0.160

It can be seen from Table 1 that for independent sample T, whether it is the total score or the P value of influence, interpersonal, psychological, physiological, rules and psychological value, it is less than 0.05, indicating that the intervention results are significant. Significant changes occurred before and after the intervention, and the elderly's sense of self-worth was improved. However, the P values of the control group's sense of interpersonal value, sense of physiological value, sense of rule value and sense of psychological value are all greater than 0.05, indicating that the effect of the control group is not significant.

Table 2 Comparison of the effects of recall intervention on self-worth.

	Before intervention		After intervention		The P values of the specific and summary scores of the five dimensions	
Subjects	Intervention group (n=235)	Control group (n=200)	Intervention group (n=235)	Control group (n=200)	Intervention group (n=235)	Control group (n=200)
Total score	846±74.1	899±77.0	997±84.4	846±73.6	0.01	0.008
Influence	165±12.4	157±11.5	197±14.5	149±13.9	0.005	0.014
Relationships	197±16.7	213±18.5	238±20.7	201±18.6	0.002	0.095
Physiological value	183±15.8	209±19.2	225±21.4	195±17.6	0.024	0.068
Rule	156±17.9	175±15.1	179±15.5	162±12.7	0.014	0.081
Psychological Value	145±11.3	145±12.7	158±12.3	139±10.8	0.013	0.092

As shown in Table 2, the "self-worth" of the elderly who participated in the recall group was significantly improved. From the comparison of the total scores of "self-worth" of the intervention group and the control group, it can be seen that the total score of "self-worth" of the intervention group increased from 846 to 997 before and after participating in the recall group, which was significantly improved, indicating that the recall method is effective in intervening in the self-worth of the elderly. It is worth noting that in the 8 months between the pre- and post-tests, the total score of "self-worth" of the control group decreased from 899 to 846, showing a downward trend, indicating that it is necessary to intervene in the self-worth of the elderly in the institution. The possible reasons for this trend are the physical and social functions of the elderly will undoubtedly deteriorate over time. At this time, if the institution does not intervene or the elderly do not exercise on their own, the self-worth of the elderly will show a negative trend. This also shows from another perspective that the "recall method" has played a role in delaying and preventing the decline of the elderly.

3.3. Qualitative study on the self-worth of the elderly using the recall method

The author has carefully recorded each "group recall" theme as data for qualitative analysis of the effect of the recall method. The data are supplemented through individual interviews to understand the subjective experience of the elderly participating in the recall method. During the interview, the elderly recounted the memories of their childhood growth, the ups and downs of the social background, the hardships of raising children, marriage, career, family, etc. After sorting out the interview materials, combined with the observation records during the interview process, and analyzing them word by word, it is concluded that in the process of recalling, the topics that the elderly are concerned about mainly include: difficult years, the process of setting life goals, responsibility to the family, past glory, self-realization, the achievements of children and grandchildren, etc., and the main role of the recall method is manifested in the following aspects.

3.3.1. Improve the sense of value of interpersonal relationships

Through the "recall method", the levels of improving the interpersonal relationships of the elderly mainly include: the relationship with group members, the relationship with other elderly people in the welfare home, the relationship with children, and the relationship between generations. In the relationship with group members, in the early stage of the group, each elderly person had no intersection in private, and basically came alone every time to participate in activities. During the activities, the elderly rarely interacted with each other, only shared their own experiences or listened carefully to the experiences of others, and rarely discussed with other group members; when the group entered the middle stage, due to the recall method activities, the relationship between group members became more harmonious and the connection between group members became closer. For example, every time they came to participate in activities, grandpa and grandma came together. When there were activities, Grandpa Zhu would take the initiative to run to Grandpa Xu's room to wait for Grandpa Xu and then come to the activity room together. In the process of the group, the interaction between grandpa and grandma also became more frequent. These are all the results of the subtle influence of the recall method on the group members. The improvement of the interpersonal value of the elderly through this recall method is very obvious, and it is a multi-level and all-round improvement. In the process of participating in the activities, the elderly not only gained a good interpersonal value experience, but more importantly, they will bring this good experience into their daily life and let this sense of value continue. This also achieves the real purpose of our research.

3.3.2 Enhance the sense of influence and value

The recall method can be used to enhance the sense of influence and value of the elderly, which is mainly reflected in three aspects: whether they are helpful and influential in the group, whether they have influence in the group, whether they have influence in their previous work and life, and whether they can provide guidance to the younger generation. First, the recall method is obviously helpful for internal communication within the elderly group; second, whether they have their own influence in work or life, through the recall method, they can more clearly realize their value in this regard; finally, they learn from the experience of the elderly the good qualities of hard work and simplicity and cherishing the present. When volunteers express what they have learned to the elderly, they can enhance their guidance to the younger generation.

3.3.3 Enhance the sense of value of rule quality

In the recall group, the enhancement of the rule quality dimension within the sense of value was primarily achieved through the thoughtful design of question outlines. These outlines were carefully crafted to prompt the elderly participants to reflect on and revisit the positive qualities and understanding of rules they had developed throughout their life experiences. By engaging in this reflective process, the participants were encouraged to reconnect with their past actions, decisions, and the principles that guided them, reinforcing their sense of self-worth and value. The intervention aimed to tap into the rich life experiences of the elderly, allowing them to recognize and affirm the wisdom, resilience, and adherence to societal norms and personal values they had accumulated over the years. This process not only helped in reinforcing their understanding of the importance of rules but also highlighted the role these rules played in shaping their identities and social interactions. The outcomes of this intervention were notably positive, as evidenced by significant improvements in the rule quality dimension of the participants' sense of value. The elderly showed a greater appreciation for the rules and values they had upheld, which in turn bolstered their overall sense of purpose and self-regard. The clear and structured approach of using question outlines proved to be an effective strategy, as it provided a framework that facilitated introspection and meaningful recall, making the benefits of the intervention both tangible and impactful. The noticeable effect after the intervention underscores the value of targeted, reflective exercises in enhancing the sense of value among the elderly, particularly in reinforcing the internalization of positive qualities and the importance of rule-based cognition in their lives.

3.3.4 Improve the sense of value of psychological quality

The enhancement of the sense of value related to psychological quality was primarily achieved through two key activities: "Passionate Years" and "Gradually Disappearing Occupations." These activities were carefully designed to evoke and rekindle the positive psychological attributes of the elderly, such as resilience, adaptability, and self-confidence, by immersing them in stimulating experiences and encouraging them to reflect on their past. The primary objective was to help the elderly reconnect with these positive qualities, enabling them to better cope with the challenges of their future lives. "Passionate Years" focused on revisiting moments of personal achievement, enthusiasm, and passion from the participants' pasts, allowing them to relive experiences that had previously brought them joy, fulfillment, and a strong sense of self-worth. This activity was designed to ignite a sense of pride and accomplishment, reinforcing the elderly's psychological resilience and fostering a renewed sense of purpose. "Gradually Disappearing Occupations" aimed to highlight the skills, knowledge, and values that the elderly had cultivated through professions or roles that may no longer be as prevalent or valued in today's society. By reflecting on these occupations, participants were encouraged to appreciate the enduring relevance of their contributions, thus validating their experiences and strengthening their sense of self-worth. The interactive nature of these activities played a significant role in awakening and enhancing the elderly's sense of value regarding their psychological qualities. Engaging with peers, sharing stories, and drawing parallels between past experiences and current coping strategies provided a supportive environment where the elderly could openly explore and affirm their inner strengths. This social interaction not only reinforced their personal reflections but also fostered a community of shared experiences, which further bolstered their psychological resilience and sense of belonging. Overall, these activities were effective in stimulating introspection and positive emotional responses, leading to noticeable improvements in the participants' perception of their psychological quality. By tapping into the rich reservoirs of the elderly's life experiences, "Passionate Years" and "Gradually Disappearing Occupations" provided a meaningful way to reconnect with their intrinsic value, thus enhancing their capacity to face future life with greater confidence and optimism.

3.3.5 Promote physiological value

The elderly who participated in the recall method were all over 85 years old. Their physiological abilities have already irreversibly deteriorated, and the situation will only get worse as time goes by. The improvement of the physiological value of the elderly through the recall method is mainly reflected in two aspects: one is to strengthen the existing self-care ability of the elderly through the recall method, and the other is to let the elderly experience the game in person and tell interesting stories through the development of the recall method to delay the degradation of physiological functions. Most of the elderly who participated in this recall method can take care of themselves and have a clear mind. However, the elderly usually live a dull life in the welfare home and do not realize the important physiological value of being able to take care of themselves.

4. Conclusion

This study used the "recall method" to intervene in the self-worth of 530 elderly people in welfare institutions for 8 months through eight group activities, six of which were concentrated intervention activities. It was found that the use of the "recall method" to intervene in the self-worth of the elderly in the institution improved all dimensions of the self-worth of the service recipients. Therefore, it can be said that the use of the "recall method" can improve the self-worth of the elderly. Through the intervention study of the elderly with low self-worth in N welfare institutions, according to the analysis of the results before and after the intervention, and the comparative analysis of the intervention group and the control group, it was found that the "recall method" had a positive and effective impact on the self-worth of the elderly in the institution, and the "recall method" intervention activity design was operational for the social work practice of the elderly in the institution. That is, the social work intervention method with "recall method" as the main element has a good effect.

In addition, the implementation plan of the recall method should be selected according to the actual environment and the actual situation of the social and cultural background. This study mainly focuses on group recall, and conducts more than 15 thematic recalls, each recall lasting 1 hour, with the social workers in the institution as guides. The results of the study show that the recall intervention implementation plan developed by social workers is highly feasible and has a significant intervention effect. In the qualitative analysis of group and case interview records, it is concluded that the recall method has a good effect on both the individual and social levels of the elderly. At the individual level, it helps to: reconstruct the meaning of one's life through reviewing one's own life experience; gain pleasure through narrative activities; promote self-affirmation and regain self-dignity; at the social level, it helps to: increase communication opportunities with peers, improve social willingness and ability; improve the quality of life and discover the joy of life; relearn social habits and social skills, and give full play to the remaining heat; promote communication between generations. In terms of the relevant dimensions of self-worth, the sense of value of each dimension has been improved in terms of scores, especially the sense of influence value, which to a certain extent shows that these situations have indeed been improved during the intervention process. Therefore, the implementation of the recall method in nursing homes is helpful to improve the self-worth of the elderly in the institutions, which is of great significance to promoting the healthy aging of society.

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Digitalization and Management Innovation III
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Automatic Modeling Technology of Low-Voltage Distributed Photovoltaic Networks Based on Account Information k-Connected Topology

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Abstract. The rapid increase in distributed photovoltaic (PV) generation worldwide demands more efficient large-scale modeling methods. This study investigates an automatic modeling technique for low-voltage distributed PV network topology based on ledger information. By analyzing PV system ledger data, we construct and automatically generate the topology model using automated algorithms. Our data-driven method and complex network theory-based algorithm improve system resilience and operational efficiency. Experimental results validate the effectiveness of our approach. Future research will focus on optimizing these algorithms and evaluating their applicability across various scenarios to support optimal PV system regulation and control.

Keywords. Distributed photovoltaic, distributed, low-voltage

1. Introduction

With the global increase in demand for renewable energy and heightened awareness of environmental conservation, photovoltaic (PV) power generation plays an increasingly important role in the energy sector as a clean and renewable energy source[1]. Distributed PV systems are widely utilized in urban, rural, and industrial areas due to their high flexibility, short construction cycle, and lack of pollution. According to reports from the International Energy Agency (IEA)[2], the installed capacity of distributed PV generation is continually growing worldwide and is expected to maintain a rapid growth trajectory in the future[3].

The operation of photovoltaic (PV) power plants requires a highly reliable electric communication network[4]. Precise analysis of ledger data enables the assessment of operational maintenance quality and informs policy-making for management[5]. However, distributed PV plants are characterized by complex structures, decentralized deployment, and heterogeneous equipment, resulting in extensive ledger and alarm data. Conventional data analysis methods often struggle to handle such diverse and

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voluminous data[6]. Therefore, researching how to leverage big data processing techniques for analyzing ledger data is crucial in providing significant support for the operation and maintenance management of electric communication networks[7].

The contributions of this paper are as follows:

a) We have proposed an automatic modeling technique for low-voltage distributed photovoltaic (PV) network topology based on ledger information, filling a gap in existing research in this field and offering a new approach and method for PV system topology modeling.
b) We have designed and implemented an automated modeling algorithm capable of generating a system's topological model based on the ledger information of photovoltaic (PV) systems. This algorithm achieves the automation and intelligence of PV system topology modeling.
c) The effectiveness and feasibility of the proposed algorithm were validated in practical photovoltaic (PV) systems, providing a new technical approach for the operation and management of PV systems with promising application prospects and practical value.

2. Related Work

2.1. Ledger information

The ledger information in distributed energy systems, such as operational data and equipment information of photovoltaic systems, serves as a crucial foundation for achieving intelligent management and optimizing system operations [8]. By observing existing research, we can gain a clear understanding of the application and value of ledger information in distributed energy systems.

The operational data of photovoltaic (PV) systems includes parameters such as PV power generation, voltage, and current, enabling real-time monitoring and evaluation of system performance [9]. The approach proposed by Liu et al. achieves real-time monitoring and analysis of PV system operational data [10]. This method utilizes statistical analysis of PV generation and voltage data to achieve real-time tracking of system operational status and anomaly detection.

The photovoltaic equipment information, including component models, installation dates, and maintenance records, is crucial for the management and maintenance of photovoltaic systems [11]. The management strategy proposed by Chen et al. integrates photovoltaic equipment information with operational data to achieve intelligent management and preventive maintenance of PV system equipment [12]. Through regular updates and analysis of equipment information, this strategy enhances the reliability and stability of photovoltaic systems.

The comprehensive utilization of photovoltaic system operational data and equipment information enables comprehensive monitoring and evaluation of system operational status [13]. The method proposed by Xu et al. leverages a ledger information database, integrating operational data and equipment information of photovoltaic systems to achieve real-time tracking and intelligent scheduling of system operational status [14]. Through comprehensive analysis of system operational status, this method enhances the operational efficiency and reliability of photovoltaic systems.

From the comprehensive studies above, it is evident that ledger information holds significant application value and development prospects in distributed energy systems.

Future research can further explore methods for mining and utilizing ledger information to enhance the intelligence and operational efficiency of distributed energy systems [15].

2.2. Topology modeling of photovoltaic network

The topology modeling of photovoltaic networks is a key step in achieving system optimization and operational management, and various methods and technologies have been applied in this field. Through a review of existing research, we can gain a comprehensive understanding of the methods and techniques previously used for photovoltaic network topology modeling, as well as their limitations and areas for improvement.

The traditional network topology modeling methods are mainly based on power system theory and network analysis techniques, constructing network topology models through the connection relationship between nodes and lines [16]. These methods include models based on node degree distribution, small world networks, random networks, etc., to preliminarily describe and analyze the topological characteristics of photovoltaic networks [17]. However, these methods often overlook the specificity of photovoltaic systems and cannot accurately reflect the actual operating conditions of photovoltaic systems.

In recent years, complex network theory has been introduced into photovoltaic network topology modeling to address the limitations of traditional methods [18]. Complex network models include scale-free networks, small world networks, modular networks, etc., which can better describe the relationships and topological features between nodes in photovoltaic systems [19]. However, these methods still involve simplification of photovoltaic system characteristics and differences between theoretical models and actual situations.

With the development of data science and machine learning technology, more and more research is adopting data-driven methods to model the topology of photovoltaic networks [20]. These methods utilize a large amount of operational data and ledger information to achieve accurate modeling and prediction of photovoltaic networks through data analysis and machine learning algorithms [21]. However, data-driven methods require high data quality and model interpretability, and have a strong dependence on data quantity and quality.

Based on the above research, it can be concluded that modeling the topology of photovoltaic networks is a complex and critical issue, and current methods and technologies have their own advantages and disadvantages. Future research can continue to explore methods based on complex network theory and data-driven approaches, combined with the actual situation of photovoltaic systems, to achieve accurate modeling and optimization of photovoltaic network topology [22].

3. Our Solution

3.1. Ledger Data Preprocessing

For better modelling of low voltage distributed PV networks, the ledger information needs to be processed using preprocessing techniques. Assume the original data domain is represented as $\{D_1, D_2, \dots, D_{N_D}\}$, where N_D denotes the dimensionality of the original data domain. The initial step involves preprocessing the raw data. Given the severe multivariate and heterogeneous nature of the data, attribute reduction is a critical aspect of the preprocessing stage. Let A $\in \{D_1, D_2, \dots, D_{N_D}\}$ be a vector representing the desired attributes. The goal is to achieve all desired attributes through data preprocessing by defining an attribute reduction method, denoted as sig. Data cleaning will yield the following result:

$$\{A_1, A_2, \dots, A_{N_A}\} = sig\{D_1, D_2, \dots, D_n\}$$

where N_A represents the dimensionality of the important attribute data domain. The subsequent sections will detail the specific implementation of attribute reduction, denoted by the method sig.

To define the symbol W_{A_p} as a derived algorithm from the Apriori data mining algorithm, this paper introduces an attribute association degree C as a convergence constraint. Thus, the data mining problem can be summarized by the following expression:

$$R\{a_{n1}, a_{n2}, \cdots, a_{nN_E}\} = W_{A_P}(\{A_1, A_2, \cdots, A_{N_A}\})$$
$$s.t.\, \mathrm{su\,p}\left(R(a_{n1}, a_{n2}, \cdots, a_{nN_E})\right) > C$$

where $R\{a_{n1}, a_{n2}, \dots, a_{nN_E}\}$ denotes the distribution and association relationship of the attribute values $a_{n1}, a_{n2}, \dots, a_{nN_E}$ and $sup\left(R(a_{n1}, a_{n2}, \dots, a_{nN_E})\right)$ represents the support of this distribution and relationship. The entire analysis process is illustrated in Figure 1. The details of the model are discussed in the next few subsections.

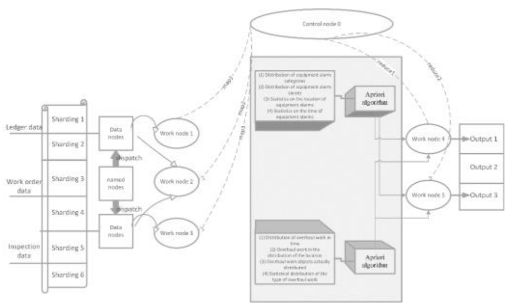

Figure 1. Process of analysing inspection work based on big data technologies.

During the preprocessing phase, data auditing, correction, and cleaning are essential to ensure data quality. The steps are as follows:

(1) Data Auditing: Initial data auditing manual operations such as data extraction, verification, and review. Audit rules are then established for software auditing. The software utilizes these rules to perform rapid data audits.

(2) Data Correction: Errors in the data are addressed following relevant business processes. To avoid directly altering the original data, corrections are classified based on the data type and the cause of the errors, ensuring a more systematic approach to rectification.

(3) Data Cleaning: Data cleaning targets primarily two types of erroneous data: missing values and outliers. Missing values are managed through deletion strategies, while outliers are corrected using re-filling strategies to ensure data integrity.

3.2. k-Connected Topology Construction

To efficiently identify critical nodes in the network and to ensure that network connectivity and stability are maintained when building connected topologies locally and across clusters. Determining critical nodes within each cluster is essential for constructing a local k-connected topology. In this paper, a method based on Depth-First Search (DFS) is employed to identify critical nodes.

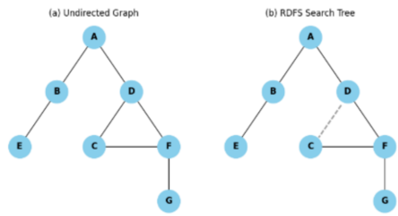

Figure 2. Depth-First Search

During the Depth-First Search process, the order in which node u is traversed is denoted as $num(u)$, and the lowest ancestor node that can be reached from node u or its subtree via a non-parent-child edge is represented by $low(u)$. The formula for calculating $low(u)$ is given by:

$$low(u) = \begin{cases} \min\{low(u), low(v)\}, (u, v) \text{ represents a tree edge} \\ \min\{low(u), num(v)\}, (u, v) \text{ represents a tree edge} \end{cases}$$

where (u, v) is a tree back edge and v is not the parent of u.

Once the local k-connected topology within each cluster is constructed, cluster heads are selected to establish inter-cluster k-connected topology. The construction of inter-cluster k-connected topology among cluster head nodes also follows the Harary graph's concept. During the construction of inter-cluster k-connected topology and when transmitting data collected from the intra-cluster information, cluster member nodes can enter a sleep phase to conserve energy.

4. Experiment

4.1. Experiment Design

Using the Matlab simulation platform, we simulated and analyzed the performance of the resilience topology construction method proposed in this paper. Bi-connectivity is a fundamental requirement for network resilience. On the other hand, when node connectivity exceeds 4, it not only leads to excessive communication energy consumption but also increases system motion constraints. Therefore, we use the topology of cluster heads with 3-connectivity as an example to verify the effectiveness of our algorithm. The monitored area size is set to 100 m × 100 m with 40 nodes, each having a communication radius of 30 m. There are 4 clusters, and the topology of cluster heads is designed to be 3-connected.

In this paper, we use node betweenness centrality, average connectivity of the network, and network robustness to compare and analyze changes in the resilience performance of the network within each cluster before and after removing critical nodes.

4.2. Experimental Results Presentation and Analysis

4.2.1. betweenness centrality assessment

The betweenness centrality B_p of node p reflects its influence within the entire system. It is defined as the ratio of the number of shortest paths in the network that pass through node p to the total number of shortest paths. The formula for betweenness centrality B_p is:

$$B_p = \sum_{(i,j)} \frac{g_{ipj}}{g_{ij}} (i, j \neq p, i \neq j)$$

$$W_p = \frac{2 \sum_{(i,j)} \frac{g_{ipj}}{g_{ij}}}{n(n-1)}$$

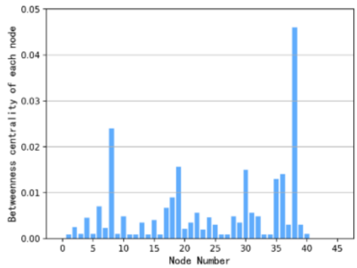

Figure 3. Distribution of node betweenness centrality in the network before removing the critical nodes within the cluster.

The distribution of node betweenness centrality in the system before removing the critical nodes is shown in Figure 3. In Figure 3, the node numbered 37 has the highest betweenness centrality. This is because communication between nodes on either side of the critical node must pass through it. As shown in Figure 4, the betweenness centrality of the critical nodes 22, 30, and 38 has decreased, while the betweenness centrality of nodes 16, 8, 28, 4, and 33 has correspondingly increased

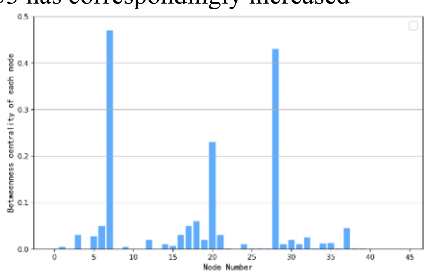

Figure 4. Distribution of node betweenness centrality in the network after removing the critical nodes within the cluster.

4.2.2. network robustness evaluation

Network robustness is used to measure the average impact on the connectivity between remaining nodes after the removal of any node. It is defined as the ratio of the number of node pairs that remain connected after the removal of any node to the total number of node pairs in the network. Suppose the remaining set of nodes in the network after the removal of a certain node is G_k. The formula for calculating network robustness n_R is as follows.

$$n_R = \frac{1}{n(n-1)} \sum_{i \in G_k} \sum_{j>i} l_{ij}$$

where n represents the total number of nodes in the network, C_{ij} represents the number of connected node pairs in the network. If there is a path between nodes i and j, then $C_{ij} = 1$; otherwise, $C_{ij} = 0$.

4.2.3. average connectivity evaluation

The degree of a node reflects its impact on the network's connectivity, typically referring to the number of edges directly connected to a given node. The formula for calculating the degree k_i of node i is as follows.

$$k_i = \sum a_{ij}$$

If node i and node j are directly connected, then $a_{ij} = 1$; otherwise, $a_{ij} = 0$.

The average degree (or average connectivity) D of a network is the average value of degrees of all nodes in the network. The formula for calculating D is as follows.

$$D = \frac{\sum_{i=1}^{n} k_i}{n}$$

The performance comparison analysis of the network before and after removing the critical node is shown in Table 1. Initially, the network is looser and there may be some critical nodes acting as bridges. However, removing these critical nodes improves the overall robustness of the network as more connectivity paths are formed between nodes within the clusters, although connectivity between clusters decreases. This means that even though the network is divided into more small clusters, the connectivity within each cluster is tighter, thus improving the overall robustness.

Table 1. Network Performance Comparison Analysis.

Performance metrics	Including critical nodes	Removing critical nodes.	Improvement rate (%)
average connectivity	4.90000	5.40000	9.26
Robustness	0.18619	0.26276	29.14

5. Conclusion

This study presents an innovative approach to automatically model low-voltage distributed network topology in PV systems using ledger information. By leveraging data-driven methods and complex network theory, an automated algorithm was developed, enhancing system resilience and operational efficiency. The accuracy of ledger information is crucial for effective modeling, and automated algorithms streamline the process. Future work should focus on optimizing the algorithm, extending its application to other energy networks, and further refining data-driven methods to improve PV system performance and reliability.

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Digitalization and Management Innovation III
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Research on Profile Control, Water Plugging and Oil Displacement Technologies for Low-Permeability Fractured Reservoirs

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Abstract. Low permeability fractured reservoirs have strong heterogeneity, low efficiency and ineffective circulation, high water content, and low recovery rate. Conventional profile control measures significantly stabilize oil and control water, but the increase in recovery rate is small. Taking low-permeability fractured reservoirs in the periphery of Daqing as the research object, this study conducts research on the synergistic potential tapping technology of plugging, regulating and driving, and conducts pilot tests to verify the feasibility and adaptability of the technology. The effect of plugging, adjusting and driving is significantly better than that of deep profile control, and the experiment can increase the recovery rate by more than 10 percentage points; Injecting three cycles of rock cores can increase the recovery rate by 16.8 percentage points. During the pilot test of plugging, adjusting and driving, the recovery rate was increased by 1.95 percentage points within 2 cycles. This technology has important practical significance for improving the recovery rate of similar oil reservoirs in China.

Keywords. Fractured reservoir; Profile control; Water blockage; Improve recovery rate

1. Introduction

Daqing Oilfield has entered the stage of "post reservoir" development, the medium to high permeability reservoirs that were put into production earlier have entered the high and ultra-high water cut stage, with a high degree of recovery [1-2]. The potential for well network densification, injection production system and injection production structure adjustment are small, and the effectiveness of measures is poor [3-4]. The stable production of oil fields is facing severe challenges, and it is urgent to explore new ways to replace production [5]. At present, low-permeability fractured reservoirs have low recovery rates and abundant reserves, which are expected to become important

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supplementary objects to fill the production gap [6]. In recent years, low-permeability fractured reservoirs have achieved stable oil and water control effects through measures such as well network optimization and adjustment, shallow profile control of well groups, periodic water injection, and oil well plugging, but the improvement in extraction degree and oil recovery rate is limited. The existing development and adjustment technologies cannot meet the demand for stable production in oil fields. Therefore, it is urgent to study effective tapping techniques suitable for low-permeability fractured reservoirs [7].

At present, low permeability reservoirs with developed fractures mainly face three challenges: firstly, the development of natural fractures, artificial fractures, and dynamic fractures induced by water injection in the reservoir exacerbates heterogeneity, resulting in severe ineffective water injection cycles, affecting the efficiency of impact and restricting the overall recovery rate of the reservoir. The second issue is that The range of blockage adjustment is limited, a short effective period, and an unclear effect on increasing oil production. The third issue is that the pore throats in the matrix area are small, and the water flooding method has poor effectiveness. The commonly used oil displacement agents do not match the reservoir, making it difficult to effectively enter the matrix and use the matrix to enrich the remaining oil.

In response to the above issues, following the idea of "plugging fractures+lateral displacement along fractures", a plugging+adjusting displacement depth tapping technology is proposed. Through investigation, polymer gel can selectively enter into large channels, blocking large pores and improving flow resistance in advantageous seepage areas, forcing the subsequent injection media to have fluid flow diversion. At the same time, it is viscoelastic and can act on the deep part of large channels or high permeability areas; Polymer nanospheres have the advantages of low initial viscosity, small particle size, and good injectability. They expand and adsorb when in contact with water to gradually block the formation pores and achieve the goal of deep water control and flooding. Indoor comparative analysis of the oil displacement effects of single injection method and combined injection method of plugging, adjusting and driving, revealing the mechanism of the synergistic effect of plugging, adjusting and driving, taking Block C of the low-permeability fracture development oilfield in the periphery of Daqing as the research object, conducting on-site experiments on the synergistic effect of plugging, adjusting and driving, tracking and evaluating the experimental results and technical adaptability, and provide technical support for effectively improving oilfield development efficiency.

2. Experimental Study on Blocking, Adjusting and Driving Indoor

The water sample was taken from Block C of Daqing peripheral oilfield. The viscosity of crude oil under geological conditions is. The experimental water (prepared to simulate the formation water in Block C) had a mineralization degree of 7259 ppm and an experimental temperature of 45 ℃. Using artificial fractured flat core(450mm×450mm×50mm) as shown in Fig.1, the fractures are arranged at an angle of about 22.5 ° to the well row, simulating the reverse nine-point method well network (1 injection, 8 mining). The permeability of core matrix is $50\times10^{-3}\mu m^2$, and the fracture permeability is about $500\times10^{-3}\mu m^2$.

Fig.1 Artificial flat core diagram

2.1. Experimental steps

(1) Saturated water: Vacuum the core and inject pre-configured formation water into the core until the injection pressure remains constant.
(2) Saturated oil: Inject simulated oil until the pressure stabilizes;
(3) Water flooding: Inject formation water into the model to displace simulated oil, with a displacement rate set at 1.5mL/min, until the produced fluid reaches 100% water content;
(4) Plugging, profile control and displacement: inject 0.3PV of polymer gel slug and polymer nano microsphere slug into the model, and set the displacement speed as 1.0mL/min;
(5) Subsequent water flooding: Inject simulated formation water until the produced fluid reaches 100% water content.

2.2. Experimental Result

Each cycle is independent. The results in table 1 showed that for the artificial fracture flat core, the plugging, adjusting and driving effect was more significant than that of deep profile control and water drive. The deep profile control of core II only increased the recovery rate by 3.7 percentage points, while the plugging, adjusting and driving synergy of core III increased the recovery rate by 13.3 percentage points, achieving a significant improvement. The multi cycle injection method is more effective than the single injection method. The recovery rate of core IV and V is further improved by multi cycle injection, and the effect becomes more obvious with the increase of injection cycles. The recovery rate of core IV is 2.3 percentage points higher than that of core III, and the recovery rate of core V is further improved by 3.9 percentage points than that of core III.

Table 1. Experimental results of flat core oil displacement

No.	Segment Combination	Cycle	Stage extraction degree (%)				Increase in recovery rate compared to core I (%)
			Water flooding stage	Blocking, regulating and driving	Subsequent water flooding	Final	
I	water	-	31.2	-	-	31.2	-
II	Polymer gel (0.1PV)	1	30.9	1.6	2.1	34.6	3.4
III	Polymer gel (0.1PV)+polymer nanospheres (1PV)	1	31.4	11.3	1.8	44.5	13.3

IV	Polymer gel (0.05PV)+polymer nanospheres (0.5PV)+water (1.5PV)	2	29.8	13.8	1.6	45.2	14.0
V	Polymer gel (0.02PV)+polymer nanospheres (0.33PV)+water (1PV)	3	31.0	15.8	1.2	48.0	16.8

2.3. Mechanism analysis

Indoor experiments have confirmed that multi cycle plugging and flooding can significantly improve the recovery rate. In the first cycle, gel enters into the complex fracture system, increasing the seepage resistance of complex fractures near the well. The polymer microspheres flow along the fractures and into the matrix near the well, increasing the matrix seepage resistance, forcing the subsequent injected water to have a fluid flow diversion and expanding the coverage of the near well area; In the second cycle, the gel continues to flow into the fractures, pushing the injected gel in the first cycle to migrate to the deep part of the fracture system, playing the role of deep profile control. The polymer microspheres flow into the matrix along both sides of the fractures, pushing the injected microspheres in the first cycle to migrate to the wells, playing the dual role of plugging the high permeability strip of the matrix and oil displacement. The subsequent injected water further pushes the microspheres to migrate to the deep, and the affected area is further expanded; Injecting the third cycle further expands the range of profile control and increases the resistance of fracture seepage. By utilizing the viscoelasticity of polymer microspheres, it promotes the migration of polymer microspheres injected in the first two cycles to the deep part, further exerting the role of harmonic displacement, effectively utilizing the remaining oil in the matrix, and subsequently injecting water to achieve fluid flow diversion in the deep part of the reservoir, utilizing the remaining oil in the deep part to compensate for the shortcomings of single profile control. In summary, the plugging, regulating, and flooding technology fully considers the problem of poor matrix permeability and adopts a "multi-stage plugging, multi cycle, low-dose, slow injection" approach to improve crude oil recovery.

3. Experimental Study on Blocking, Adjusting and Driving Indoor

The reservoir of Block C in the peripheral oil fields of Daqing is affected by the development of complex fracture systems, and the water wells in the direction of water well discharge have early water breakthrough and rapid increase in water content, resulting in severe ineffective water injection circulation. Through large-scale profile control, the increase in water content has been alleviated, but there is a problem of multi-directional water influx within the well cluster, resulting in a decrease in water injection efficiency and sweep efficiency, and a rapid decline in production. In recent years, significant water control effects have been achieved through deep investigation measures, but the recovery rate has only increased by 0.76 percentage points. In order to effectively improve crude oil recovery rate, a pilot test of plugging, adjusting and driving was carried out in Block C in July 2019, with 4 injection wells and 21 production wells selected.

3.1. The first cycle

The first cycle: polymer gel slug (0.02PV) +polymer microsphere slug (0.05PV) +water slug.

One is a steady increase in injection pressure. The polymer gel slug is injected slowly. The injection pressure rises rapidly at the initial stage, and rises slowly and slightly in the middle and later stages. The single well injection pressure is 13.3MPa, 1.6 MPa higher than that before the test. Inject polymer microsphere plugs and adjust the injection pressure according to the pre experiment water ratio. The injection pressure slightly increases and gradually stabilizes. Inject water into the plug, maintain the injection speed constant, and keep the pressure stable.

The second is to increase the degree of utilization. The water absorption of the main layer with well-developed cracks significantly decreases, while the water absorption of the secondary main layer increases, and some non-main layers exhibit good water absorption capacity. After the polymer microsphere plugging was completed, four injection well profiles were tested, and the results showed that the proportion of liquid absorption in the main layer with well-developed fractures decreased from 71.3% before the experiment to 58.4%, the proportion of liquid absorption in the secondary main layer increased from 24.6% to 29.5%, and the proportion of liquid absorption in the non-main layer increased from 4.1% to 12.1%.

Thirdly, Significant effect of increasing production and reducing precipitation in oil extraction wells. The average daily oil production of a single well in the C well area increased from 0.9 tons before the experiment to 1.7 tons, an increase of 0.8 tons. The water content of a single well decreased from 89.3% to 83.8%, a decrease of 5.5%. The accumulated oil production during the stage was 4042 tons, and the recovery rate increased by 0.43 percentage points. Among them, 16 wells showed significant results, with oil production doubling and water content decreasing from 89.3% to 85.4%.

3.2. The second cycle

The second cycle: polymer gel slug (0.04PV) +polymer microsphere slug (0.1PV) +water slug.

One is to maintain a stable injection pressure. The polymer gel slug was injected, and the slow injection was maintained. The injection pressure increased slightly by 0.3 MPa. Inject polymer microsphere plugs, maintain injection speed, and keep injection pressure stable. Inject a water plug, increase the injection speed appropriately, and maintain a stable injection pressure.

Secondly, the utilization of the secondary main force layer and some non-main force layers has further improved in Fig. 2. After the polymer microsphere plug is completed, test the profiles of four injection wells. Before injecting the polymer microsphere plug, the F151 and F161 sub layers have a large amount of liquid absorption, the F133 sub layer has a small amount of liquid absorption, and the F32 and F331 sub layers do not absorb liquid; After injecting polymer microsphere plugs, the liquid absorption of F151 and F161 layers was controlled, the liquid absorption of F133 layer increased significantly, and F32 and F331 layers began to absorb liquid. Compared to the first cycle, the proportion of reservoir fluid absorption has significantly increased.

The third is an increase in the recovery rate. Compared with the first cycle, the average daily oil production per well in the C well area increased from 1.7 tons to 1.9

tons, with a water content of around 83%. The accumulated oil production during the stage was 14141 tons, and The recovery rate has further increased by 1.52 percentage points.

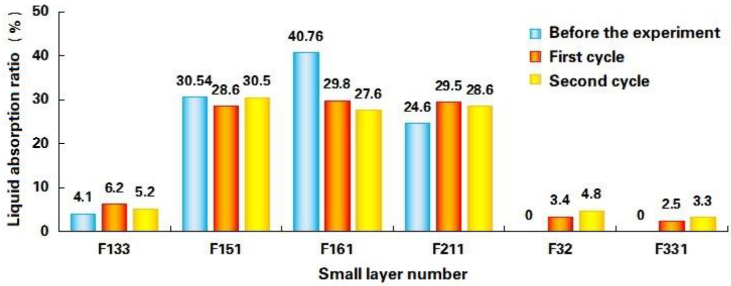

Fig.2 Profile test results of 4 injection wells in the experimental area

4. Economic benefit evaluation

The investment cost for C well area is 29.25 million yuan, including 17.08 million yuan for chemical fees and 12.17 million yuan for on-site operation costs. The accumulated oil production during the stage is 18184 tons. The economic benefits of the experiment are evaluated based on a price range of 45 to 70 US dollars. When the crude oil prices are $45, $55, and $70, the input-output ratios are 1:31, 1:1.60, and 1:2.04, respectively, and flooding technology has good economic benefits.

5. Conclusion and Suggestions

The experimental results of low-permeability artificial fracture flat core oil displacement confirm that the plugging and profile control technology is more effective than traditional deep profile control technology, and the more injection cycles, the more obvious the effect.

The plugging, adjusting and driving technology can improve the permeability resistance of fractures, reduce the difference in permeability between fractures and matrix, force the injected fluid into the matrix, and utilize the remaining oil in the interlayer, effectively improving the development effect.

The pilot test has shown significant results, verifying that the plugging and regulating flooding technology is suitable for low-permeability fractured reservoirs and can be used as an effective means of recovery.

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The Impact of CEO's Overconfidence on Operational Risks of Listed Companies in Vietnam

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Abstract. The study examines the impact of CEO overconfidence on the business risks of listed companies in Vietnam during the period 2012-2022. The author utilizes two measures of overconfidence: one based on excess cash flow and the other on excess earnings, as well as two measures related to revenue management and cost management. Additionally, the study considers the moderating roles of ownership structure, income diversity, and stock market growth in influencing CEO overconfidence. The results indicate that overconfidence, driven by cash flow or earnings, tends to increase business risks. In contrast, overconfidence related to earnings management reduces risks, likely due to the involvement of multiple stakeholders in monitoring the behavior of listed companies. Furthermore, the findings reveal that the interaction effects of overconfidence can be both positive and negative. These results provide valuable implications for controlling CEO overconfidence to mitigate operational risks for businesses.

Keywords. CEO overconfidence; operational risk and listed companies in Vietnam

1. Introduction

Research on corporate performance and operational risk has traditionally been approached from a financial perspective. However, behavioral finance research examining the impact of CEO overconfidence on firm performance and risk remains scarce and often controversial. Existing studies predominantly explore the influence of CEOs on business performance Bilicka [1] or corporate risk Kim et al [2], focusing on conventional measures, with mixed results. In Vietnam, recent studies Truong Dinh Bao Long [3] have primarily adopted the measures proposed by Malmendier and Tate [4] to assess the impact of CEO overconfidence on investment, financing policies, and company debt.

According to Trieu Van Huan et at [5], Vietnam's stable policies have made it a standout in the region. The country ranked 12th in the financial health rankings of 66 emerging economies (The Economist, 2020), placing it among the safer countries

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following the Covid-19 pandemic, with stable financial indicators. Furthermore, the National Assembly's ratification of the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) in 2018, along with the signing of the Free Trade Agreement (EVFTA) and the Investment Protection Agreement (IPA) with the EU in 2019, created opportunities for attracting large-scale investments, fueling strong growth recovery.

While favorable business conditions create opportunities, they may also foster overconfidence, particularly among CEOs. This overconfidence, often associated with strong performance, can lead to overinvestment and misguided decisions such as unrelated diversification, increasing business risks and reducing efficiency Vu Thanh et al [6]. Previous research has largely focused on the relationship between overinvestment and operational risk, without examining the specific impact of CEO overconfidence on business performance.

2. Literature Reviews

Optimistic overconfidence, i.e. overestimation of average outcomes, is measured using options-based approaches Malmendier and Tate [7], earnings forecast-based approaches (Otto, 2014 [8]), and newspaper-based approaches Malmendier and Tate; Hirshleifer et al [9]. According to Otto, first create an indicator variable and compare it with the High Forecast, the overconfidence variable will equal 1 if a company's EPS forecast exceeds the actual EPS. Therefore, the high forecast provides a measure of a CEO's optimism about earnings. Huang and Kisgen [10] create another index, called the point estimate, which equals 1 when a company provides a point EPS forecast and equals 0 when it provides an EPS forecast within the range. Tien-Shih Hsieh et al. [11] used the Earnings Management measure as a measure for CEO overconfidence, the authors used models of: Accrual-based Earnings Management Dechow et al [12], Real Activities-based Earnings Management Cohen et al [13] and Threshold-based Earnings Management (Athanasakou et al) [14].

Operational risk is the risk of business loss due to inadequate internal processes, people, systems or external events (Klaus Böcker) [15]. Operational risk plays a key role in developing overall risk management programs that include business operations and disaster recovery planning, compliance measures, and information security. The most prominent methods used to measure operational risk include statistical risk distribution, probability, standard deviation, regression, and correlation. Many organizations rely on standard deviation from the historical mean as a measure of risk (Rachev, Stoyanov, and Fabozzi) [16]. Meanwhile, optimistic overconfidence means overestimating the average outcome, which is measured using options-based approaches (Malmendier and Tate, 2008), earnings forecast-based approaches (Huang and Kisgen, 2013; Otto, 2014), and newspaper-based approaches (Malmendier and Tate, 2008; Hirshleifer et al., 2012). Recent studies consistently show that companies with overconfident CEOs face a higher risk of failure, which means they take on more risk (Jingsi Leng et al) [17]. Which studied CEO overconfidence (measured by two measures of option and press) and the likelihood of firm failure in the UK and found that firms with overconfident CEOs faced a higher risk of failure, i.e., higher risk. The presence of overconfident CEOs led to a higher risk of bankruptcy in innovative environments, but the effect was insignificant in non-innovative environments.

Furthermore, overconfident CEOs may increase the risk of bankruptcy of firms with less conservative accounting practices.

Regarding the impact of firm size on performance, studies have yielded mixed results. Some research suggests that large firms tend to outperform smaller firms due to their ability to exploit economies of scale in transactions, which leads to higher profitability (Cuong Vu Hung et al) [18]. However, other studies indicate that larger firms may experience negative effects on performance due to inertia, bureaucracy, and other structural issues (Lin and Fu) [19].

In terms of business ownership, studies generally show a positive impact on firm performance, as ownership helps reduce agency costs by aligning the interests of decision-makers and owners (Lin and Fu). In contrast, Ping & Hsien [20] argue that business ownership does not significantly affect performance, suggesting that investors act as passive monitors, primarily concerned with short-term gains.

The debt ratio also plays a key role, influencing dividends and shareholder risk, which subsequently affects a firm's cost of capital and market value. Some studies report a positive relationship between leverage and financial performance (Dona Ganeesha et at) [21], while others highlight a negative correlation between financial performance and leverage (Umer Iqbal) [22].

Similarly, most research finds a positive relationship between liquidity and firm performance (Nguyen Ngoc Phuong Anh) [23]. Older companies tend to have more stable capital structures, greater resources, and extensive social experience, which allows them to invest more in R&D and thus improve competitiveness and firm value (Cuong Vu Hung). Conversely, younger companies often face limitations in terms of budget, experience, and market information, leading to lower competitiveness and declining performance (Liu Yilun) [24].

Industry characteristics also play a role in firm performance. Olokoyo [25] found that industry effects were not significantly related to book efficiency (ROA) but were significantly related to market efficiency (Tobin's Q), with the technology and service sectors being more efficient than other industries. Zbigniew Matyjas [26] demonstrated that industry characteristics influenced the book efficiency of Polish firms between 2007 and 2010. Similarly, Nguyen Trong Nghia [27] found that enterprises in the pharmaceutical, healthcare, information technology, and industrial production sectors performed more efficiently than those in other industries.

3. Data and Methodology

The author uses four measures of CEO overconfidence. To do this, the author regresses industry-specific and year-specific models to estimate the Over variable. For the first method, the author uses the expected operating cash flow model (Benjamin Noury et al) [28] according to the following model:

$$\mathbf{OCF_{it} = a_0 + a_1OCF_{it-1} + a_2AR_{it-1} + a_3AP_{it-1} + a_4INV_{it-1} + a_5DEP_{it-1} + a_6Other_{it-1} + e_{1it}\ (1)}$$

Where:

OCF_{it} is the operating cash flow in year t of company i (Operating cash flow: OCF = (EBIT + Depreciation - Tax)

OCF_{it-1} is the operating cash flow in year t-1 of company i

AR_{it-1} is the change in receivables for year t and t-1 of company i

AP_{it-1} is the change in payables for year t and t-1 of company i

INV_{it-1} is the change in inventories for year t and t-1 of company i
DEP_{it-1} is the depreciation for year t-1 of company i
$Other_{it-1}$ represents the accrual for year t-1 of company i, calculated as follows:
Other = E – (OCF + AR + INV – AP – DEP) (E=Earning)
Based on the postulate of Malmendier and Tate [29] and according to the overinvestment effect from excess cash flow (Le Ha Diem Chi and Nguyen Thi Minh Chau [30]), when company i experiences excess cash flow, it leads to overinvestment and thus overconfident behavior of the CEO, and then the residual (e_1) in the above model will have a positive value. The author uses model (1) of cross-sectional regression for each year, classified by industry group according to the standard (GICS) to find CEOs in companies with overconfidence behavior occurring when the residual (e) of the model >0 is assigned the value =1, companies with residual <0 will be assigned the value =0 (ie there is no phenomenon of CEO overconfidence). With this measurement, in this thesis, it is called the **Over1** variable.

For the second measure to calculate overconfidence behavior, instead of relying only on the difference between the announced plan number and the actual EPS achieved, the author applies the regression model through the origin (RTO) according to Hocking [31]. The proposed model is as follows:

$$\mathbf{EPS_{it}} = \overline{\boldsymbol{EPS_{it}}} + \mathbf{e_{2it}}\ \mathbf{(2)}$$

Also based on the postulate of Malmendier and Tate, the author uses regression according to equation (2) above, CEOs in companies with overconfidence behavior occur when and only when the residual (e2) of the model >0, assigned the value = 1, companies with residual <0 are assigned the value = 0. The author uses cross-sectional data to process for each year, classified by industry group. This helps to effectively evaluate both models of CEO overconfidence behavior when CEOs have cash flow or EPS expectations exceeding the average of the whole industry. This measure is very consistent with the concept of overconfidence of Alicke [32] when it is assumed that the overconfidence behavior of CEOs when they predict the results to be greater than the average or the "better-than-average" effect (Malmendier, U., & Tate. G) [33]. This measure, in this thesis, is called the **Over2** variable.

In addition, authors Cohen et al or Tien-Shih Hsieh et al argue that overconfident CEOs will try to manage earnings upward. To manage earnings upward, companies with overconfident CEOs will tend to increase cash flow from operations and reduce production costs more than companies with less confident CEOs

First, the author calculates the normal cash flow from operations by assuming that normal OCF is a linear function of revenue and changes in revenue, as follows:

$$\frac{OCF_{it}}{ASSETS_{it-1}} = k_1 \frac{1}{ASSETS_{it-1}} + k_2 \frac{SALES_{it}}{ASSETS_{it-1}} + k_3 \frac{\Delta SALES_{it}}{ASSETS_{it-1}} + \varepsilon_{3it} \quad (3)$$

In which: OCF = cash flow from operating; Asset = Total assets; Sales = Revenue

Abnormal cash flow from operations (R-OCF) = Actual OCF minus Normal OCF based on the estimated result from equation (3). In case of abnormal cash flow >0, it is coded = 1 (overconfidence exists) and otherwise =0 (no overconfidence of the CEO). R-OCF is used to measure the actual management of the company's activities related to accelerating the sales period through increasing price discounts or credit terms to be more favorable than usual. By this measure, the variable is called **Over3.**

In addition, assuming that the cost of production and business includes the total cost of goods sold, administrative costs, selling costs and other costs, the estimate of the normal cost of production and business in equation (4) is as follows:

$$\frac{PROD_{it}}{ASSETS_{it-1}} = l_1\frac{1}{ASSETS_{it-1}} + l_2\frac{SALES_{it}}{ASSETS_{it-1}} + l_3\frac{\Delta SALES_{it}}{ASSETS_{it-1}} + l_4\frac{\Delta SALES_{it-1}}{ASSEST_{it-1}} + \varepsilon_{4it} \ (4)$$

Abnormal production costs (R-PROD) are actual production costs minus normal production costs as estimated from equation (4). Companies with abnormal production costs <0 are coded = 1 (overconfidence exists), otherwise assigned = 0 (overconfidence does not occur). Based on the actual OCF operating cash flow and the usual estimate, the business production cost, we can calculate the abnormal cash flow from operations (R-OCF), abnormal production cost (R-PROD) as a proxy for the actual management activities. By this measure, in this thesis called the **Over4** variable.

In models (1), (2), (3) and (4), the author uses cross-sectional data for each year, divided by industry group. This helps to effectively evaluate both models of CEO overconfidence behavior when CEOs have cash flow or income expectations that exceed the average of the whole industry.

Model for assessing the impact of overconfidence on operational risk:

Model 1:

Risk$_{it}$ = β_0+ β_1Over1$_{it}$ +β_2FO$_{it}$ + β_3SO$_{it}$ +β_4D-income$_{it}$ + +β_5Stock-growth$_{it}$ + β_6CEO-Ownership$_{it}$ +β_7Size$_{it}$ + β_8Age$_{it}$ + β_9Growth$_{it}$ + β_{10}Lev$_{it}$ + β_{11}Liq$_{it}$ + β_{12}(Over1*FO)it + β_{13}(Over1*SO)$_{it}$ + β_{14}(Over1*D-income)$_{it}$ + β_{15}(Over1*Stock-growth)$_{it}$ + $\beta_j \sum_{j=1}^{7} Indus_j$ +u$_{it}$ (7)

Model 2:

Risk$_{it}$ = β_0+ β_1Over2$_{it}$ +β_2FO$_{it}$ + β_3SO$_{it}$ +β_4D-income$_{it}$ + +β_5Stock-growth$_{it}$ + β_6CEO-Ownership$_{it}$ +β_7Size$_{it}$ + β_8Age$_{it}$ + β_9Growth$_{it}$ + β_{10}Lev$_{it}$ + β_{11}Liq$_{it}$ + β_{12}(Over2*FO)it + β_{13}(Over2*SO)$_{it}$ + β_{14}(Over2*D-income)$_{it}$ + β_{15}(Over2*Stock-growth)$_{it}$ + $\beta_j \sum_{j=1}^{7} Indus_j$ +u$_{it}$ (8)

Model 3:

Risk$_{it}$ = β_0+ β_1Over3$_{it}$ +β_2FO$_{it}$ + β_3SO$_{it}$ +β_4D-income$_{it}$ + +β_5Stock-growth$_{it}$ + β_6CEO-Ownership$_{it}$ +β_7Size$_{it}$ + β_8Age$_{it}$ + β_9Growth$_{it}$ + β_{10}Lev$_{it}$ + β_{11}Liq$_{it}$ + β_{12}(Over3*FO)it + β_{13}(Over3*SO)$_{it}$ + β_{14}(Over3*D-income)$_{it}$ + β_{15}(Over3*Stock-growth)$_{it}$ + $\beta_j \sum_{j=1}^{7} Indus_j$ +u$_{it}$ (9)

Model 4:

Risk$_{it}$ = β_0+ β_1Over4$_{it}$ +β_2FO$_{it}$ + β_3SO$_{it}$ +β_4D-income$_{it}$ + +β_5Stock-growth$_{it}$ + β_6CEO-Ownership$_{it}$ +β_7Size$_{it}$ + β_8Age$_{it}$ + β_9Growth$_{it}$ + β_{10}Lev$_{it}$ + β_{11}Liq$_{it}$ + β_{12}(Over4*FO)it +

$\beta_{13}(Over4*SO)_{it} + \beta_{14}(Over4*D\text{-}income)_{it} + \beta_{15}(Over4*Stock\text{-}growth)_{it} + \beta_j \sum_{j=1}^{7} Indus_j + u_{it}$ (10)

Operational risk in this study is calculated by the moving average of the standard deviation of ROA for 3 consecutive years. Regarding industry classification: In the research sample, the industry is divided based on the industry classification standard of GICS (built by MSCI and S&P Dow Jones Indexes). In this study, the author excludes the financial industry group, accordingly the remaining industry groups in the research sample include: (1) IT: information technology industry group (standard industry), (2) CN: industrial production, (3) YD: medical, pharmaceutical, (4) HHDV: consumer goods and services, (5) NVL: production of materials, (6) CN: industrial production, (7) TT: information and communication. Details of the variables and their calculations are detailed in Table 1 below.

Table 1. Summary of variable descriptions and calculations

Interpretation	Variable	Measure variables
Dependent variable		
Standard deviation of ROA	σ_{ROA}	Calculated by the standard deviation of the ROA index over 3 years using the continuous sliding method
Dependent variables		
+ CEO Overconfidence	Over1	Measured by operating cash flow surplus, from model (1)
+ CEO Overconfidence	Over2	Measured by the difference over the industry average EPS, from model (2)
+ CEO Overconfidence	Over3	Measured by excess abnormal operating cash flow, from model (3)
+ CEO Overconfidence	Over4	Measured by abnormal business production costs, from model (4)
Moderating variable		
+ The interaction between CEO confidence and foreign ownership	Over1*FO	Measured by the interaction variable between Over1 and foreign ownership. Examine the role of foreign ownership in CEO overconfidence behavior.
+ The interaction between CEO confidence and state ownership	Over1*SO	Measured by the interaction variable between Over1 and state ownership. Examine the role of state ownership in CEO overconfidence behavior.
+ The interaction between CEO confidence and income diversification	Over1*D-income	Measured by the interaction variable between Over1 and diversification. Examine the role of corporate income diversification on CEO overconfidence behavior.
+ The interaction between CEO confidence and foreign ownership	Over2*FO	Measured by the interaction variable between Over2 and foreign ownership. Examine the role of foreign ownership in CEO overconfidence behavior.

+ The interaction between CEO confidence and state ownership	Over2*SO	Measured by the interaction variable between Over2 and state ownership. Examine the role of state ownership in CEO overconfidence behavior.
+ The interaction between CEO confidence and income diversification	Over2*D-income	Measured by the interaction variable between Over2 and diversification. Examine the role of corporate income diversification on CEO overconfidence behavior.
+ The interaction between CEO confidence and foreign ownership	Over3*FO	Measured by the interaction variable between Over3 and foreign ownership. Examine the role of foreign ownership in CEO overconfidence behavior
+ The interaction between CEO confidence and state ownership	Over3*SO	Measured by the interaction variable between Over3 and state ownership. Examine the role of state ownership in CEO overconfidence behavior
+ The interaction between CEO confidence and income diversification	Over3*D-income	Measured by the interaction variable between Over3 and diversification. Examine the role of corporate income diversification on CEO overconfidence behavior.
+ The interaction between CEO confidence and foreign ownership	Over4*FO	Measured by the interaction variable between Over4 and foreign ownership. Examine the role of foreign ownership in CEO overconfidence behavior.
+ The interaction between CEO confidence and state ownership	Over4*SO	Measured by the interaction variable between Over4 and state ownership. Examine the role of state ownership in CEO overconfidence behavior.
+ The interaction between CEO confidence and income diversification	Over4*D-income	Measured by the interaction variable between Over4 and diversification. Examine the role of corporate income diversification on CEO overconfidence behavior.
+ The interaction between CEO confidence and stock market growth index	Over1*Stock-growth	Measured by the interaction variable between Over1 and stock growth. Examine the role of stock growth on CEO overconfidence behavior.
+ The interaction between CEO confidence and stock market growth index	Over2*Stock-growth	Measured by the interaction variable between Over2 and stock growth. Examine the role of stock growth in CEO overconfidence behavior.
+ The interaction between CEO confidence and stock market growth index	Over3*Stock-growth	Measured by the interaction variable between Over3 and stock growth. Examine the role of stock growth in CEO overconfidence behavior.
+ The interaction between CEO confidence and stock market growth index	Over4*Stock-growth	Measured by the interaction variable between Over4 and stock growth. Examine the role of stock growth on CEO overconfidence behavior.
Control variables		
+ CEO ownership	CEO-Ownership	Measured by percentage of shares owned by the CEO
+ Diversify income	D-Income	HHI = $(NON/NETOP)^2 + (NET/NETOP)^2$, NON is main income, NET is other income and NETOP is net income, NETOP = NON + NET, income diversity level is calculated by DINC = 1 – HHI (value from 0-0.5)

+ Stock market growth	Stock-growth	(Stock index year t- Stock index year t-1)/ Stock index year t-1)
+ Foreign ownership	FO	Number of foreign investors owning shares / Total shares
+ State ownership	SO	Number of state-owned shares/Total shares
+ Size	Size	Natural logarithm of total assets
+ Age	Age	Number of years in operation as of the calculation year
+ Growth	Growth	(Year t revenue minus year t-1 revenue) divided by Year t-1 revenue
+ Leverage	Lev	Total Debt/ Total Assets
+ Liquidity	Liq	Current Assets / Current Liabilities

Source: Compiled from the author

The data used in the study is in the form of balanced panel data, the author selected a sample of enterprises listed on the Ho Chi Minh City Stock Exchange and the Hanoi Stock Exchange. The data source is based on the database provided by Fiinpro (www.Fiinpro.com) and Refinitiv Eikon (formerly Thomson Reuters). Enterprise data is collected from audited financial statements or annual reports published by enterprises over the years. Data is collected annually, calculated from financial statements, annual reports, ownership reports and mandatory reports published in the period from 2012-2022.

4. Results and Discussion

Table 2. Descriptive results of variables

Variable	Obs	Medium	Standard deviation	Min	Max
σ_ROA	5.554	0,0286	0,0384	0,0001	0,5744
SO	5.554	0,2258	0,2520	0,0000	0,9927
FO	5.554	0,0988	0,1386	0,0000	0,9493
D-income	5.554	0,0902	0,1394	0,0000	0,4999
Stockgrowth	5.554	0,1086	0,2148	-0,3324	0,4781
CEO-Owner	5.554	1,6678	4,7383	0,0000	56,4800
Size	5.554	27,3888	1,5979	23,3300	33,9895
Age	5.554	9,2600	3,9700	5,0000	23,0000
Growth	5.554	0,3143	4,2667	-1,0000	244,4550
Lev	5.554	0,4757	0,2221	0,0006	1,3757
Liq	5.554	2,6573	4,6637	0,0338	146,9157

Source: Author's calculation

Table 2 shows the results of descriptive analysis of variables (excluding variables with binary values 0 and 1). The average risk value of ROA is about 2.86%. Regarding ownership structure, the average results show that state ownership accounts for 22.58%, while foreign ownership has a still low average value of 9.88%, despite the regulation allowing an increase in the foreign investor ownership ratio (Decree 60/2015/ND-CP on allowing an increase in the foreign investor ownership ratio). The level of income diversification calculated by DINC index = 1-HHI has a value from 0-0.5 (0.5 is high income diversification), with an average value of 0.09, meaning a low level of income diversification. Although diversification is a risk reduction strategy, this result also creates limitations when businesses generally focus on traditional business segments and income arising from pure business segments.

The stock index growth rate during the period had an average value of 10.86%, while the falling period caused the index to drop by -33.24%. The strong fluctuations in the stock index also caused instability in policies and financial situations for businesses. Regarding ownership ratio, the average value of CEO's stock holding is 1.67%, there are enterprises where CEO does not hold (0%), the highest percentage of CEO holding is 56.48% belonging to major shareholders with controlling power. The variables of size, age, revenue growth, leverage and liquidity have average values of 27.38; 9.26; 31.43%; 0.47 and 2.65 respectively. The deviation value and the difference between the smallest and largest values are also high. This phenomenon needs to be overcome in the quantitative results.

Table 3. Quantitative results of the impact of overconfidence on corporate operational risk

Variable	Model1	Model2	Model3	Model4
	Coefficient	Coefficient	Coefficient	Coefficient
Over1	0,0005			
Over2		0,0063(*)		
Over3			-0,0010	
Over4				-0,0091(*)
SO	-0,0196(*)	-0,0168(*)	-0,0191(*)	-0,0253(*)
Over1*SO	0,0008			
Over2*SO		-0,0053		
Over3*SO			-0,0039	
Over4*SO				0,0066
FO	0,0050	0,0198(*)	0,0028	-0,0137(**)
Over1*FO	-0,0049			
Over2*FO		-0,0385(*)		
Over3*FO			-0,0004	
Over4*FO				0,0262(*)
D-Income	-0,0050	-0,0066	-0,0124(**)	-0,0040

Over1*D-income	-0,0008			
Over2*D-income		0,0021		
Over3*D-income			0,0108(***)	
Over4*D-income				-0,0027
Stockgrowth	0,0002	-0,0058(***)	-0,0019	-0,0087(**)
Over1*Stockgrowth	-0,0051			
Over2*Stockgrowth		0,0084(***)		
Over3*Stockgrowth			-0,0005	
Over4*Stockgrowth				0,0101(**)
CEO-Owner	-0,0001	-0,0001	-0,0001	-0,0000
Size	-0,0015(*)	-0,0014(*)	-0,0015(*)	-0,0014(*)
Age	-0,0004(*)	-0,0003(*)	-0,0003(*)	-0,0004(*)
Growth	0,0006(***)	0,0006(***)	0,007(***)	0,0006(***)
Lev	-0,0273(*)	-0,0287(*)	-0,0272(*)	-0,0257(*)
Liq	0,0003	0,0003	0,0003	0,0003
BDS	0,0006	0,0003	0,0006	0,0007
CN	0,0071(***)	0,007(***)	0,0072(***)	0,0076(***)
YD	0,0077	0,0079	0,0079	0,0082
HHDV	0,0036	0,0032	0,0037	0,0039
NVL	-0,0009	-0,0013	-0,0008	-0,0005
TT	-0,0137(*)	-0,0141(*)	-0,0136(*)	-0,0139(*)
Const	0,0897(*)	0,0858(*)	0,0904(*)	0,0934(*)

Source: Author's calculation (*); (**); (***) corresponding to significance levels of 1%; 5% and 10%

Table 3 presents the results of the analysis on the influence of CEO overconfidence and other factors, including the moderating effect of overconfidence on business risk. The findings show that overconfidence driven by surplus operating cash flow (OCF) or higher earnings compared to industry forecasts amplifies business risk. When a company has an abnormal surplus of OCF and higher-than-average income, it often leads to deviant investment behavior and the acceptance of higher-risk investment projects Nguyen Trong Nghia. This aligns with previous studies Zulfiqar Ali Memon et al [34] that show CEO overconfidence increases company risk, as overconfident CEOs tend to believe they are consistently successful (Hiller & Hambrick) [35], leading to faster decision-making based on a perceived perfect understanding of situations and opportunities. Similar results are observed when overconfidence is combined with excess OCF and higher-than-average industry earnings.

However, the results are contradictory when overconfidence is related to abnormal cash flow (Over3) linked to accelerated sales through increased price discounts or more favorable credit terms, and abnormal cost control behavior (Over4). In these cases, overconfidence (measured by Over3 and Over4) has a negative relationship with business risk, meaning it reduces business risk. While confident CEOs can easily manipulate receivables, inventories, provisions, and accruals to adjust revenue, expenses, and gross profit (Omar et al.,) [36], the transparency requirements for public companies and the involvement of multiple monitoring parties make it easier to detect abnormal deviations (Jagjeevan Kanoujiya et al) [37]. This reduces overconfidence and mitigates risks for businesses.

Regarding state ownership (SO), the results indicate a negative relationship with operational risk, meaning that increased state ownership reduces business risk. This finding contrasts with the results of previous studies Tran Thai Ha Nguyen [38] but supports research from Kelly Anh Vu et al [39], which argue that state-owned enterprises (SOEs) benefit from political connections and policy incentives that enhance operational efficiency and competitiveness. Managers believe they can mitigate external uncertainties through political connections, and state-dominated ownership structures help curb CEO overconfidence, thus reducing risk (Zulfiqar Ali Memon et al) [34]. Additionally, the relinquishment of government control, the increase in private ownership, foreign investment, and improved governance institutions are key factors influencing corporate risk-taking behavior (Boubakri et al) [40].

Foreign ownership also influences corporate operational risk, with the results showing that its impact is moderated by overconfidence. Foreign ownership appears to support CEO overconfidence when excess OCF or earnings increase operational risk (Boubakri et al), but it helps to restrain risk when overconfidence leads to earnings management (Sekar Langit et al) [41]. Foreign ownership plays a risk-moderating role for CEO overconfidence behavior, reducing risk in cases where overconfidence increases risk, and increasing risk where overconfidence reduces it, thus helping to balance efficiency and risk for the company.

The research also shows that income diversification reduces operational risk. Diversification across production, business, and investment activities provides a buffer in case one segment underperforms (Camila Adam) [42]. However, income diversification interacts with CEO overconfidence (Over3), increasing operational risk when combined with revenue management behavior. Overconfident CEOs may seek to generate unexpected revenue through diversified activities, leading to heightened risk.

Stock index growth has a risk-reducing effect on businesses. A growing stock market reflects a positive macroeconomic environment with greater business and investment opportunities, improved financial conditions, and reduced risks (Nam Hoai Tran & Le Dat Chi) [43]. Additionally, when stock indexes rise, CEOs are more likely to make timely investment decisions—buying at market lows and selling at highs—resulting in future profits (Khoa Duong Dang et al) [44]. However, the interaction results show that overconfident CEOs, combined with a growing stock market, are further encouraged in their overinvestment behavior, thereby increasing business risk (Jie Cao) [45].

5. Conclusion and Recommendation

The objective of this study is to quantitatively analyze the impact of CEO overconfidence on the operational risk of listed companies. The findings indicate that overconfident CEOs who aim to increase efficiency also tend to elevate business risk. Conversely, overconfidence driven by earnings management, when under controlled conditions, helps to reduce risk. Additionally, income diversification, company size, and state ownership play significant roles in mitigating risk. These factors are particularly relevant for both managers and investors who seek to minimize operational risk.

Moreover, industry-specific risks reveal that the information and communication sector, along with the raw materials production industry, exhibit lower operational risks compared to other sectors. In contrast, the industrial production industry faces higher risks, largely due to the numerous external factors influencing both its input and output.

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An Empirical Analysis of the Impact of AI on Regional Economic Resilience

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Abstract. Regional economic resilience reflects the capability of a country or region to renew normal economic growth when the economy encounters exterior shocks. A new round of scientific and technological change has spawned the application of AI technology and improved digital governance capabilities, which is of great significance for enhancing regional economic resilience. Based on 2013-2022 data from 30 provinces in China, this article empirically investigates the impact of AI on regional economic resilience using fixed-effect models and mechanism test models. The research shows that AI significantly promotes regional economic resilience, and AI affects regional economic resilience through economic agglomeration.

Keywords. AI, economic agglomeration, regional economic resilience

1. Introduction

In the wave of science and technology in the 21st century, artificial intelligence (AI), as one of the most subversive technologies, is reshaping the global economic pattern and regional development at an unprecedented speed. With the continuous breakthrough and integration of key technologies such as big data, cloud computing and machine learning, AI has not only profoundly changed the mode of production, consumption pattern and social structure, but also become an important impulse to improve the transformation and elevation of regional economic performance and improve the resilience of regional economy.

The subsistent literature on regional economic resilience primarily concentrates on the following three aspects. (1) Connotation disclosure. In order to conceptualize and analyze how regional economies respond to and renew from shocks, Reggiani brings regional resilience into the field of economics[1]. Three crucial aspects are included in the meaning of regional economic resilience: engineering, ecological, and evolutionary resilience. The capability of the economic system to replace to the previous proportion or achieve it after a shock is known as regional economic resilience from the standpoint of engineering resilience. This ability is demonstrated by the economy's resistance to the impact and its quick restoration to the pre-shock state[1]. From the perspective of ecological resilience, regional economic resilience denotes the capacity of an economic system to absorb disturbances without altering its structure, characteristics, and functionalities. From the standpoint of evolutionary resilience, regional economic

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resilience encompasses the immediate applicability of economic systems to impacts, as well as their long-term capacity to forge new avenues of growth. (2) Measures of regional economic resilience. There are four approaches to estimate economic resilience in the literature: case comparison method, econometric model, core variable method and comprehensive index method[2]. Some scholars use the case comparison approach to judge the resilience of regional economy through data collection, investigation and interview[3][4][5]. Some scholars use econometric models such as surface-to-uncorrelated regression model (SUR), vector error correction model (VECM), nonlinear smooth transfer autoregressive model (STAR) and Arima model to measure economic resilience[6][7][8]. (3) Analysis of the factors influencing of regional economic resilience. Relevant domestic and international studies on regional economic resilience have surfaced in recent years. Scholars have discussed the impact of digital economy[9], industrial structure[10], innovation[11], urban governance[12] and other factors on regional economic resilience.

A review of subsistent studies shows that there are few literatures designed to research the mechanism of AI on regional economic resilience. Taking this into consideration, this paper enriches the research on the influence of AI on regional economic resilience by examining the true influence and mechanism of AI on regional economic resilience through panel data of 30 Chinese provinces (excluding Tibet) from 2013 to 2022.

2. Mechanism Analysis

With self-learning and adaptive characteristics, combined with big data analysis, AI technology can accurately simulate external shocks, enhance early economic warning and system resilience. In the face of shocks, AI quickly develops optimal response strategies, efficiently allocates resources, and accelerates economic recovery. Its infrastructure attributes need the support of government investment, and the perfect digital infrastructure will promote communication efficiency, matching accuracy and resource reorganization ability to significantly improve[13]. AI has greatly increased production efficiency and product quality by using intelligent and automated methods. Intelligent manufacturing systems can optimize production processes, reduce human error, and increase production flexibility and response speed. By adopting advanced production processes and automation equipment, intelligent transformation firms further productive efficiency and expand market size, which in turn affects the production layout choices of enterprise suppliers and partners. In order to reduce transaction costs, transportation costs and communication costs, suppliers and partners usually establish production bases or factories close to major customers[14], resulting in economic agglomeration, which usually brings productivity advantages and positive externalities such as resource allocation optimization and productivity improvement to economic development[15], helping to improve the capability of regional economy to withstand exterior impact.

Hypothesis 1: AI has a significant effect on regional economic resilience.

Hypothesis 2: AI promotes the regional economic resilience through economic agglomeration.

3. Research Design

3.1 Model Design

The next benchmark regression model is built to examine the overall influence of AI on regional economic resilience according to the theoretical analysis appeared hereinabove:

$$ERS_{it} = \alpha_0 + \alpha_1 AI_{it} + \alpha_2 control_{it} + \beta_i + \gamma_t + \varepsilon_{it} \tag{1}$$

Establish a mechanism test model, as shown in formula (2), to examine the relationship between economic agglomeration (EA) in AI and regional economic resilience, referring to the practice of Jiang Ting[16], this article examines the significance of θ_1 in the formula (2) on the basis of the significance of α_1 in the formula (1), if θ_1 is significant, it indicates that EA is a possible role channel.

$$EA_{it} = \theta_0 + \theta_1 AI_{it} + \theta_2 control_{it} + \beta_i + \gamma_t + \varepsilon_{it} \tag{2}$$

3.2 Dependent Variable

With reference to the existing literature[17], regional economic resilience is mainly affected by five dimensions: economic development, degree of openness, industrial structure, institutional guarantee, and innovation ability. Therefore, this dimension is taken as a first-level indicator, and to reduce the influence of dimensions, a set of 15 second-level indicators is chosen in order to construct an all-encompassing indicator system of regional economic resilience. In this paper, the second-level indicators are standardized by the range method, taking into account the bias brought by subjectivity, and the economic resilience development of 30 provinces in China is measured from 2013 to 2022 using the entropy method.

Table 1. Regional Economic Resilience Index System

Goal	Primary Index	Secondary Index
Regional Economic Resilience	Economic Development	GDP (100 million yuan)
		Per capita GDP (Yuan)
		Per capita disposable income (Yuan)
	Degree of Openness	Import and export (US $10,000)
		Total investment (US $100 million)
		Registered capital (USD 100 million)
	Industrial Structure	Proportion of output value of primary industry in gross output value (%)
		Proportion of industrial added value to total output value (%)
		Proportion of tertiary industry output value in gross output value (%)
	Institutional Guarantee	General budget income (billion yuan)
		General budget expenditure (billion yuan)
		Number of people taking part in unemployment insurance at the end of the year (10,000)

	Innovation Ability	Number of students in the college (students) R&D personnel all-time equivalent (person-year) R&D expenditure (ten thousand yuan)

3.3 Explanatory Variable

With reference to the existing literature[18], although the patent data itself cannot contain the technical inventions and applications that have not applied for patent protection, and the quality of patents is uneven, it can be more accurately divided into the parts belonging to artificial intelligence technology. In this paper, the AI patent classification number in the Reference Relation Table of Strategic Emerging Industries Classification and International Patent Classification (2021) is indicative of the level of AI progress in the area. The provincial AI patent data of China is obtained from the State Intellectual Property Office, and the number obtained is logarithmic.

3.4 Mechanism Variable

Economic agglomeration (EA): In order to obtain the advantages of production and management, economic activities continue to gather in a specific area, and then form a certain scale cluster in geographical space. The main indicators of economic agglomeration include Herfindahl index, Gini index and location entropy, but they do not take into account the differences caused by the small geographical area of individuals. The economic aggregate generated per unit area can better measure the degree of economic agglomeration in a region[19], so this paper adopts the logarithm of the rate of the gross industrial product of each province to the total region to measure.

3.5 Control Variables

Marketization level (Mar), scientific and technological innovation level (RD), urbanization level (Urban), openness to the outer world (Open), infrastructure standard (Infr), human capital quality (HQ) and government intervention (GOV) were chosen as control variables. The marketization level is assessed using five sub-indices: relationship between the market and the government, expansion of the privately owned department of the economy, product and factor markets, establishment of the intermediary entity in the market, and legal system environment. The level of scientific and technological innovation is measured by the technical market turnover of each province and logarithm. The share of the total population in each province that lives in an urban area serves as a proxy for the level of urbanization. The rate of the region's GDP to the sum of each province's import and export trade indicates how open a province is to the outside world; The level of infrastructure is measured by the highway mileage per square kilometer in each province and logarithmically. The quality of human capital is surveyed by the multipliers of the number of higher education graduates and the average money wages at the end of the year. Government intervention is surveyed by fiscal expenditure as a percentage of the annual GDP of respective province (autonomous region or municipality directly under the central government).

3.6 Sample Selection and Data Source

This article uses panel data from the China Statistical Yearbook, EPS database, State Intellectual Property Office, National Bureau of Statistics, and other sources for analysis samples of 30 provinces in China (excluding Tibet) from 2013 to 2022.

4. Results and Discussion

4.1 Empirical Results and Analysis

After conducting the Hausman test, double fixed effects were selected to investigate the influence of AI on regional economic resilience, and the results were shown in Table 2. Among them, column (1) does not consider the control variable, column (2) introduces the control variable, column (3) controls the province on the basis of column (2), and column (4) further controls the year. According to the findings, AI significantly affects regional economic resilience. Both effects are significant at the 1% level, and hypothesis 1 has been tentatively confirmed.

Table 2. Baseline Regression Result

	(1) RES	(2) RES	(3) RES	(4) RES
AI	0.050***	0.022***	0.025***	0.018**
	(0.003)	(0.006)	(0.005)	(0.007)
N	300	300	300	300
R^2	0.521	0.704	0.956	0.961
YearFE	NO	NO	NO	YES
IDFE	NO	NO	YES	YES
Controls	NO	YES	YES	YES
F	323.838	86.361	152.543	135.211

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.2 Robustness Test

Explanatory variables lag by one phase. Considering that there is a certain lag in the influence of artificial intelligence on regional economic resilience, this paper conducts a one-stage lag for the explanatory variables and re-examines the connection between AI and regional economic resilience. The findings are revealed in column (1) of Table 3. The research in this paper is still robust, as evidenced by the regression coefficient between AI and regional economic resilience for lagging processing, which is still significantly positive.

Replace the explained variable. The macroeconomic essential variable of GDP is selected to measure the level of regional response to economic impact. The corresponding regression findings are displayed in column (2) of Table 3. The regression coefficient of AI and regional economic resilience remains markedly positive, and the core explanatory variable's coefficient symbol and significance level remain unchanged, suggesting that the research presented in this paper is still sound.

Dynamic panel - system GMM regression results. Dynamic panel regression method is adopted to verify the connection between AI and regional economic resilience, and system GMM is used for parameter estimation. In terms of model setting, considering that the lag period of regional economic resilience may affect the regional economic resilience of the current period, this article introduced the regional economic resilience lag period (L.RES) as an explanatory variable to build a dynamic model, and used the system generalized moment estimation method (system GMM) for parameter estimation. In Table 3, column (3), the corresponding regression results were presented. The findings of AR (1), AR (2) and Hansen tests reveal that SYS-GMM has first-order autocorrelation but no second-order autocorrelation, manifesting that the instrumental variables are reliable and the endogeneity problem is excluded. The above robustness test results show that the conclusion that AI promotes regional economic resilience has not changed. Thus, hypothesis 1 is verified.

Table 3. Robustness Test

	(1) RES	(2) RES	(3) RES
L.AI	0.016**		
	(0.008)		
AI		0.066***	0.005**
		(0.016)	(0.001)
L.RES			0.930***
			(0.034)
R^2	0.962	0.996	
YearFE	YES	YES	YES
IDFE	YES	YES	YES
Controls	YES	YES	YES
AR (1)			0.034
AR (2)			0.124
Hansen Test			0.950
F	127.514	1334.130	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.3 Heterogeneity Analysis

The regression results are shown in Table 4 below. In the eastern region, AI significantly increases regional economic resilience; it has no discernible impact on regional economic resilience in the central region; and it significantly reduces regional economic resilience in the western region. The eastern region has a more advanced economy, a more advanced digital industry, and a stronger technological foundation than the central and western region. These factors may encourage the faster application of AI, thereby enhancing regional resilience. For the central and western zones, due to the comparatively weak economic foundation and limited technical conditions, the application effect of AI technology needs to be further improved.

Table 4. Heterogeneity Analysis

	(1) East Part	(2) Middle Part	(3) West Part
AI	0.056***	0.001	-0.006*
	(0.019)	(0.004)	(0.003)
R^2	0.966	0.990	0.975
YearFE	YES	YES	YES
IDFE	YES	YES	YES
Controls	YES	YES	YES
F	86.806	217.487	116.308

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.4 Mechanism test

The regression results are shown in Table 5 below. AI significantly promotes economic agglomeration, and the in-depth application of AI technology can markedly boost the intelligence degree of traditional industries, promote their transformation to high-end, intelligent and green directions, lower production costs while increasing output quality and efficiency, and enhance the market competitiveness of enterprises. Thus, attracting more relevant enterprises to gather in the same region, thus enhancing the resilience of regional economy.

Table 5. Mechanism Test

	(1) EA
AI	0.152***
	(0.029)
R^2	0.996
YearFE	YES
IDFE	YES
Controls	YES
F	1381.403

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusion

AI has become a crucial force source for promoting high-quality regional economic progress. By improving production efficiency, optimizing resource allocation, promoting industrial upgrading and spawning new industries, AI technology has injected new vitality into the regional economy. As a scientific and technological engine in the new era, AI is promoting the development of regional economy to a more intelligent and resilient direction with its unique advantages. Utilizing data from 30 provinces in China spanning from 2013 to 2022, this article empirically investigates the influence and mechanism of AI on regional economic resilience through the utilization of a baseline regression model and a mediation effect model. The empirical findings indicate that AI significantly enhances regional economic resilience and exerts an influence on regional economic resilience industries by means of industrial structure upgrading.

The objective of this paper is to offer fresh insights, concepts, and tactics for the continuable growth of the regional economy by methodically examining the influence of AI on the resilience of regional economy. In the future, with the continuous maturity of AI technology and the continuous deepening of application, the regional economy will show stronger resilience and broader prospects for development.

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Banks Stability in Islamic and Conventional Banks: The Role of Credit and Liquidity Risks – An Applied Study on Banks Operating in Middle East

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Abstract. Examining the impact of credit risk and liquidity risk on the stability of Islamic and conventional banks is the goal of this study. We conducted the study on a sample of 17 banks over a 15-year period, from 2008 to 2022. We used OLS regression, incorporating bank size and age as conditional variables. According to the research findings, the average for bank stability is (4.8) which is greater than (1.98) and this indicates the presence of stability in these banks. For Islamic banks, we found that their credit risks have a negative effect on bank's stability with a regression coefficient of -12.4, and liquidity risks also have a negative impact with a regression coefficient of -10.06. As for conventional banks, we found that their credit risks have a positive effect on a bank's stability with a regression coefficient of 14.5, and liquidity risk has a positive effect with a regression coefficient of 3.63.

Keywords. Credit risk, liquidity risk, and bank stability.

1.Introduction

The global financial crisis of 2008 presents different viewpoints on acceptable risk levels, and nations need to take action to maintain the stability of the financial system. The financial system plays a vital role in facilitating the flow of funds from individuals or entities with excess funds to those with a shortage, thereby satisfying the allocation function. The presence of instability in the financial sector will inevitably result in an economic disaster. Banks, as financial institutions, bear a vital duty in guaranteeing the stability of the financial system [1].

As maintaining sufficient liquid assets is crucial for banks to achieve optimal financial performance and stability[2] , effective liquidity risk management is required. This ensures that banks can meet their obligations while still earning profits from their

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cash holdings. Banks face a unique challenge: most of their funds come from external sources and mature at different times. Distributing these funds through loans and investments reduces the bank's immediate access to cash, potentially hindering its ability to meet upcoming liabilities. Furthermore, predicting when money from current and savings accounts will be repaid is harder than with traditional deposits. Because of this, a high financing-to-deposit ratio (FDR) may indicate elevated liquidity risk [3].

Additionally, [4] discovered that bank stability is severely harmed by both credit risk and liquidity risk, whether considered together or separately. Similarly, [5] observed there is a significant negative impact on bank stability when credit and liquidity risk are combined, increasing the likelihood of bankruptcy. [6] Determined that bank failures primarily stem from liquidity issues. According to [7], a higher proportion of liquid assets in a company improves bank stability. However, [8] found that credit risk significantly impacts bank stability, whereas liquidity risk does not have the same influence.

Our research will shed light on the anticipated effects of liquidity and credit risks on the stability of conventional and Islamic banks in the Middle East, which will add to the current body of knowledge. Since earlier research has indicated differences, this study will also look into whether these risks affect the stability of Middle Eastern banks differently. While some research has shown a positive effect, other investigations have found the opposite to be true. Insights into the real effect of these risks on bank stability during the last fifteen years will be provided by the study's findings, which will help policymakers and bank managers improve bank stability.

2.Theoretical Framework and current hypothesis

2.1Credit and liquidity risks in Islamic banks

The 2008 global financial crisis (GFC) raised concerns about all financial institutions' financial soundness[9].Financial stability cannot be guaranteed even in a stable macroeconomic environment due to the complex relationship between financial and macroeconomic stability. Not ignoring financial stability analysis is critical. Banking is the nation's economic foundation. Bankruptcies affect governments, corporations, employees, executives, shareholders, borrowers, and lenders, influencing the economy. Thus, scholars and policymakers must understand stability factors[10].

Liquidity and credit risk have attracted considerable attention from several researchers. Efficiently controlling these risks is a vital element in improving a bank’s performance. as referenced by authors[11] and [12]. The effectiveness of managing banking operations hinges on the banks' ability to sustain liquidity risk [13]. Augmenting liquidity can improve operational stability, but it may restrict the ability to disburse funds to the community [4] .in order to enhance their financial results, banking institutions can optimize the distribution of funds to the public. Nevertheless, implementing this decision may lead to a decrease in the ability to meet financial obligations promptly, as highlighted by [13].

Therefore, additional inquiry is necessary to comprehensively analyze this liquidity problem. Studies investigating the influence of liquidity risk on banks' stability have yielded inconclusive results. [11] Argue that proficiently handling liquidity risk can enhance both the stability and performance of the Islamic banks. In their study, [14] discovered a positive correlation between banks that had substantial liquidity risk and their overall stability. [12] found that optimizing high liquidity risk can result in improved operational performance and enhanced earnings.

However, other research indicate that increased liquidity risk will weaken the financial sector's stability. [4] research clearly shows that liquidity risk significantly undermines the stability of Islamic banks. [15] conducted a study that produced divergent results compared to previous research. More precisely, they found that liquidity risk has a substantial and negative effect on the stability of banks. In their research, [11] discovered that the presence of liquidity risk did not exert any influence on the stability of banks. The contradictory results found in studies on the impact of liquidity risk on financial stability underscore a gap in research, which raises fundamental inquiries about the essence of liquidity risk and its capacity to uphold favorable stability in Islamic institutions.

In research, [11] discovered that credit and liquidity risks had a notable negative impact on the stability of Islamic banks, both when considered together and separately. Similarly, [16] found that the combination of credit and liquidity risks has a detrimental impact on the stability of Islamic banks. Furthermore, they observed that higher levels of credit and liquidity risks correspond to an increased likelihood of bank insolvency.[16] also found that liquidity problems primarily cause bank failures. [7] demonstrated that as the percentage of liquid assets in a company increases, the bank is more inclined to promote stability. Conversely,[8] discovered that while credit risk significantly influences bank stability, liquidity risk does not. Furthermore, [17] discovered that factors such as inadequate capital, low earnings, high exposure to certain loans, and a high number of loan defaults primarily determine a bank's collapse. This statement suggests that liquidity risk does not have a substantial impact on bank stability. However, it emphasizes that the amount of capital is a crucial factor in determining bank failure.

2.2 Credit and liquidity risks in conventional banks

Banking institutions primarily engage in credit-risky lending, which serves as the cornerstone of their profitability. Moreover, credit risk is the primary determinant of a bank's regulatory capital requirement. It is an inherent aspect of banking operations. Therefore, it is imperative to handle it with utmost care. To effectively assess credit risk, the bank must utilize both qualitative and quantitative judgment abilities to the fullest extent [18]. Credit risk refers to the potential for funds provided by a bank to a customer not being repaid. It is defined as the probability of an unfavorable scenario in which the borrower fails to repay the borrowed funds. First and foremost, we need to address it as a risk that needs to be managed[19]. According to [20], credit risk refers to the likelihood that certain assets of a financial organization, particularly its loans, will decrease in value and potentially become completely worthless. Credit risk, as defined by[21], refers to the potential financial loss that a bank may experience if a borrower, also referred to as the counterparty, fails to fulfill their obligations and return the loan's principal amount and accumulated interest, as per the predetermined terms. [22] defines credit risk as the possibility of a counterparty in a financial transaction failing to meet their obligations. In such instances, the party that is not in default may incur a financial detriment. Several studies have investigated the correlation between financial performance and credit risk. According to [23], as well as [24], credit risk has been identified as a major factor that has a detrimental effect on the stability and performance of banks.

Furthermore, [25]suggests that enhancing the database and diligently scrutinizing interest rates contribute to improving credit risk management in banks, thereby influencing bank's stability. The same context [26] asserts that four distinct categories of risks, namely credit and liquidity risks, impact bank's stability. We deem the overall impact of these risks to be positive. However, both [27] and [28] contend that there are additional variables that can indirectly influence the stability of the banking sector. [27] argues that the Corona virus era had an impact on liquidity concerns, which in turn influenced financial stability. [28] Posits that the Arab Spring upheavals had a consequential effect on bank liquidity levels, thereby influencing the financial sector's stability.

The theoretical model for the present research (Figure 1) was constructed using findings from bank's risk research and bank's stability. Figure 1 illustrates the causal connections between the variables examined in this study. These relationships consist of two hypotheses:

H1: There is a statistically significant effect of credit and liquidity risks on the stability of Islamic banks operating in Middle East.

H2: There is a statistically significant impact of credit and liquidity risks on the stability of conventional banks operating in the Middle East.

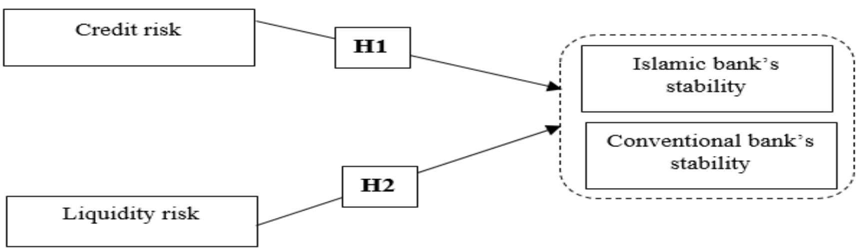

Figure 1. Study Model

3.Methodology

The research sample includes 17 banks from the Middle East region, except for Israel and Yemen, including 7 Islamic banks and 10 conventional banks. The analysis period was 15 years, from 2008 to 2022.the study utilized a comparable model to that employed by [21]. The dependent variable employed in this study was the Z-score, which measures the stability of banks. The nonperforming loan ratio and loan loss reserves were used to analyze the independent variable, credit risk. The liquidity ratio was assessed by calculating the proportion of liquid assets to total assets (LTTA) [29] , which were deemed appropriate for the country under investigation and were readily available in accordance with reporting standards. The data for these variables was obtained from the bank's website, using the bank's financial statements for the period from 2008 to 2022.

The model: Z-score = $\beta_0 + \beta_1$NPL+ β_2LTTA+ + β_3SIZE + β_4AGE +e

Where $\beta0$ is a constant term, $\beta1$- $\beta4$coefficients of independent variables

Z-score is a dependent variable; NPL is Nonperforming loan ratio; LTTA is Liquid assets To Total Assets ratio; SIZE is Total Assets; AGE is Age of the bank.

The Z-score variable is employed to evaluate the degree of bank stability. It is computed by dividing the return on assets by the standard deviation of the return on assets. A high Z-score suggests greater stability for a bank, as it is inversely related to the likelihood of the bank going bankrupt [30]. We utilized the ratio of nonperforming loans to loans (NPL) as a measure of credit risk, using the methodology given by [31] and [9]. The ratio estimates the proportion of gross loans in the banks' loan portfolio that are classified as nonperforming or questionable. It is often regarded as a highly significant measure of credit risk and loan quality within the bank's industry.

Were used liquid assets ratios, which are assets that are easy to convert into cash because of the ability of this ratio to explain the extent of the bank's ability to meet its short-term obligations? The higher these ratios are, the better it is in terms of liquidity[21]. The size and age of the bank were utilized as conditional variables. The bank's size was quantified by employing the logarithm of its total assets [30] . The age of the bank was divided into three categories: less than 50 years, from 50 years to less than 100 years, and the last category is more than 100 years.

4. The Study's Findings

Table 1 displays the descriptive statistics of the variables utilized in the study, including the four measures of credit liquidity hazards and the conditional variables indicator, which represents the ratio of NPL, LTTA, SIZE, AGE and the measure of bank's stability Z-SCOR

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.
ZSCORE	255	4.806	8.943
NPL	255	.088	.115
LTTA	255	.044	.003
Size	255	10.214	1.268
Age	255	1.529	.607

Table 1 shows that the average bank stability is (4.806) and this value indicates a high level of Stability for banks operating in Middle East due to low credit risks (0.088) as well as liquidity risks (0.044)

Table 2: Results of the Regression Analysis for the Islamic banks

VARIABLES	(OLS) ZSCORE
NPL	-12.4
	(454.8)
LTTA	-10,061
	(20,666)
Size	-26.75
	(58.45)
Constant	410.0
	(615.8)
Observations	105
R-squared	0.064

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Adjusted R-squared is a statistical measure that quantifies the proportion of variability in the dependent variable that can be explained by changes in the independent variable. Based on the data shown in the table above, the R-squared value is 0.064, indicating that there was a variation of 6.4% in the bank's stability of the Islamic banks due to changes in credit and liquidity risk ratios at a 95 percent confidence interval.

As expected, the effect of the nonperforming loan ratio on bank's stability is found to be negative but non-significant, indicating that high nonperforming loans reduce bank's stability. Keeping other repressors constant, the results show that a one-unit rise in nonperforming loans decreases the bank's stability by 12.4 units. Additionally, there is a negative effect of liquid assets on a bank's stability, with no significant indication that a high liquid assets-to-total-assets ratio reduces bank's stability. When all other factors that depress bank's stability are held equal, the findings indicate that a one unit increase in LTTA leads to a decrease in bank's stability of 10.61 units.

Table 3: Results of the Regression Analysis for the Conventional banks

VARIABLES	(OLS) ZSCORE
NPL	14.5**
	(62.90)
LTTA	3,863
	(2,828)
Size	3.406
	(5.260)
Age	-10.42
	(11.40)
Constant	-52.55
	(64.96)
Observations	150
R-squared	0.025

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The adjusted R-squared is a statistical measure that quantifies the proportion of variation in the dependent variable that can be attributed to changes in the independent variable. The table reveals that the R squared value is 0.025, indicating a 2.5% variance in the stability of conventional banks caused by fluctuations in credit and liquidity risk ratios, with a 95% confidence level.

There is a positive and significant effect of the nonperforming loan ratio on bank's stability, indicating that high nonperforming loans reduce bank's stability. When all other factors that depress returns are held constant, the findings indicate that a one unit increase in nonperforming loans leads to a 14.5 unit increase in bank's stability.

Additionally, there is effect of liquid assets on bank's stability that is found to be positive but not significant, indicating that a high liquid assets-to-total assets ratio reduces bank's stability. When all other repressors are held equal, the findings indicate that a one unit increase in LTTA leads to a fall in bank's stability by 3.86 units.

5. Conclusion

The objective of this study is to study the impact of credit and liquidity risks on the stability of banks in the Middle East. The spatial limits of the research were the Middle East region, with the exception of Israel and Yemen, while the time limits of the research were 15 years from 2008 to 2022. According to the previous analysis, the average for bank stability is (4.8), which is greater than (1.98), indicating that these banks have stability. We found that Islamic banks' credit risks have a negative effect on bank's stability with a regression coefficient of -12.4, and liquidity risks have a negative impact with a regression coefficient of -10.06. This result is consistent with a study of [11], [12] and [11], These researchers found that the relationship between liquidity, credit risks and bank's stability is an inverse relationship. They explain this by saying that a decrease in liquid assets in banks means an increase in risks, that is, an increase in the funds used in participating in projects leads to a decrease in the overall net profit, and this happens because the increase in payback period for those projects or exposure to loss as Islamic banks rely more on participation, which leads to a decrease in bank's stability because net profit is the basic element used in measuring bank's stability. Regarding conventional banks, we found that their credit risks have a positive effect on a bank's stability with a regression coefficient of 14.5, and liquidity risk has a positive effect with a regression coefficient of 3.63. This result is consistent with a study of [11]. These researchers found a positive relationship between liquidity and credit risks and bank stability. They explain this by saying that a decrease in liquidity in the bank means an increase in loans, which means an increase in net profit, which is used to measure bank's stability, and vice versa. This is due to the different activities in Islamic banks, which depend on participation, speculation, and Murabaha, whereas traditional banks rely more on loans. We suggest the need to pay attention to reducing the level of risks through increasing attention to credit examination and providing an appropriate level of liquidity, and here we can rely on the decisions of Basel 3. We also suggest that researchers expand the study of the reasons for the difference in the effect of credit and liquidity risks on the stability of Islamic and conventional banks.

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A Catalyst for the High-Quality Development of Enterprises: Open Public Data

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Abstract. High-quality development represents the principal objective of establishing a modern socialist country in all respects. In this context, the opening of public data serves as an important measure for China to reform its public governance and stimulate the high-quality development of enterprises by leveraging data elements within the new developmental landscape. This paper offers a theoretical analysis concerning how the opening of public data can empower enterprises towards achieving high-quality development. Our study reveals that opening public data effectively enhances the high-quality development of enterprises through several mechanisms: promoting the transformation of production factors, facilitating a shift in driving forces, reducing transaction costs, and expanding knowledge horizons.

Keywords. Open public data, High-quality development of enterprises, Digital transformation.

1. Introduction

High-quality development of enterprises is a multidimensional concept that encompasses various levels, including high-level competition among enterprises, production momentum driven by production factors, output of products and services, and comprehensive value creation. This development is primarily propelled by resource-driven initiatives, innovation-led strategies, and the creation of value for diverse stakeholders. The openness of public data represents not only a novel approach to public governance but also introduces a new technical and economic paradigm characterized by the interplay between "data elements - technical foundation - digital governance - digital ecology." This paradigm is grounded in public data, technology, and derivatives thereof while being shaped collaboratively with the digital economy, digital society, digital government, and even the broader context of digital ecology. As a significant strategy for advancing the construction of both digital government and the digital economy, the openness of public data can seamlessly integrate data into the entire value creation process of enterprises. By extracting valuable insights from open public data, businesses can generate visualized knowledge that supports their production activities. This enables the application of public data at the micro-enterprise level, driving a wide array of empowering effects on the high-quality development of businesses. These effects include

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value creation, enhanced capabilities, and a variety of other positive impacts on business performance. So, this paper will thoroughly analyze the underlying logic behind how opening public data can empower high-quality enterprise development.

2. The key prerequisites for empowering the high-quality development of enterprises through open public data

Firstly, data-driven elements serve as the foundational prerequisite for public data openness to empower the high-quality development of enterprises. The rapid expansion of public data resources has made large-scale accessibility a reality, endowing public data with the core qualities of a production factor. At the same time, the rapid development of digital technologies such as blockchain, artificial intelligence, and cloud computing— within the context of the third wave of informationization — has facilitated extensive connections both within and outside enterprises, fundamentally reshaping production entities, objects, and tools, and driving significant changes in production methods. As an innovative application of these digital technologies, the launch of public data platforms allows public data to permeate the entire value creation process of enterprises. By extracting valuable insights from open public data, enterprises can generate visualized knowledge that supports production activities, creating new application scenarios for public data at the micro-enterprise level. This, in turn, fosters a wide range of empowering effects, value-enhancing impacts, and other positive outcomes, driving the high-quality development of enterprises.

Secondly, the potential value transformation of public data is the intrinsic driver for public data openness to empower the high-quality development of enterprises. On a macro scale, China is currently undergoing an economic structural transformation. The efficiency with which data is transitioning from production factors to innovation factors and, ultimately, to capital factors is generally lower than the optimal level expected in a steady-state economy. However, the return on investment generated by data as a production factor is significantly higher than the diminishing returns associated with traditional production factors. Utilizing public data elements to empower traditional industries can accelerate their transformation and upgrading, while also reshaping the competitiveness of various industries within the modernized industrial system. Specifically, "integration" refers to the ability of enterprises to deeply mine, process, and analyze different types of public data, allowing it to be flexibly applied across various scenarios. The "value" of public data lies in the collection of business data and information from government departments at all levels, as well as public management and service areas. What makes public data unique is its evolution within the "technology-economy" paradigm, where public data elements undergo a transformative process— from being technology-driven to becoming production factors, then to integrated development, and ultimately contributing to shifts in economic patterns. As a result, even a small amount of public data can hold significant value for specific domains. "Openness" refers to the ability of public data to be shared and circulated within government agencies, between the government and the market, and between the government and society. This openness helps enhance government transparency and balance the interests between government, enterprises, and other market participants. Therefore, the ability to access and leverage as many public data resources as possible, and to unlock their intrinsic value, has become a key strategy for enterprises to establish competitive advantages in the digital economy era.

3. The Impact of Public Data Access on High-Quality Enterprise Development

3.1 Open public data can promote changes in corporate production factors

Data elements are widely recognized as a key driver for high-quality development of enterprises. Generally, data elements can significantly alter the traditional production functions of enterprises, thereby facilitating the enhancement and evolution of total factor productivity, which in turn propels the development of enterprise. From the perspective of neoclassical economics theory, production factors include land, labor, capital, technology and other types of factors. Enterprises build their own unique combination of production factors based on the above production factors and try to supply products and services in the form of optimal production functions, striving to maximize production efficiency. Amidst the ascendancy of the digital economy, data has emerged as a novel and pivotal production factor. Open public data has effectively reshaped the production factor attributes and functions of public data, providing a new type of data production factor for the high-quality development of enterprises. The reason for the phenomenon is that, from the government data to public data, the scope of data collection is constantly expanding, and the functions of data are also changing accordingly. Specifically, the primary function of government data is to improve the transparency of public governance and satisfy citizens' right to know. It has the attribute of "governance element" but not the attribute of production factor. In contrast, public data can not only be used to improve the public governance and public services with the "governance" attributes but can also be applied to the production operations and service innovations of enterprises, showing the attribute of "production factor". Therefore, as the carrier of public information and knowledge, the analysis of public data can help enterprises make more effective use of factor endowments, the analysis of public data can help enterprises to make production decisions more effectively[1], and provide a new information and knowledge base, reshape the resource base for enterprise to participate in the market competition, so that the firms are able to increase their competitiveness in ways that are difficult for other competitors to imitate or surpass.

For the high-quality development of enterprises, the opening of public data provides a new resources pool for enterprises to improve their input-output structure, and this brand-new elemental resource also has its own special characteristics. Firstly, public data elements is value-added. With the accumulation of scales and types of open public data, the intrinsic value of public data elements will continuously improve, because the information they contain is more abundant than the general data elements, which can more comprehensively reflect the changes in external policies and market environments and providing a new knowledge base and decision support for enterprises. Secondly, public data elements have dual attributes of public goods and information. The public goods attribute of public data elements can alleviate the data acquisition dilemma for enterprises, allowing them to obtain data resources without charge. At the same time, public data resources with public goods attributes are “small data” that is of support to corporate decision-making [2]. Furthermore, the non-rivalrous nature of public data also allows it to be combined with other production factors, thereby overcoming the "tragedy of the commons" in the use of resource-based public goods. Thirdly, public data elements possess a wealth of application scenarios and can be extensively utilized across various facets of enterprise production, operations, and sales services. This enables the realization of "invisible" circulation and the creation of value through the circulation process. Fourth, public data elements have synergistic effects with other factors of production. Public data elements can be integrated into the production process to achieve adaptive adjustment of production allocation ratio, improve the synergy between factors by connecting other kind of factors such as labor and capital, and finally realize the optimal combination of production factors, and drive the high-quality development of enterprises by factor allocation effects [3].

3.2 Open public data can reshape business productivity dynamics

From the perspective of production kinetic energy, innovation is an important foundation for the new and old transformation of enterprise production kinetic energy. Under the new techno-economic paradigm shaped by opening public data, public data elements can reshape the production function of enterprises and promote the formation and evolution of new production dynamics with digital innovation. Specifically, the essence of public data is still data, which not only has the substitution effect on traditional factors of production such as capital, labor and land, but also has the optimization effect on traditional factors of production. Through the platform of public data, public data elements can enter the production function of enterprises, which helps to realize the new combination of various factors in the production function and realize the "creative destruction" to the original equilibrium system [4], thus promoting the overall leap and upgrade of the enterprise's production kinetic energy and drive the enterprise's high-quality development with the innovation of production kinetic energy. The hypothesis of technological progress points out that once the factor endowment is upgraded, the pressure of profit and market competition will make enterprises spontaneously carry out technological development and product service upgrading, and the technological progress will favor the production factors with better efficiency, the allocation of factors will be tilted to the high-efficiency production factors. As efficient factors, the public data will promote the original factor allocation structure upgrade, so that enterprise development can match the direction of technological progress and market demand better, because the policy information and the immediacy of market information which the public data contains can strengthen the insight and prediction ability of enterprises, coupled with profit and competitive pressure, enterprises will improve the existing products, services and user experience proactively. This provides a broad economic space and innovation space for enterprises to carry out production innovation for the digital economy, forming multiple innovation modes such as product innovation, technological innovation and business model innovation driven by public data elements.

On the other hand, Schumpeter's innovation theory explains economic development in terms of "innovation" and "new combinations" and believes that enterprise innovation is essentially a recombination of production factors [5]. Public data can enter the enterprise production function as a production factor, providing a forward-looking research boundary and scientific research tools for enterprise innovation [6]. High-value density of public data enables enterprises to use data productivity as a driving force, which promotes the transformation of enterprise production and operation modes, leads to an all-round transformation and resource allocation, updates business models and expands enterprise value creation paths [7]. These transformations are the changes in the composition and structure of the elements in the existing production function, that is, the process of "new combinations" derived from the enterprise industry model, business form, management process and value creation, which is also the innovation process of the enterprise's production kinetic energy. For example, after the Guangdong Provincial has launched the Public Data Open Platform, China Electronic Information Group and the Guangdong Provincial Government jointly explored a new model of open public data utilization and formed the Digital Guangdong Company, further expanding the digital business landscape.

3.3 Public data openness helps businesses save the transaction costs

Based on the theory of transaction costs, the high-quality development of enterprises can be regarded as the process of maximizing benefits by minimizing costs, and the opening public data has a significant effect on reducing the transaction costs of enterprises. Specifically, enterprises are bound to face friction with the public system and market players in the process of production and operation, thus generating various types of transaction costs, which are the key factors affecting the expansion of enterprise boundaries. Among them, the cost of friction with the public system is mainly caused by the complicated administrative approval, biased judicial protection, non-market resource allocation and other institutional barriers to transaction costs; the friction with market players is reflected in the information asymmetry triggered by the limited rationality of the management-type transaction costs, the object of the transaction opportunism and the market environment caused by uncertainty of market-type transaction costs. All kinds of transaction costs will inevitably crowd the limited production resources of enterprises, which make an adverse effect on the high-quality development of enterprises.

At the same time, the opening of public data yields several cost-saving benefits by reducing transaction costs associated with the friction between enterprises, the public system, and market participants. From the perspective of institutional transaction costs arising from the friction between enterprises and the public system, the openness of public data can enhance government administrative functions and improve the public service system. This helps to mitigate the institutional transaction costs encountered by enterprises. Theoretically, institutional transaction costs represent a manifestation of market failure arising from the interplay between human factors and the transactional environment. The establishment of a robust institutional framework can significantly mitigate these transaction costs, thereby playing a crucial role in fostering the high-quality development of enterprises. Public data encompasses the resources generated, collected, and acquired by government departments in the execution of their public management and service functions. This data serves as a comprehensive reflection of the actual information pertaining to public policy. On the one hand, by collecting and identifying public data, enterprises and other market participants can more effectively oversee the mechanisms of government decision-making, implementation processes, and outcomes. This enhances public accountability through increased supervision and participation, compelling local governments to improve transparency in governance [8]. Such improvements are conducive to optimizing the institutional environment, facilitating smooth market operations, and enhancing resource allocation efficiency. On the other hand, feedback from enterprises and other market actors regarding the utilization of public data fosters a two-way interaction model of governance. This reciprocal relationship not only improves endogenous governance efficiency but also promotes innovation in collaborative governance models at the governmental level. Consequently, this leads to advancements in public policies such as enhancements to government service systems and administrative reforms while simultaneously reducing systemic transaction costs for enterprises [9].

From the perspective of friction between enterprises and market participants, the openness of public data can enhance the efficiency of information collection and matching for businesses. This improvement creates opportunities and conditions conducive to reducing both market-based and management-related transaction costs. In the era of data-driven factors, the information asymmetry inherent in the modern market system can result in a deficit of decision-making information resources. Furthermore, the imperfections within the data factor market may lead to inefficiencies in the circulation of data resources, exacerbating the challenges of information asymmetry that enterprises face. This situation complicates efforts for businesses to effectively identify customers, explore potential market demands, and enhance management oversight. Public data openness facilitates the efficient circulation and real-time sharing of enterprise information resources. This approach enhances the efficiency of information collaboration and integration, thereby effectively reducing performance costs, negotiation expenses, and management expenditures. Specifically: Firstly, enterprises can analyze a diverse range of real-time customer credit data, as well as industrial and commercial administrative penalties and other publicly available information. This approach enables them to effectively mitigate the opportunistic behaviors of trading partners and avoid performance costs associated with incomplete information and uncertain risks [10]; secondly, Enterprises can extract information regarding their locations from public data resources, thereby gaining insights into consumer preferences, as well as trends in enterprise innovation and sales. This practice enhances the efficiency with which enterprises assess market demand while simultaneously reducing costs associated with commercial operations and business management. By improving the efficiency of market demand assessments, organizations can mitigate uncertainty and address incomplete information during business negotiations. Furthermore, this approach minimizes both the informational and temporal costs incurred by both parties involved in fulfillment processes [11]; thirdly, public data openness can enhance the intensity of stakeholder supervision over enterprises and assist them in reducing management costs. Capitalists and regulators can leverage open public data to gain insights into both the status of individual companies and broader industry dynamics, as well as factors that may influence a company's performance [12]. By juxtaposing this information with that disclosed by the company, external investors and regulators will be better positioned to assess the company's operational conditions more accurately. Moreover, such transparency facilitates the exposure of opportunistic behaviors exhibited by managers, thereby effectively mitigating risks associated with managerial opportunism stemming from principal-agent problems. This process ultimately fosters a mechanism for cost savings within enterprise governance structures.

3.4 Public Data Openness Boosts Enterprise Knowledge Boundary Expansion

Based on knowledge base theory, knowledge serves as a fundamental source of sustainable competitive advantage and is crucial for enterprises aiming to achieve high-quality development. Furthermore, the availability of open public data presents a novel paradigm and mechanism that enables enterprises to absorb, integrate, and innovate knowledge effectively [13]. This openness, characterized by generativity and integration through digital technologies, creates a new digital environment that facilitates enterprise knowledge search, knowledge acquisition, and knowledge integration. In this context, the openness of public data enhances data availability, thereby enabling enterprises to integrate diverse sources and types of data. This integration allows for the combination of public and private datasets, facilitating mutual verification among various data forms. Enterprises can also transcend the limitations associated with intra-enterprise and inter-enterprise knowledge acquisition, learning, integration, and innovation. By reshaping their channels for knowledge acquisition and learning, they can facilitate the generation of new information and knowledge. The openness of public data can enhance the absorption, creation, and dissemination of knowledge, thereby fostering organizational innovation. The integration of public data into production factors such as labor and capital facilitates a synergistic effect among these data-driven elements. This integration enables the optimal allocation of innovative resources—including data, capital, and talent—and stimulates new collaborative efforts among enterprises and even across entire industries. The knowledge overflow generated by cooperative innovation is rapidly disseminated along the industrial chain to both upstream and downstream dependent enterprises. This process fosters an open interaction mechanism for innovative outcomes, thereby facilitating the development of new products, services, and business models. For instance, public environmental data can be utilized in the research, development, and production of solar environmental protection battery modules. Additionally, demographic data may serve as a basis for assessing technological advancements and the feasibility of technological transformation, among other applications.

4. Conclusions

This paper examines the fundamental logic behind how the openness of public data facilitates the high-quality development of enterprises from a macro perspective. The findings indicates that such openness can enhance high-quality enterprise development by reshaping production factors, driving transformations in production dynamics, assisting enterprises in reducing transaction costs, and expanding the boundaries of knowledge innovation within enterprises. These insights hold significant implications for investigating the influence of data elements on the high-quality development of micro-enterprises. Future research should incorporate econometric methods to provide further empirical evidence supporting the theoretical analysis presented herein.

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Research on the Application of UAV Intelligent Patrol Inspection Technology in Photovoltaic Construction Management

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Abstract. In order to improve the quality of patrol inspection results for photovoltaic construction projects and realize intelligent management of safe production in photovoltaic construction, technologies such as the Internet of Things, artificial intelligence, machine learning, and GIS are employed to study unmanned aerial vehicle (UAV) intelligent patrol inspection technology suitable for photovoltaic construction management, and to realize the automation, digitalization, and intelligent management of photovoltaic construction project patrol inspection. Through the construction of UAV intelligent power station in suitable location of photovoltaic field, it realizes automatic take-off and landing, autonomous charging and switching of power; the UAV flies regularly according to the patrol inspection cycle and route tasks, automatically collects data and returns it to the photovoltaic intelligent patrol inspection platform, which intelligently identifies and statistically analyzes the patrol inspection data and visualizes the defects and hidden dangers, the project situation and the progress of the project information on the platform. This technology can not only be applied to the patrol inspection of photovoltaic construction projects, but also provide technical support for wind power construction patrol inspection, desert environmental monitoring and other fields.

Keywords. Unmanned aerial vehicle (UAV); UAV intelligent power station; patrol inspection; photovoltaic intelligent patrol inspection platform

1. Introduction

Safety patrol inspections in photovoltaic project construction management are characterized by comprehensiveness, timeliness, and intuitiveness, which cannot be replaced by fixed-point monitoring instruments and their automated systems. According to statistics, more than half of the major safety hazards in photovoltaic construction are identified and addressed in advance through patrol inspection work. Therefore, in the process of photovoltaic construction management, patrol inspection is an important on-site management method [1].

In traditional photovoltaic construction management patrol inspections, a model of manual patrol inspections combined with written records and photographs is usually adopted. This patrol inspection method has certain delays, making it difficult to analyze, compare, and identify issues in the patrol inspection results, and it is even harder to fully

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present the occurrence and development of on-site defects and safety hazards. Additionally, the effectiveness of patrol inspections relies on the attitude, experience, and technical level of the staff, resulting in a lack of standardization, systematization, and completeness in the patrol inspection results. The construction area of photovoltaic projects is large, with dispersed work sites and tight schedules, making patrol inspection work not only require a significant investment of human and material resources, which increases patrol inspection costs, but also face low patrol inspection efficiency and high risks due to open construction sites and complex working conditions, posing threats to the personal safety of staff and failing to meet modern safety production management requirements. Therefore, there is a need to develop and introduce high-tech patrol inspection methods and a management mechanism for analyzing patrol inspection results and early warning [2].

As drone technology matures, various industries have begun to use drones for large-scale patrol inspection work due to their characteristics of maneuverability, safety, speed, timely information feedback, and high work efficiency. Drones have undoubtedly become the best tool for patrol inspection personnel to efficiently and safely complete patrol inspection tasks [3, 4]. However, in the actual application of drone patrol inspections, it is necessary for the operator to manually control the drone to reach the site and perform patrol inspection tasks, and the operator's skill level directly determines whether the patrol inspection quality meets standards, with work efficiency, quality, and frequency all needing improvement [5].

With the rapid development of artificial intelligence technology, the application of drones is becoming increasingly automated, intelligent, and unmanned. In recent years, advancements in drones and related technologies have provided smarter and more efficient solutions for application scenarios such as power grid patrol inspections, traffic patrols, and water conservancy patrol inspections. This not only reduces the need for specialized operators but also digitizes and standardizes all operational processes, effectively improving the operational efficiency and quality of industry drones, achieving flight automation, on-site automation, and identification and diagnosis automation [6, 7].

This article will explore the application of intelligent drone patrol inspections in photovoltaic construction management, aiming to achieve automation and intelligence in photovoltaic construction patrol inspections. By redeveloping and introducing drones to replace manual operations, a new type of UAV intelligent patrol inspection technology suitable for photovoltaic construction management will be established. This technology will enable scheduled patrol inspections without human control, intelligent data analysis and storage, and automatic generation of patrol inspection reports, thereby realizing the intelligence of patrol inspections in photovoltaic construction management, improving management efficiency, reducing safety risks, and comprehensively enhancing the level of intelligence in photovoltaic construction management [8].

2. UAV intelligent patrol inspection technology

UAV intelligent patrol inspection technology is a method that utilizes drones for efficient and automated patrol inspection and monitoring of target objects or areas. By selecting drones suitable for large-scale patrol inspections in photovoltaic fields, constructing intelligent drone stations in appropriate areas for key patrol inspections based on the actual conditions of the photovoltaic fields, developing a photovoltaic intelligent patrol inspection platform suitable for photovoltaic construction management. This includes research on defect identification, real-time hazard warning, positioning, and tracking technologies in photovoltaic fields, establishing a complete intelligent patrol inspection system for drone management in photovoltaic construction. Drones can collect data in real-time and transmit it back to the platform control center, providing convenient solutions for photovoltaic construction management after processing and analysis [9, 10].

The implementation of UAV intelligent patrol inspection technology relies on three key aspects: selecting the appropriate UAV, building UAV intelligent power station, and developing corresponding intelligent platform to achieve intelligent, digital, and networked management of patrol inspection tasks, so that the UAV can autonomously complete the patrol inspection task without human intervention, improve the patrol inspection efficiency and accuracy, and comprehensively enhance the level of PV construction management.

The overall architecture of the UAV intelligent patrol inspection technology is shown in Figure 1, consisting of three main components: drone, UAV intelligent power station, and photovoltaic intelligent patrol inspection platform. Drone data collection is the cornerstone of the entire patrol inspection technology, providing data support for the photovoltaic intelligent patrol inspection platform; the UAV intelligent power station is the basic guarantee for the entire patrol inspection technology, enabling flight planning and control for the drones; the photovoltaic intelligent patrol inspection platform integrates, identifies, analyzes, and displays high-precision oblique photography models with drone patrol inspection data, achieving functions such as visualization of patrol inspection results, patrol route planning, defect identification, and hazard warning, fully leveraging the advantages of drone patrol inspections.

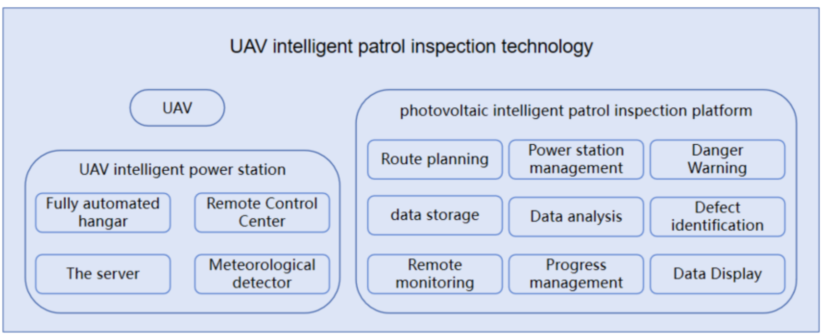

Figure 1. Overall architecture of UAV intelligent patrol inspection technology.

2.1. Drone

The selection of drones must consider various indicators required for the patrol inspection of photovoltaic fields, such as positioning accuracy, hovering height, maximum horizontal flight speed, endurance time, and image quality, as well as the limitations imposed by the natural environmental conditions of the project site, such as the maximum flight altitude of the drone, maximum wind speed it can withstand, and working environment temperature. The drone configuration is primarily chosen based on the patrol inspection content and requirements of the photovoltaic construction site, exploring the advantages and disadvantages of different drones in terms of shooting accuracy, positioning accuracy, real-time data transmission, and intelligent control, as well as the adaptability of different configurations for various types of on-site data collection, and then selecting the best UAV and its configuration according to the actual situation of the type of PV construction project [11, 12].

This study selected the DJI Phantom 4 RTK, a small multi-rotor high-precision aerial survey drone designed specifically for low-altitude photogrammetry applications. It is equipped with a high-definition aerial survey camera featuring a 1-inch CMOS sensor, capable of outputting 20 million pixel high-definition images. The DJI Phantom 4 RTK integrates a centimeter-level precision RTK GNSS positioning system, including multiple satellite systems such as GPS, BeiDou, GLONASS, and Galileo, ensuring high-precision positioning in various environments. It uses a global mechanical shutter exposure mode, effectively reducing the jelly effect caused by high-speed motion, ensuring clear and stable images. It is equipped with an intelligent flight control system that supports various intelligent flight modes and obstacle avoidance functions, as well as advanced flight features like automatic return and point hovering, enhancing flight safety and convenience. The real-time image transmission system based on OcuSync technology can achieve 1080P/720P high-definition transmission within a range of 7 kilometers, ensuring real-time monitoring and data transmission during flight, while also supporting internet connectivity for remote control. With the addition of an intelligent power station, the DJI Phantom 4 RTK's strong endurance capability makes it particularly suitable for long-duration, large-area patrol inspection tasks.

2.2. UAV intelligent power station

The UAV intelligent power station is the ground infrastructure for achieving automated drone flight and is an important component for enabling functions such as automatic takeoff and landing, storage, automatic charging/replacement, remote communication, data storage, and intelligent analysis. It includes key equipment and facilities such as fully automated hangars, remote control centers, servers, and meteorological detection instruments [13, 14].

The fully automated hangar is deployed in the photovoltaic construction area based on the actual project situation, capable of automatic drone takeoff, high-precision visual automatic landing, automatic battery replacement, and supporting high-frequency operations, allowing for a re-launch within three minutes. However, its operation relies on a strong power and communication support system. Therefore, when constructing UAV intelligent power station, it is essential to fully consider patrol inspection requirements, emergency patrol inspection tasks, and plan the patrol inspection radius for each intelligent power station based on drone flight duration, dividing patrol inspection areas. Additionally, the power and network demands of the intelligent power station should be taken into account, selecting locations that are elevated, with convenient power supply, communication, and transportation, minimal airspace interference, and proximity to major patrol inspection areas while avoiding villages, roads, and civil aviation routes, to reasonably position the intelligent power stations.

The remote-control center is a management platform for intelligent power stations and drones, capable of remote control, task planning, and real-time status monitoring of intelligent power stations and UAVs. The control center communicates directly with the drones and intelligent power stations, sending and receiving commands and transmitting data through a server, allowing users to monitor the status and flight conditions of the drones at any time via the patrol inspection platform's display screen.

The meteorological detection instrument monitors and collects environmental parameters in real-time, providing data support for the patrol inspection platform to assess whether the current weather conditions are suitable for drone operations, ensuring the safety of the drone and its surrounding environment. At the same time, the data provided by the meteorological detection instrument can help the drone calculate the optimal flight path, offering more precise navigation assistance.

2.3. Photovoltaic Intelligent Patrol Inspections Platform

According to the characteristics of photovoltaic construction site and the distribution of intelligent power station, the use of GIS technology and computer 3D graphics engine technology to achieve the visualization of patrol inspection results program, the development of B / S architecture of intelligent patrol inspection information platform for patrol inspection data management, real-time display of the construction site of the various regions of the situation, and comprehensively enhance the level of intelligent management of photovoltaic construction management. The UAV intelligent patrol inspection information platform development architecture is sequentially divided into four layers: hardware layer, data layer, service layer, and application layer [15, 16].

The hardware layer includes drones, PC servers that support the operation of various systems, and UAV intelligent power stations, providing the foundational support for the entire platform's operation. The data layer is responsible for collecting data gathered during drone patrol inspections, mainly including aerial images, videos, and meteorological data collected by weather sensors; it also includes analysis result data and document data from the platform's AI recognition. The service layer offers various functions, such as the platform's alert service, which can automatically determine whether to issue a warning and send notifications, scheduled data collection services, and data AI recognition and analysis services that ensure real-time data updates and processing. The platform's automatic training of recognition models continuously improves recognition accuracy, while services like automatic log report generation facilitate operations and maintenance. The application layer integrates this data and services into a visual scene, displaying project patrol inspection information, allowing users to query patrol inspection results based on different criteria, monitoring construction progress, and initiating emergency command work in case of emergencies, thus forming a comprehensive and efficient intelligent patrol inspection system.

3. Engineering Applications

Two UAV intelligent power stations are constructed in a photovoltaic construction project in Yunnan, and the patrol inspections cover two types of typical projects, namely, photovoltaic construction site and booster station area. The photovoltaic intelligent patrol inspection platform is established to realize the integration, analysis and display of patrol inspection data, including the functions of route planning and setting, defect identification, danger warning and visualization display, intelligent power station and patrol inspection data management, and progress management, etc. The following is a detailed introduction of the UAV intelligent patrol inspection technology function board based on this project. The following is a detailed introduction of the UAV intelligent patrol inspection technology function boards and applications based on the project.

3.1. Route planning

Normally, it is inconvenient to carry out route planning through the UAV control center to a certain extent. Therefore, the route planning function is developed in the intelligent patrol inspection platform of UAV intelligent patrol inspection technology, so that the staff can access the platform at any time and place through any client to carry out the route planning operation. Route planning is divided into fast route planning and refined route planning, which can be adjusted and selected according to actual needs.

3.2. Defect identification

Based on the UAV patrol inspection data, a defect database is established to achieve standardized classification and archival management of defects, which requires processing, identification, marking and coding of the original database. The platform has developed a variety of defect recognition algorithms, including image processing, pattern recognition and deep learning technology. After the patrol inspection data is entered into the database, the platform uses machine vision to enhance the digital image, denoising, image segmentation, edge detection and other processing, and adopts machine learning algorithms based on supervised learning to identify defects in the image, thus solving the problem of defect classification and defect marking. The application of defect identification functions can significantly improve the efficiency and accuracy of patrol inspections, reducing the possibility of manual intervention and misjudgment.

3.3. Danger Warning

During the patrol inspection process, the photovoltaic intelligent patrol inspection platform can monitor the safety status of the photovoltaic field in real-time, including the operating status of equipment and environmental changes. Once abnormal conditions are detected, the platform will immediately issue an alarm. By combining historical data and on-site monitoring data, the platform can use various algorithms for comprehensive analysis, predicting potential risks and failure points, and timely issuing early warning information to management personnel along with corresponding handling suggestions, helping to take measures in advance to prevent accidents. In addition, this function can help managers optimize patrol inspection plans and resource allocation, enhancing overall construction management efficiency.

3.4. Visualization Display

The platform's 3D visualization function is a spatial information carrier supported by a 3D graphic database. It not only features 3D map browsing, layer management, and map attribute querying, but also integrates various data sources, including real-time information monitoring, equipment information querying, patrol inspection data querying, and defect dynamic analysis applications. This enhances the value of data utilization, provides visual decision support for the safe production of photovoltaic fields, and improves project management efficiency and management levels.

3.5. Platform Information Management

The photovoltaic intelligent patrol inspection platform integrates various types of information from the entire technical system, including device information such as the status of the intelligent power station and the flight status of the drone, as well as data information such as patrol inspection results and defect conditions, achieving standardized storage, unified management, and quick querying of information.

Information management for UAV intelligent power stations. It connects and displays the operational status data of intelligent power station equipment, monitors the status information of devices in real-time, and includes observational data from external meteorological sensors, providing safety assurance for drone work tasks.

UAV flight status management. It can view the flight profile information of the UAV performing the mission, including altitude, duration, and electric power, etc. Meanwhile, it can view the flight path of the UAV in real time, as well as the aerial images. Support early warning and disposal of abnormal status.

Patrol inspection information management. Centralized management of completed historical task information and patrol inspection data, supporting classified retrieval of information, and allowing further viewing and exporting of statistical analysis results.

3.6. Progress Management

In photovoltaic construction projects, progress management is key to ensuring timely completion. Progress management based on UAV intelligent patrol inspection technology can achieve comprehensive, efficient, and precise management of photovoltaic construction projects through the integrated application of functions such as real-time monitoring of construction progress, automatic generation of progress reports, and optimization of construction plans and resource allocation, thereby improving construction quality and safety while reducing operation and maintenance costs and risks.

4. Conclusion

This article comprehensively discusses the application of UAV intelligent patrol inspection technology in photovoltaic construction management, aiming to enhance patrol inspection efficiency and quality through technological innovation and management strategies.

The implementation of UAV intelligent patrol inspection technology relies on three key aspects: selecting suitable drones, building UAV intelligent power stations, and developing corresponding intelligent platforms. By using drones for efficient and automated patrol inspections and monitoring of photovoltaic fields, data is collected in real-time and sent back to the photovoltaic intelligent patrol inspection platform for analysis and processing, providing convenient solutions for photovoltaic construction management. Practical applications of the project indicate that the use of UAV intelligent patrol inspection technology in photovoltaic construction management has achieved unmanned, clustered, networked, and intelligent patrol inspections. The application of UAV intelligent patrol inspection technology in photovoltaic construction management has significant advantages and potential. In the future, with continuous technological advancements and deeper promotion of applications, UAV intelligent patrol inspection technology will play an increasingly important role in photovoltaic construction management.

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Smart Aging and the New Layout of the Elderly Industry

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Abstract. By utilizing technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI), smart aging not only addresses resource shortages and service quality disparities in elderly care but also drives the digital transformation and upgrading of the industry. This paper uses case analysis, interviews, and surveys to examine the current status and development trends in the smart aging industry. Policy support, funding, and tax incentives have provided essential safeguards for its stable growth. Smart aging has become a catalyst for social and economic development, fostering the growth of related enterprises and enhancing the efficiency of the industry value chain. We call on the government to continue providing policy support and guidance, encourage social participation and mutual assistance, and promote the sustainable development of the smart aging industry, ultimately establishing an ecosystem that seamlessly integrates technology with human-centered elderly care.

Keywords. Smart Aging, Digital Transformation, Innovative Aging Services, Elderly Care Industry

1. Introduction

By the end of 2023, China's elderly population aged 60 and above reached 297 million, or 21.1% of the total population, with 217 million aged 65 and above, accounting for 15.4% (See Figure 1 below). China now faces significant pressures from an aging society, impacting both the quality of life for the elderly and socio-economic stability. China's efforts to address these challenges, including promoting the silver economy and strengthening the old-age security system, provide valuable insights for the global community. These initiatives are progressively alleviating pressures on the elderly and offering Chinese solutions to aging issues faced by other developing nations.

The elderly care industry has become a key social issue in China, strongly supported by the government and integrated into the national strategy to address population aging. As a vital driver of economic and social progress, the industry's digital transformation is reshaping its structure and attracting significant attention. While domestic investment plays a central role, foreign capital is increasingly vital, reflecting China's economic openness and financial market development amid global aging trends. With growing demand for elderly care services, the pension finance sector

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has emerged as a crucial pillar of the system, drawing increased foreign interest. Advancements in digitalization and globalization are accelerating the development of intelligent elderly care, with foreign investment contributing to a more structured and sustainable industrial framework.

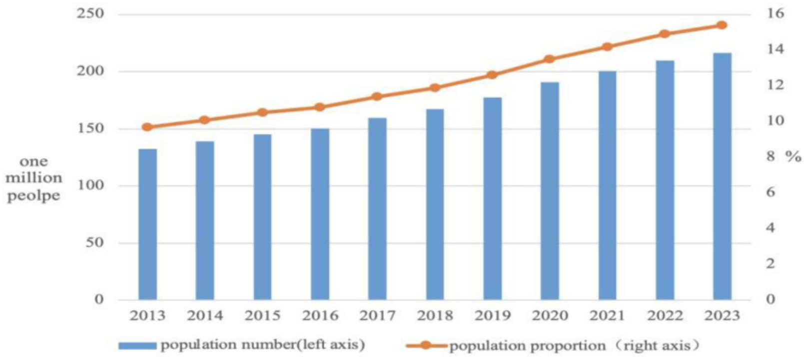

Fig.1 Elderly Population Aged 65 and Above: Numbers and Proportion (2013-2023)[2]

This paper focuses on the two most important aspects of the smart senior care industry, senior care services and senior care finance, and explores the impact of smart senior care on the new layout of the senior care industry from various aspects. Subsequently, it also puts forward corresponding policy recommendations, suggesting how to utilize smart aging to promote the development of China's aging service and aging finance business.

2. Related works

The academic discourse on digital elderly care highlights technology's transformative role in reshaping care practices, focusing on enabling technologies and evolving service models. Pu et al. (2024) highlighted the importance of technology suitability for aging populations and service collaboration in developing high-quality smart elderly care services. They emphasized that improving elderly life quality requires comprehensive policy reform and efficient resource allocation [1]. Yuan et al. (2024) identified risks in constructing smart elderly care systems, such as the value-driven technical approach and inadequate regulations. They recommended a multi-governance model to clarify responsibilities and strengthen policy support for industry development [2]. Huang et al. (2020) examined the role of policy tools in promoting industry growth, using the Policy Tools and Technology Pathways (P-TRM) model. They identified gaps between sector needs and current policies, offering strategic solutions [3]. Gao et al. (2020) analyzed the role of foreign investment in fostering an open framework and addressing elderly needs, emphasizing its importance in talent acquisition and government support to enhance China's smart elderly care industry [4].

Although many practical cases of smart old-age care have emerged all over the world, the core areas still need to be further explored. Our research is dedicated to an in-depth exploration of the diversified challenges faced by digital elderly care. After carefully analyzing the process of digital elderly care in China and conceiving a more

[2] The data is sourced from the National Bureau of Statistics. The data source for the following figure is the same.

practical plan on how foreign capital can enter China, we hope that digital elderly care can be more widely promoted in China and innovative measures can be implemented.

3. Digitizing the Senior Care Industry

3.1. Policy Package Released to Encourage Digital Senior Care Services

China's elderly population has surged during its period of modernization, with diverse groups—such as widows, orphans, the economically disadvantaged, and those with mobility issues—growing rapidly. This demographic shift, compounded by urbanization and challenges at the "three-phase" economic development stage, has intensified the aging issue, attracting widespread attention [5]. As the focus on intelligent elderly care grows, it is essential to evaluate the practical implementation of these systems, the evolution of related policies, and the challenges they face. Such assessments will provide insights to optimize policies, guide future aging initiatives, and strengthen China's elderly care system. Effective policy support is crucial for advancing the elderly care industry.

3.1.1 Policies to increase financial subsidies for digital pensions

The government reduces the operating costs of digital senior care service enterprises by setting up special funds and improves the financing efficiency of the digital senior care service industry by optimizing financial services. Capital investment is an important guarantee for the digital elderly service industry, and the investment of the government and social capital provides the necessary financial support for the digital elderly service industry and promotes the favorable development of the digital elderly service industry. Table 1 shows policies related to increasing financial subsidies for digital pensions.

Table 1. Policies related to increasing financial subsidies for digital pensions

Timing	Deal	Element
January 2024	Opinions of the General Office of the State Council on Developing the Economy to Promote the Well-being of Older Persons	Enhance fiscal and financial support. Use local government special bonds to fund eligible silver economy projects. Leverage special refinancing for inclusive elderly care and provide credit support.
December 2021	National Plan for the Development of the Aging Career and the Elderly Service System in the Fourteenth Five-Year Plan	Encourage financial institutions to develop savings, wealth management, insurance, trust, public fund-raising and other financial products for the elderly

3.1.2 Policies to encourage the application and innovation of digital ageing technology

Technology drives the development of digital elderly care services, with innovation being essential for progress. The government supports the application and innovation of new technologies in senior care. By leveraging intelligence, informatization, and other technologies, service efficiency and quality can be improved, while enhancing the smart capabilities of digital elderly care. Examples include smart wearables for monitoring health and providing personalized advice, and intelligent platforms offering online consultations and booking services for better access to healthcare. Table 2 outlines policies encouraging the application and innovation of digital aging technologies.

Table 2. Relevant policies to encourage the application and innovation of digital aging technology

Timing	Formulation	Element
2024	Shanghai Action Program for Promoting Innovation and Development of Elderly Science and Technology	To promote the deep integration of "science and technology" and "old age" as the main line, to strengthen the key technology research and development as the main direction, to accelerate the application of emerging technology inheritance and integration of innovation as the path.
December 2023	Programme of Work for the Promotion of Quality Development of Ageing with Digital Technology	Deepening the high-quality development of digital technology for ageing in the field of industry and information technology

3.1.3 Policies to encourage the development of digital aged care talents

Policies to strengthen the training and recruitment of elderly care professionals include encouraging universities and vocational colleges to offer specialized courses. Policies supporting employment and entrepreneurship in elderly care aim to attract talent through various channels and promote cross-industry mobility. Enterprises are encouraged to enhance staff training, while the influx of international talent has revitalized the sector. Table 3 outlines policies fostering the development of digital elderly care professionals.

Table 3. Relevant policies to encourage the development of digital elderly care talents

Timing	Deal	Element
January 2024	Opinions on Strengthening the Elderly Service Talent Workforce	It is explicitly proposed to break the limitations of academic qualifications, age, status and geography, so as to recruit talents and cultivate talents in practice.

The implementation of the policy package has led to significant progress in the digitization of elderly services. Enhanced digital infrastructure has supported service intellectualization, while new technologies have improved efficiency and quality. The government plans further policy reforms, including tax incentives, subsidies, cross-sector collaboration, and the refinement of laws and standards. These measures will elevate the intelligence and quality of senior care services. As the market expands, more diverse and personalized products will emerge to meet the varied needs of the elderly, driving the growth of the service industry chain [6].

3.2. The development status of the digitalized elderly care service industry

Intelligent senior care solutions, also known as smart senior care, leverage modern information and communication technology to integrate multiple service systems, aiming to provide innovative care services for the aging population. This model transcends traditional frameworks of home, community, and welfare institutions. Utilizing remote monitoring technology, it collects and analyzes data on the physiological conditions and behavioral patterns of the elderly, enabling meticulous management of elderly care. As a result, this approach significantly enhances the quality of life for older adults.

3.2.1 Main Features

Intelligent elderly care is defined by advanced intelligence, refined services, and increased efficiency, addressing the diverse needs of the elderly. First, its intelligence automates daily activities through network technology and electronic tools, enabling remote monitoring of health and location in real-time, ensuring safety. Second, it enhances service precision by using technologies like the Internet to create smart platforms that offer personalized care, transforming senior care into a more intelligent, precise, and diversified model. Lastly, it improves efficiency by facilitating rapid information exchange, networked management, and resource sharing, reshaping traditional care models through technological innovations and system upgrades.

3.2.2 Service model

Intelligent elderly care services encompass various models designed to provide comprehensive, round-the-clock care for seniors. The "service provider to service demander" (P to D) interaction model represents a bilateral active engagement, where the elderly care provider proactively shares relevant service information with the elderly care demander. Service providers must integrate, collect, and analyze data from the demand side in advance. For example, the 'Jingtong e' app, China's first comprehensive platform for seniors, allows users to access services via the government's website. Community organizations manage service selection, regulated by industry standards and public oversight, enabling seniors to use government subsidies for home care services.

3.2.3 Industry trend

As global aging intensifies, the digital transformation of the smart aging and senior care industry has become an irreversible trend. Governments, including China, have introduced policies to support its development, integrating smart aging into broader smart city initiatives and regulating market dynamics through relevant standards. With advancements in IoT, cloud computing, big data, and AI, the quality and efficiency of smart elderly care services will continue to improve. Future innovations will include more intelligent and user-friendly products and services to meet the growing needs of seniors. Additionally, smart aging will drive cross-sector integration, connecting industries such as healthcare, insurance, and real estate, fostering synergy across the industry chain and advancing senior care to new heights.

3.3. Main Models and problems of the Digital Senior Care Service Industry

As shown in Figure 2, from 2017 to 2019, the number of community service agencies in China steadily increased, alongside the development of intelligent, age-friendly residential areas in several cities. In these areas, not only did the number of community institutions rise, but digitalization also enhanced the intelligent care facilities, making them comparable to international "senior communities" with automated food, housing, and transportation services. For example, in 2016, Hubei province saw a surge in community service agencies, with Wuhan's Qiaoxi community introducing intelligent elderly care services. This initiative established a home-based care network utilizing technologies such as the Internet, mobile networks, and IoT, offering 6,863 elderly residents' access to services like laundry, cooking, repairs, hairdressing, and food delivery. While some cities have advanced in digitalization, the distribution of these services remains uneven across China, requiring continued efforts for comprehensive digital pension solutions. The following outlines the three main models of digital aging in China.

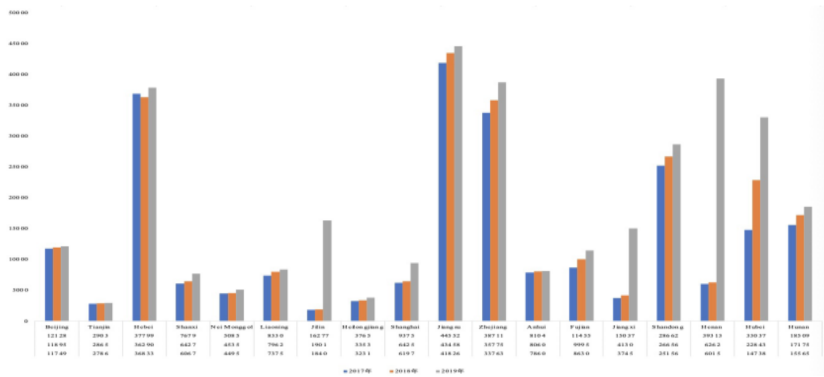

Fig.2 Number of community service agencies (2017-2019)

3.3.1 Main modalities

Digital home care primarily utilizes telemedicine, health consultations, mobile health monitoring, and smart home technology. Telemedicine and health consulting services enable the integration of elderly health management systems with community service centers and senior service stations, providing health monitoring, teleconsultation, and emergency response services. Through intelligent device apps, seniors can access convenient home health advice via integrated health data. Mobile health monitoring employs wearable devices, like smartwatches and bracelets, to track physiological data—such as heart rate, blood pressure, and blood sugar—in real time. These devices alert users to abnormal health readings and offer online medical consultations, allowing seniors to receive professional healthcare without leaving home. Smart home technology enhances security and convenience. Devices like smart refrigerators and smart lamps improve daily life, while security features such as smoke alarms and anti-theft sensors on doors and windows ensure a safe home environment for the elderly.

Digital institutional care includes intelligent travel and emotional accompaniment. One of the intelligent travels can be for the elderly in the nursing home to facilitate the mobility of the elderly to organize sunset red tourism, so that the elderly to participate in more cultural activities to carry out social exchanges.

3.3.2 Main Problems

The domestic intelligent aged-care industry is still in its infancy. China's current intelligent elderly industry has not yet established a large-scale operating system, high service costs, the industry's internal differences have increased significantly; the lack of effective and systematic methodology of operation and management, pension resources have not been fully utilized, the service system is extremely decentralized; smart elderly, although an emerging field, but has not yet built up a complete industrial chain, the lack of large-scale operation, sustainable development of the strength of the relatively weak. The strength of sustainable development is relatively weak.

China's smart elderly care system has several deficiencies. For example, as shown in Figure 3, the coverage rate of elderly care institutions varies significantly across the country, with cities like Beijing and Shanghai exceeding 100%, while some regions remain below 50%. Actively attracting foreign investment is a crucial initiative to address these disparities. Foreign-funded enterprises in the smart elderly care sector often possess advanced technology and extensive service experience, enabling them to offer more personalized and specialized services that meet the diverse needs of the elderly. By introducing foreign investment, China can drive technological innovation and product upgrades within its smart elderly industry, accelerating the establishment of a competitive industry chain and ecosystem. In conclusion, attracting foreign investment in China's smart elderly care sector is a strategic decision of considerable significance. By enhancing international cooperation and promoting joint development and innovation, we can provide higher-quality and more efficient services for the elderly, improving their well-being and quality of life in their later years.

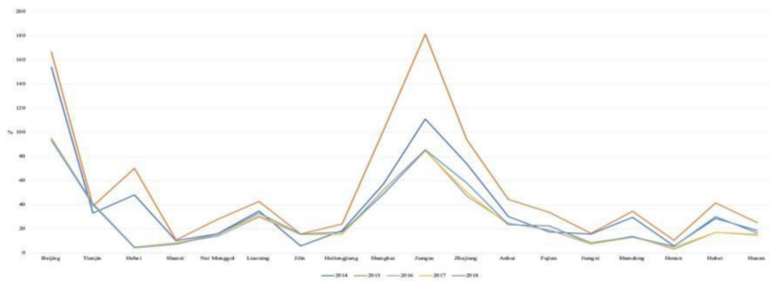

Fig.3 Coverage of community services (2014-2018)

4. Foreign investment into China's digital smart aging industry

4.1. New Policy Package to Boost Foreign Investment in China's Digital Aging Industry

4.1.1 Policies Encourage Foreign Investment in China's Smart Aging Industry

In recent years, China has a positive and open attitude towards foreign investment in the field of digitalized intelligent ageing, considering it an important way to enhance the level of China's ageing services and promote innovation in the industry. At the same time, the state also focuses on regulating and guiding foreign investors to ensure that they abide by Chinese laws and regulations, participate in market competition in an orderly manner, and jointly promote the healthy development of the smart elderly care industry.

4.1.2 Policies to encourage foreign investment in the pension finance industry

Since 2019, China's financial sector regulators have launched a series of heavyweight open-door policy initiatives, including the approval of a large number of major foreign-invested institutions' administrative licenses, involving the removal or relaxation of foreign-invested shareholding restrictions, the relaxation of access conditions for institutions and businesses, and the expansion of foreign-invested institutions' business scope. Table 4 summarizes the policy benefits related to encouraging foreign investment in the pension finance industry. Under the continuous release of policy dividends, China's diversified pension financial market has also been continuously energized by foreign financial institutions. Increased financial support can meet the large new demand for pension services and pension finance, bringing opportunities for foreign financial institutions and a greater supply of long-term capital to the capital market. The implementation of the personal pension system will also bring new opportunities for existing pension financial products, optimize the financial structure and promote the rapid development of the financial market.

Table 4. Key Policies to Encourage Foreign Investment in the Pension Finance Industry

Timing	Deal	Element
December 2021	Regulations on Insurance Asset Management Companies (Exposure Draft)	Clarify that there is no restriction on the maximum percentage of shares held by foreign-funded insurance companies in domestic insurance asset management companies, and that there is no differentiation between shareholders due to differences between domestic and foreign countries
December 2021	Circular on Clarification of Measures Concerning the Opening-up of the Insurance Intermediary Market to the Public	Substantial removal of entry restrictions and lowering of entry thresholds for foreign insurance brokers
March 2021	Decision on Amending the Implementing Rules of the Regulations on Foreign Insurance Companies	Clarify the admission criteria for foreign insurance group companies and offshore financial institutions to invest in foreign insurance companies
January 2020	Circular on Clarifying the Points of Eliminating the Restrictions on the Ratio of Foreign Investment in Joint Venture Life Insurance Companies	Formally abolished the restriction on the proportion of foreign investment in joint venture insurance companies operating life insurance business, and the proportion of foreign investment in joint venture life insurance companies can be up to 100%.
July 2019	Relevant Initiatives on Further Opening Up of the Financial Sector to the outside World	Released 11 measures to open up the financial sector to the outside world: for example, foreign investment access restrictions were lifted and foreign financial institutions were allowed to invest in domestic pension management companies.

4.2. Modes of Foreign Investment into China's Digital Smart Aging Industry

In recent years, China's senior care market has rapidly expanded, with a steady increase in the number of provincial elder care institutions. According to the "China Senior Care Industry Investment Analysis and Prospect Forecast Report," the number of nursing home beds reached new annual highs from 2016 to 2020. The senior care industry in China features an extended industrial chain and broad field coverage. Between 2016 and 2020, market consumption exceeded 10 trillion yuan, with an average annual growth rate of 17%. The elderly industry is projected to surpass 20 trillion yuan within the next two decades, attracting significant interest from foreign companies. In line with the ongoing promotion of China's open policy for the senior care sector, several regions have implemented policies to relax access conditions for the market and actively encourage investment from social capital. As a result, the number of pension institutions across various provinces has continued to soar since 2020. These initiatives have created a favorable environment for foreign investors, positioning China as a key player in the global strategic landscape for foreign organizations. Among the many foreign-funded senior care companies, the "French faction" represented by Gallize, Opéra and Domouvie Pension Group tends to adopt the asset-light cooperation model to enter the Chinese market.

4.3. Characteristics of foreign investment into China's digital smart aging industry

4.3.1 Late entry of foreign capital

Over the past decade, the U.S. senior care sector has rapidly advanced, driven largely by private investment and commercialized operations. Compared to the United States and Europe, China's digital smart elderly care industry has developed later and at a slower pace. Policy constraints have led to relatively delayed foreign investment in China's senior care sector. Currently, China is primarily in the phase of learning and adapting foreign capital practices within its senior care industry. With the vast scale of China's senior care market and recent supportive policies, foreign companies have a promising future in China's digital smart senior care sector. The rollout of new policies underscores China's commitment to developing its digital senior care industry, presenting a timely opportunity for foreign enterprises. By leveraging their advanced experience in other markets and innovating in alignment with China's senior care policies, foreign-funded firms can contribute significantly to China's senior care system, enriching it with diverse, high-quality smart care products.

4.3.2 Diverse forms of foreign investment

Since the State Council promulgated the Several Opinions in 2013, the utilization of foreign investment in the intelligent senior care service industry has accelerated significantly [7]. Between 2013 and 2024, the number of foreign companies involved in China's senior care services will continue to rise. Foreign investment in the senior care industry is not only characterized by the rapid growth in the number of enterprises, but also by the diversification of their investment patterns. In terms of the composition of invested enterprises, the proportion of Chinese-foreign cooperative enterprises and wholly foreign-owned enterprises in all invested enterprises exceeded the 60% threshold between 2013 and 2024, and the proportion of these two types of enterprises soared to a high of 90% between 2017 and 2019 in particular. In terms of the size classification of investment enterprises, enterprises with registered capital below 10 million yuan dominate the market, with their proportion maintained between 40% and 87%; while enterprises with registered capital between 5 million yuan and 10 million yuan show a decreasing trend year by year, although their share ranges from 6% to 40%; and those with registered capital of more than 50 million yuan take up a share of 10% to 20%. In summary, foreign investment in China's senior care industry is dominated by small and micro enterprises with registered capital of less than 50 million yuan.

4.4. Foreign investment to empower China's digitized smart aging industry

In assessing the impact of competition from foreign multinational corporations on China's elderly care industry, it is essential to differentiate between long-term effects and short-term fluctuations, while adhering to principles of anti-monopoly, competition promotion, and equal treatment of foreign investment. The "catfish effect" generated by the presence of foreign multinationals should be leveraged to enhance the operational efficiency and competitiveness of China's service industry. By adopting a long-term perspective with a tolerant, open, and inclusive mindset, China can encourage foreign multinationals to enter high-end sectors of the service industry [8]. This approach not only fosters talent development in China's digital smart aging industry but also suggests that implementing a "going out" strategy—strengthening exchanges and cooperation with foreign industry associations, higher education institutions, and research institutes—can promote innovation in China's service industry. Such collaboration can improve organizational models, operational mechanisms, and management practices, ultimately enhancing the operational efficiency and competitiveness of China's digital smart elderly care industry.

5. Conclusion

Considering China's aging population and the advancements in Internet technology, this paper examines the current state and practice models of digital smart elderly care and analyzes the impact of China's policies on foreign investment in this sector. The findings indicate that digital elderly care effectively addresses the challenges of population aging and enhances the quality of life for the elderly. China can leverage its national conditions to draw on effective foreign concepts and experiences, optimizing the smart elderly service model in a comprehensive and multi-dimensional manner while empowering the future of elderly services with innovative technologies. Strengthening policy support, innovating technology platforms, and enhancing talent training are crucial for promoting the sustainable and healthy development of smart elderly services.

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Problems and Countermeasures of Smart Home Care

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Abstract: Population aging, a sign of societal progress, presents challenges to traditional pension models, highlighting the need for a smart home care service system that is efficient, intelligent, and humanized. This paper explores the theoretical and technological aspects, practical models, and socioeconomic impacts of such a system, aiming to provide guidance for developing a more intelligent and sustainable aging society. Case studies reveal the dynamic nature of smart home care and the challenges of the digital age, such as infrastructure gaps, service uniformity, functional boundaries, and the digital divide. The paper calls for strategies that balance care with equity and justice, proposing a comprehensive approach with government, market, technology, and legal support to create an inclusive smart home care ecosystem, ensuring fair access to technological benefits for all.

Keywords. Intelligence; Smart Home Care; Aging

1. Introduction

As society evolves and the issue of an aging population intensifies, the implementation of smart home care solutions has emerged as a vital strategy for managing elderly care concerns. At present, China adopts the old-age care model based on family, relying on community, fully developed institutions and organic combination of medical and nursing care. With the rapid progress of science and technology, smart home care integrates advanced information technology with traditional care services, aiming to provide a more convenient, comfortable and safe care living environment for the elderly. At present, smart bracelets, sphygmomanometer and other equipment on the market can accurately measure heart rate, blood pressure and other data, with an error rate of less than 5%. At a few in the pilot project, intelligent health monitoring equipment is equipped for the elderly. Through big data analysis, it can be found and processed in time.

The construction of the intelligent home-based elderly care service system holds great significance in research. Firstly, the support of artificial intelligence technology will effectively break through the “bottlenecks” of community-based elderly care services in China and solve the “pain points” of community-based elderly care services [1]. Secondly, it is not only an urgent need to cope with the challenges of aging but also

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a key to promoting the development of the intelligent elderly care industry. Finally, the construction and application of intelligent home-based elderly care services reflect the deep integration of technology and humanistic care. On the one hand, it relies on advanced technology and intelligent hardware equipment and is a product of scientific and technological progress. On the other hand, its core is to meet the personalized needs of the elderly and reflect respect and care for them.

Based on the intersection of global aging trends and cutting-edge technologies, this paper adopts research methods such as comparative study, case study, and data analysis to systematically analyze the theoretical framework, key technologies, practice models, and wide-ranging socio-economic impacts of the construction of a smart home care service system.

The innovations of this paper are as follows: First, by comparing China's smart home care services with international practices, it provides a broader perspective to understand and evaluate China's development in this field. Second, this study incorporates specific case studies, such as Taikang Home and Furong South Road Community in Changsha, to validate the practicality and effectiveness of the theoretical framework. Third, this study pays attention to the innovation of technology application and service model and emphasizes the application of technology while paying special attention to how to advance technology while maintaining humanistic care and realizing the harmonious coexistence of technology and humanity. And based on this, a series of policy recommendations and practical guidance are proposed, aiming to provide theoretical guidance and practical references for building a more intelligent, inclusive and sustainable aging society.

2. Related Works

In the realm of scholarly discourse surrounding smart home care, a rich tapestry of insights has emerged that underscores the transformative potential of technology in enhancing eldercare practices. Tun et al. (2021) illuminated the pivotal role played by Internet of Things (IoT) technologies within the framework of home-based caregiving [2]. Their work underscored the significance of real-time monitoring capabilities coupled with robust data analytics as critical components in augmenting the efficacy and responsiveness of care delivery mechanisms. Concurrently, Moraitou et al. (2017) cast light upon the synergistic effects achieved when smart home care integrates seamlessly with local community resources [3]. By leveraging communal support networks, smart home care solutions can tailor their offerings to address diverse needs, thereby enriching the overall caregiving experience. Wilson et al. (2015) ventured into the intricate terrain of policy frameworks governing smart home care, identifying key hurdles and recommending strategic pathways toward overcoming them [4]. Furthermore, Stojkoska et al. (2017) revealed that user receptiveness and system intuitiveness stand at the crux of widespread adoption [5].

Despite the vast knowledge accumulated, critical areas like leveraging technology while enhancing data security and privacy remain understudied. As smart home care advances, it's crucial to balance innovation with caution, ensuring personal information's inviolability to maintain trust.

3. Analysis of the development status of smart home care

For nearly half a century, China has created the miracle of rapid economic progress and leapfrog development in human history, but this also led to the real problem of disconnection between rapid economic development and our country's system and social culture, the accelerated aging stage and its different demand for the quantity and quality of pension services [6].

Figure 1 shows the number of elderly people aged 65 and above and their proportion to the total population from 2012 to 2022 in China. In 2021, the population aged 65 and above accounted for more than 14% and began to enter a deeply aging society. By the end of 2022, the national population of 60 years old and above was 28.04 million, accounting for 19.8% of the total population; the national population of 65 years old and above was 20.978 million, accounting for 14.9% of the total population. Around in 2030, nearly half of China's total population of 800 million will be the elderly.

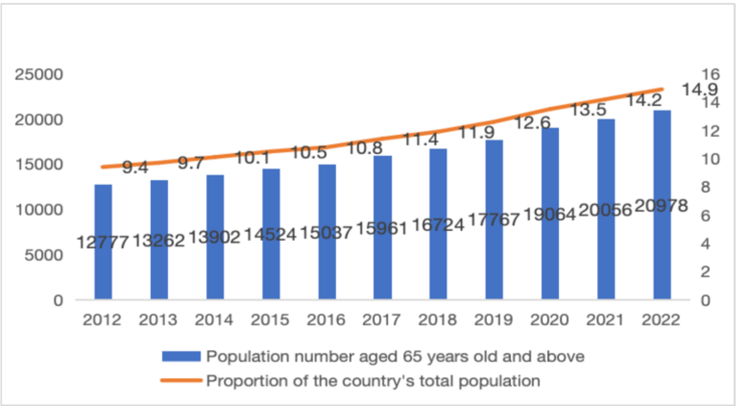

Fig.1 The number of elderly people aged 65 and above and the proportion of the total population in China (from 2012 to 2022)[2]

In general, the rapid aging of China's population structure has directly led to social challenges such as insufficient labor supply and the increasing burden of family pension. This is also the problem facing every country with an aging population [7]. Traditional elderly care service model, especially institutional elderly care, faces problems such as limited resources, insufficient service supply and uneven service quality, which makes it difficult to meet the needs of the huge elderly population.

Against this background, the construction of a smart home elderly service system is particularly important. Smart home-based elderly care, as an innovative model that integrates modern science and technology with traditional elderly care concepts, is gradually emerging and becoming a powerful tool to meet the challenges of elderly care. It not only uses cutting-edge technologies such as the IoT, big data and artificial intelligence to create a safe and comfortable home environment for the elderly, but also reflects the core values of science and technology serving mankind and promoting the harmonious development of society.

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[2] Data Source: The National Bureau of Statistics

4. Relevant cases analysis of smart home care

4.1 Case introduction

4.1.1 Taikang Insurance Group

Taikang Insurance Group's Taikang Home Project provides residents with a full range of living services and health management through intelligent equipment such as Xiaotai smart speakers, stir-fry robots, emergency positioning alarm cards and smart mattresses. At the same time, through the "Taile Smart Elderly Cloud Platform", it integrates community resources and provides one-stop elderly service solutions. Taikang Home·Chuyuan and Taikang Home (Yanyuan), as successful cases, provide high-quality elderly care services in Central China and Beijing respectively, paying special attention to cognitive-friendly and the quality of life of the elderly, and have been rated as "five-level elderly care institutions in Hubei Province".

4.1.2 Furong South Road Community, Tianxin District, Changsha City

Ning (2017) found through data surveys that the overall daily life ability of the elderly in Changsha is relatively good, and the intelligent care old services have certain needs. This project provides one-stop services such as meal assistance, consultation, bathing assistance, etc. for the community's elders through AI intelligent terminals, creating a "15-minute community home Elderly Life Circle", a project based on AI intelligent terminals, quickly place orders through intelligent terminals, and the service will be delivered to the household within 15 minutes, which is simple, convenient and efficient [8].

4.1.3 China Telecommunication Jiangsu Nanjing Branch

China Telecommunication Jiangsu Nanjing Branch uses 5G, the IoT, cloud computing and other technologies to develop a smart elderly digital platform, collect the life data of the elderly in real time through the intelligent IoT function, and provide accurate danger alarm services. Zhao et al. (2021) pointed out that through the deep integration of artificial intelligence, the Internet, the IoT, cloud computing and other technologies and intelligent devices in the field of elderly care services, it caters to the new requirements of the development of the times [9]. Through the IoT and remote intelligent security monitoring technology, it installs intelligent bracelets, networked smoke alarms and other equipment for the elderly to realize 24-hour safe automatic duty and reduce the unexpected wind of the elderly dangerous.

4.2 Case analysis

The three smart pension cases of Taikang Insurance Group, Furong South Road Community, Tianxin District, Changsha City, and China Telecommunication Jiangsu Nanjing Branch show the application of smart pension in different regions and different service modes. ll three cases attach great importance to the application of science and technology in elderly care services. Through the introduction of intelligent equipment, the construction of information platforms and other means, they have realized all-round monitoring and care for the lives and health of the elderly. Whether it's Taikang Home's Smart speakers, stir-fry robots, AI intelligent terminals in Tianxin District, Changsha City, as well as the intelligent elderly digital platform and IoT of China Telecommunication Nanjing Branch, all aim to improve the quality of life of the elderly and ensure their safety and health.

Although these cases have similarities in technology application, personalized services, safety and health monitoring, improving the quality of life, and government-enterprise cooperation, they show obvious differences in service scope, technology implementation path, service model, target group and geographical characteristics.

The service model of Taikang Home focuses more on centralized services in the community, the service model of Changsha Yinfa Health Service Co., Ltd. focuses more on home care services, and the service model of China Telecommunication Jiangsu Nanjing Branch focuses more on remote monitoring and emergency response. The services of Taikang Home may be more suitable for the elderly with a certain economic foundation, the services of Changsha Yinfa Health Service Co., Ltd. may be more suitable for the elderly who need home-based elderly services, and the services of China Telecom Jiangsu Nanjing Branch may be more suitable for remote monitoring and security. The elderly, especially the elderly with empty nests and living alone. In addition, Taikang Insurance Group, relying on its insurance business background, has deeply integrated pension services and insurance products. Through the “Taile Smart Pension Cloud Platform”, it has integrated a variety of resources such as health management, life services, social entertainment, etc. to build a comprehensive elderly service ecology. The community of Furong South Road, Tianxin District, Changsha City, pays more attention to resource integration and service innovation at the community level. By creating a “15-minute community home retirement life circle”, it realizes the comfort of the elderly at home. Relying on its communication technology advantages, China Telecommunication Jiangsu Nanjing Branch has self-developed and built a smart elderly digital platform, using 5G, IoT and other advanced technologies to provide accurate danger alarm services and remote monitoring support for the elderly.

From these three cases, we can find that smart old-age care, as an innovative practice in the field of old-age care, has been widely studied and recognized. With its unique technical advantages and broad application prospects, smart old-age care is gradually becoming an important way to solve the problem of old-age care. Zhao et al. (2021) study on this it is pointed out that with the rapid rise of the artificial intelligence era, intelligent elderly care, as a new trend in the future development of the elderly care industry, has begun to be favored by more and more people [9].

Smart old-age care solves the problem of poor information communication in traditional old-age care. Zhang (2021) found through experiments that he used smart wearable devices to integrate the physical sign data of the elderly, generate and feedback the health of the elderly through big data analysis, and promote the gradual "intelligence" of elderly care services [10]. Smart old-age care has also shown great potential in promoting health management and disease prevention. The empirical analysis conducted by Liu (2021) shows that with the rapid development of big data, cloud computing, artificial intelligence and other intelligent technologies, the artificial intelligence old-age model has become a key technology for institutional old-age care at present [11]. Through the application of smart bracelets, smart sphygmomanometers and other equipment, the elderly can monitor their health in real time, detect potential health problems in time and intervene. This preventive health management method helps to reduce the medical expenditure of the elderly and improve their quality of life.

Smart old-age care plays an increasingly important role in the field of old-age care with its unique advantages. It not only improves the quality of life of the elderly, but also alleviates the family and society. The burden of care also meets the challenges of an aging society, solves the problem of poor information communication, and promotes health management and disease prevention. With the continuous progress of science and technology and the increasing demand for elderly care, the future of intelligent elderly care will be broader. However, there are also some practical problems of intelligent home care.

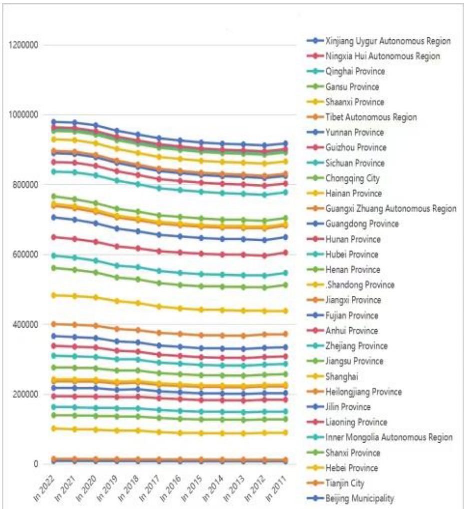

Fig.2 The number of primary medical and health institutions in China (from 2011 to 2022)

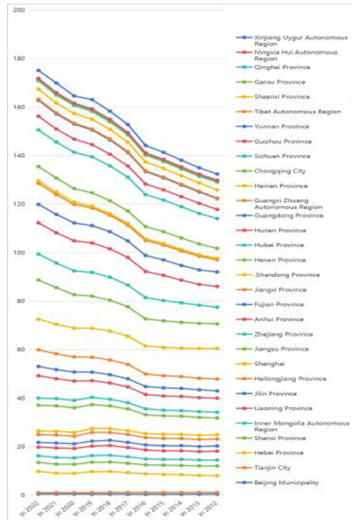

Fig.3 The number of beds in primary medical and health institutions in China (from 2012 to 2022)

5. The practical problems of smart home care

Through the analysis of the above cases, a general conclusion can be drawn: Home-based elderly care facilities focus on “services” and light “occupancy”, and provide “short, flat and fast” related services of “at home” or “away from home” for demand groups is the main mode of operation of home-based elderly care facilities. Therefore, compared with elderly care institutions, the number of elderly people living in home-based elderly care facilities is generally small, and the occupancy rate is also low. Of course, the small number of occupants and the low occupancy rate of the facility do not mean that there is a clear difference between its home elderly service function and the institutional elderly care service function. From the perspective of the demand side, factors such as the degree of acceptance of home-based elderly care services, dissatisfaction with home-based elderly care services or the ability to pay may affect the number of occupancy and occupancy rate of the facility, from the perspective of supply, whether the care resources are sufficient, service capacity and other factors will also have a significant impact on the number of occupancy and occupancy rate. However, if there are too many occupants and the occupancy rate of home-based elderly care facilities is too high, its home-based elderly care service functions tend to be institutionalized and deviate from the concept of home-based elderly care services [12].

5.1 The allocation of elderly infrastructure

5.1.1 Growth in pension infrastructure is slow

It can be seen from Figure 2 that the increase in the number of primary medical and health institutions in each region varies greatly from year to year. Some regions experienced large growth in some years, while others were relatively stable or showed a downward trend. In some areas, due to rapid economic development, the population has increased more, and the demand for medical and health services has also increased accordingly, thus promoting the growth of the number of primary medical and health institutions. It can be seen from Figure 3 that there are also regional differences and year fluctuations in the increase in the number of beds in primary medical institutions. The number of beds in some areas has increased significantly in recent years, while in others it has grown more slowly or declined.

5.1.2 The total amount is insufficient

Follow Table 1, it can be seen from the data that the number of beds in a thousand resident population institutions in Beijing is 4.8, which is a gap compared with typical Japanese cities, such as Tokyo is 10.2 and Osaka City is 15.3. This shows that the total number of nursing beds in Beijing is relatively insufficient, and it is difficult to meet the growing nursing needs of the elderly. With the acceleration of China's population aging, the number of elderly people is increasing, and the demand for nursing beds will continue to grow. Therefore, increasing the supply of nursing beds is the key to solving the problem of insufficient total nursing beds.

5.1.3 Uneven regional distribution

Figure 1 depicts the quantity of primary-level medical and health institutions. Analyzed from a regional dimension, different changing trends are presented in eastern regions such as Beijing, Tianjin, Shanghai, and others. Beijing witnessed an increase from 4,115 in 2010 to 9,915 in 2022. Tianjin had 79,493 in 2010, but it changed to 5,686 in 2022, experiencing a significant reduction followed by an increase. In the western region, Sichuan increased from 24,498 in 2010 to 70,671 in 2022, while the number in Tibet was relatively small, and the growth rate was not significant. Figure 2 reflects the number of beds in primary-level medical institutions. In the eastern region, Beijing increased from 4,400 in 2010 to 5,200 in 2022. Tianjin changed from 69,000 in 2010 to 58,000 in 2022. In the western region, Sichuan increased from 113,900 in 2010 to 151,200 in 2022, while the number of beds in the Tibet Autonomous Region was relatively small, and the growth rate was not significant.

It is found that the distribution of the number of primary medical and health institutions and the number of beds is not exactly the same. There is a large gap between the number of institutions and the number of beds, which will lead to inequality in the access of medical services, and it may be difficult for residents in some areas to obtain adequate medical security. The fluctuation of the number of institutions and the number of beds and the inconsistency in the distribution of the two reflect that there may be unreasonableness in the allocation of primary medical and health resources, which need to be further optimized and adjusted to meet the actual needs of different regions. The government should strengthen the overall planning of the allocation of nursing beds, reasonably allocate elderly resources according to the degree of aging and demand in different regions and ensure that the supply of nursing beds is suitable for demand.

5.1.4 The proportion of public and private institutions is unreasonable

The proportion of public and private institutions in Beijing is 43/57, and the proportion of public institutions in six urban district is 31/69, while the proportion of public institutions in Tokyo and Osaka Prefecture in Japan is very low. This may affect the vitality of the market and the diversity of services. The government should further optimize the proportion of public and private institutions, encourage social capital to participate in elderly care services, give full play to the decisive role of the market in resource allocation, and strengthen the supervision of the market to ensure the quality and fairness of elderly care services.

5.2 The uneven distribution of facilities

5.2.1 There are obvious regional differences

Compared with the aging rate of Beijing and typical Japanese cities, Beijing is 10.90%, while the aging rate of Tokyo and Osaka is 23.30% and 26.80% respectively, but the number of nursing beds in Beijing is relatively small. This implies that the distribution of elderly care facilities in Beijing may be uneven and cannot fully meet the needs of the elderly. The government should increase investment in the construction of elderly care facilities, especially in areas with a high degree of aging, strengthen the planning and layout of elderly care facilities, and ensure the coverage and service capacity of elderly care facilities.

Table 1 **Comparison of nursing beds in Beijing and typical cities in Japan**

Contrast items	Beijing Municipality	City Six Districts	Tokyo Metropolitan Government	District 23 in the capital	Osaka Prefecture	Osaka City
Resident population (10,000 people)	2171	1209	1364	896	883	273
Aging rate	10.9%	12.1%	23.3%	22.5%	26.8%	25.7%
Number of nursing beds	1031618	42579	133845	78224	85416	41630
The proportion of public and private institutions	43/57	31/69	3/97	-	4/96	-
The number of beds in thousands of resident population institutions	4.8	3.5	10.2	8.7	9.7	15.3
The number of beds in institutions for 100 elderly people	4.4	2.9	4.4	3.9	3.6	5.9

Data Source: Beijing Municipal Government Website

5.2.2 The gap between urban and rural areas is large

From Table 1, it can be seen that in Japan the number of institutional beds per 1,000 permanent residents is 10.2, and the number of institutional beds per 100 elderly people is 4.4. The number of institutional beds per 1,000 permanent residents is 8.7, and the number of institutional beds per 100 elderly people is 3.9. In Beijing, China, the total permanent population is 21.71 million, and the number of nursing beds is 10,316,184. The number of institutional beds per 1,000 permanent residents is 4.8, and the number of institutional beds per 100 elderly people is 4.4. Comparing these figures, it can be seen that the overall nursing bed configuration in Tokyo is better than that of its 23 districts, but the gap is relatively smaller than the urban-rural gap in Beijing. The nursing bed configuration in Beijing's six urban districts is clearly lower than the overall level in Beijing, reflecting that the urban-rural gap in China's nursing bed configuration is more significant than that in Japan.

There is a large gap between urban and rural areas in China in terms of economic development level and social security level, which also leads to an uneven distribution of elderly care facilities between urban and rural areas. There are relatively few elderly care facilities in rural areas, and the service quality is also low, which makes it difficult to meet the elderly care needs of the rural elderly.

5.3 Differences in service quality

Although the data of Table 1 does not directly reflect the information of service quality, it can be speculated from the comparison of the number of nursing beds and the aging rate that the relative shortage of nursing beds may affect the quality of service, resulting in the inability of the elderly to receive timely and high-quality services. The main reason for the shortage of professionals in elderly care service positions is that most of the employees in the current elderly care service industry are laid-offs or unemployed people with a generally low level of education, and people generally believe that the elderly care service industry has low technical content, low work intensity, low social status of employees, and low salaries, resulting in frequent loss of workers [13].

6. Countermeasures and suggestions

To address the challenges in smart home-based elderly care, we must enhance infrastructure with government policies supporting social investment in elderly care services, increasing the supply of care beds and facilities. Regional coordination should ensure balanced distribution of resources, with urban-rural integration elevating rural care standards. Service quality improvement involves establishing service standards, training professionals, and strengthening supervision. Innovation in elderly care products should integrate advanced technologies, expand service models, and strengthen resource integration to meet diverse needs. This approach aims to create a comprehensive elderly care ecosystem that supports high-quality living in the silver-haired era.

7. Conclusion

This paper examines the smart home care service system's theoretical underpinnings, technologies, practices, and socio-economic impacts, asserting its efficacy in tackling aging, enhancing elderly quality of life, and fostering socio-economic sustainability. Data and case studies confirm smart home care's positive impact on health monitoring, convenience, and safety for the elderly. The paper identifies current challenges such as infrastructure gaps, limited-service variety, vague service roles, and uneven tech application. Proposed solutions include government, societal, and market collaboration to innovate policy, technology, and social engagement for a smarter, more inclusive, and sustainable aging society, ensuring high-quality, convenient, and safe home care services for the elderly and contributing to their happiness and societal harmony.

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A Study of the Impact of Intellectual Capital on the Financialization of Firms

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Abstract. In the context of evolving investment trends that enterprises gradually detach themselves from the investment, production and circulation of the real economy and turn to the virtual economy, the article explores the impact of intellectual capital on the financialization of enterprises by using the two-way fixed-effects model with the sample of non-financial listed enterprises in Shanghai and Shenzhen A-shares from 2016 to 2022. The empirical results show that intellectual capital is negatively related to corporate financialization.

Keywords. Intellectual Capital; Financialization of Businesses

1. Introduction

Nowadays, the world is experiencing the fourth industrial revolution (Industry 4.0), which is characterized by digital technologies such as the Internet of Things (IoT), cloud computing, and big data, and is fundamentally changing the way businesses have traditionally operated. According to Ahmed et al. (2019), Industry 4.0 is profoundly altering the basis of competitive advantage from tangible to intangible resources (Secundo et al., 2020)[1][2]. In the era of industrial economy, enterprises can obtain excess profits through the possession of material resources such as equipment, land and plants, however, this has brought about the problems of overcapacity and the decline of profits in the main business, thus many enterprises have chosen to invest in the finance sector and property sector, for example, Wang Guogang (2018) found that more than 80% of the non-financial enterprises implement financial investment[3].The financialization of enterprises will make funds idle within the financial system, while the flow of funds to the industrial sector continues to decrease, resulting in the industrial development process facing a shortage of funds (Wang Yao and Huang Xianhuan, 2020) [4], greatly inhibiting the development of the real economy and the rate of economic growth. General Secretary Xi has continually stressed that high-quality development should prioritize the real economy to prevent it from shifting from "deconstruction to virtualization". Based on this background, the article studies the relationship between intellectual capital and financialization of enterprises.

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2. Literature Review and Hypothesis Formulation

The prevailing opinion in academia is that corporate financialization is primarily driven by precautionary saving and speculative motives. However, numerous studies indicate that, at this stage, the financialization of Chinese non-financial listed companies mainly aims to maximize short-term financial gains instead of setting aside funds for long-term growth. (Du Yong et al., 2017). Xu and Xuan (2021) even pointed out directly that the level of corporate income from its core business directly determines its financial investment behavior. Therefore, only by effectively improving the rate of return of industrial investment, can enterprises be prompted to make industrial investment, thus solving the problem of "deconcentration" (Xiong Lihui and Dong Ximiao, 2021)[5].Therefore, intellectual capital is more important than physical capital in adding value in the current knowledge economy era (Barpanda and Bontis, 2021)[6].Oppong and Pattanayak (2019) argue that firms rich in intellectual capital can invest more because they have information asymmetry, maximum investment efficiency and production cost efficiency which are less problematic[7]. Umar, Mosab and Suhaib et al. (2022) found that both market capitalization and intellectual capital can motivate firms to increase physical investment after empirically analyzing data from three countries, namely China, India and Pakistan[8]. Firms' limited resources mean that intellectual capital, while encouraging more physical investment, also decreases available funds for financial investment.

Drawing from the analysis above, hypothesis 1 is formulated.

H1: Intellectual capital is negatively related to financialization of firms.

3. Research design

3.1 Sample selection

The article uses non-financial companies listed on the Shanghai and Shenzhen A-shares from 2016 to 2022 as the sample and filters the data according to the following criteria: (1) exclude industries with financial characteristics, such as the financial and real estate sectors; (2) eliminate companies with missing indicator values and incomplete data; (3) exclude listed firms categorized as ST; and (4) apply shrinkage treatment to all continuous variables at the 1% and 99% levels.

3.2 Selection of variables

Explained variable: Financialization of firms (Fin). Drawing on Leilei Gu, Jianluan Guo and Hongyu Wang (2020) and Li Li and Wenjun Wei (2023), the article uses the ratio of financial assets to total assets to define corporate financialization [9]. Note that from 2018, accounting standards removed held-to-maturity and available-for-sale asset items; per Ruo-Yu Zhu, Ke-Hu Tan and Xiao-Hui Xin (2023), these were reclassified as debt investments and other investments, including equity instruments[10].

Explanatory variables: Intellectual capital (IC) is divided into three dimensions: human capital, relational capital and structural capital, and then factor analysis is performed on these eight indicators reflecting IC to extract the three principal components, to obtain the weight scores of the three dimensions of IC, and finally to calculate the comprehensive score of IC. The constructed evaluation index system is shown in Table 1.

VAIC is the sum of human capital increment efficiency, structural capital increment efficiency and relational capital increment efficiency.

Table 1. Indicator Measures of Intellectual Capital Dimensions

Level 1 indicators	Secondary indicators	Calculation method
Human capital	Employee Education	Bachelor's degree and above ÷ Total number of employees
	Average Employee Compensation	Salary costs ÷ Total number of employees
	Employee Value Added	(Total profit + cash paid to and for employees + finance costs) ÷ Total number of employees
Structural capital	Asset turnover ratio	Income from main operations ÷ [(Closing balance of assets + opening balance of assets) ÷ 2]
	Management cost ratio	Administrative expenses ÷ Operating income
	Current asset turnover ratio	Operating income ÷ [Beginning current assets + Ending current assets) ÷ 2]
Relational capital	Sales expense ratio	Selling expenses ÷ Operating income
	Customer Concentration	Total sales to top five customers ÷ Sales

3.3 Control variables

In addition to the above variables, fixed asset ratio (FA), cash asset ratio (Cash), gearing ratio (Lev), current ratio (CR), and institutional investors' shareholding ratio (Instsh) are selected as control variables in the regression model.

3.4 Modeling

$$\mathrm{Fin}_{i,t} = \beta_0 + \beta_1 \mathrm{IC}_{i,t} + \beta_2 \mathrm{FA}_{i,t} + \beta_3 \mathrm{Cash}_{i,t} + \beta_4 \mathrm{Lev}_{i,t} + \beta_5 \mathrm{Instsh}_{i,t} + \beta_6 \mathrm{CR}_{i,t} + \mu_{i_i,t} + \varepsilon_{i,t} \quad (1)$$

4. Analysis of empirical results

4.1 Intellectual capital factor analysis

Before factor analysis, these eight indicators need to be analyzed to determine whether they are suitable for factor analysis, as shown by the results in Table 3, the KMO statistic is 0.597, which is greater than 0.5, and Sig. < 0.001, indicating that intellectual capital is suitable for factor analysis.

Table 2. KMO and Bartlett's (Bartlett) test of sphericity

The Kaiser-Meyer-Olkin measure of sampling adequacy		0.597
Bartlett's test of sphericity	approximate chi-square (math.)	27284.945
	df	28
	Sig.	0.000

The article uses the variance maximizing orthogonal rotation method to perform the rotation of the factor loading matrices, and the results are shown in Table 3.

Table 3. Rotated component matrix

Variable	Factor 1	Factor2	Factor3
HC1	0.2331	0.6491	-0.2008
HC2	-0.2027	0.7714	0.1663
HC3	0.0306	0.8695	-0.0454
SC1	0.8656	-0.0322	0.0247
SC2	-0.7113	-0.0474	0.2403
SC3	0.8809	-0.0091	0.0579
RC1	-0.2368	0.0677	-0.7659
RC2	-0.2308	0.0596	0.7756

Based on the scores for each factor in Table 4, the following expressions were derived for the three common factors:

$$SC=0.09612HC1-0.07783HC2+0.01514HC3+0.39254SC1-0.30699SC2+0.40161SC3-0.15358RC1-0.05656RC2$$

$$HC=0.36029HC1+0.43654HC2+0.48715HC3-0.01334SC1-0.02366SC2+0.00053SC3+0.01692RC1+0.05265RC2$$

$$RC=-0.12284HC1+0.13529HC2-0.01028HC3+0.07104SC1+0.13959SC2+0.09811SC3-0.60024RC1+0.58240RC2$$

From this, the score for each factor can be calculated and multiplied by the ratio of the variance contribution of each common factor to the cumulative variance contribution to obtain the composite indicator. The formula for the composite indicator is as follows:

$$IC = 0.2838/0.6676*SC + 0.2239/0.6676*HC + 0.1599/0.6676*RC$$

Table 4. Matrix of component score coefficients

Variable	Factor 1	Factor2	Factor3
HC1	0.09612	0.36029	-0.12284
HC2	-0.07783	0.43654	0.13529
HC3	0.01514	0.48715	-0.01028
SC1	0.39254	-0.01334	0.07104
SC2	-0.30699	-0.02366	0.13959
SC3	0.40161	0.00053	0.09811
RC1	-0.15358	0.01692	-0.60024
RC2	-0.05656	0.05265	0.58240

4.2 Descriptive statistical analysis

The sample enterprises involved are listed enterprises for which relevant information is available, and the data volume of the enterprises involved is large. Descriptive statistics of variables are shown in Table 5.

Table 5. Descriptive statistical analysis

variant	sample size	average value	upper quartile	(statistics) standard deviation	minimum value	maximum values
Fin	13958	0.151	0.111	0.130	0.009	0.647
IC	13958	-0.000	-0.056	0.590	-2.119	3.672
Cash	13958	0.143	0.116	0.104	0.010	0.519
FA	13958	0.206	0.174	0.148	0.003	0.655
Lev	13958	0.435	0.429	0.197	0.065	0.921
Instsh	13958	43.175	44.174	23.744	0.407	90.771
CR	13958	2.152	1.572	1.861	0.340	11.894

4.3 Correlation analysis

The results of the correlation analysis are shown in Table 6.

Table 6. Results of correlation analysis

	Fin	IC	Cash	FA	Lev	Instsh	CR
Fin	1.000						
IC	-0.019**	1.000					
Cash	-0.075***	0.086***	1.000				
FA	-0.281***	-0.080***	-0.276***	1.000			
Lev	-0.173***	0.120***	-0.319***	0.069***	1.000		
Instsh	-0.065***	0.170***	0.063***	0.170***	0.180***	1.000	
CR	0.201***	-0.130***	0.398***	-0.229***	-0.680***	-0.147***	1.000

4.4 A basic model test of the impact of intellectual capital on the financialization of firms

- *Baseline regression results*

The article also conducted a Hausman test before conducting the baseline regression, and finally settled on a two-way fixed effects model (which incorporates both individual and time fixed effects, controlling for the effects of inherent individual and time characteristics on causality) for the regression analysis. The findings presented in Table 7 show that an increase in intellectual capital does inhibit corporate financialisation, as expected from hypothesis H1 of this paper.

Table 7. Results of model regression analysis

	(1) Fin	(2) Fin
IC	-0.0268***	-0.0255***
	(-5.68)	(-5.88)
_cons	0.144***	0.316***
	(69.63)	(21.48)
N	13958	13958
r2	0.0134	0.197

- *Robustness check*

To validate the conclusions, the article employed three substituting explanatory substituting explanatory variables with the Modified Value-Added Intellectual Capital Coefficient (MVAIC) for measuring intellectual capital, and (2) changing the sample to include manufacturing firms for regression analysis. Consistent results were obtained upon re-regression of the model.

Table 8. Robustness analysis results

	Replacing explanatory variables	Replacing sample size
	Fin	Fin
VAIC	-0.0000781***	
	(-2.64)	
IC		-0.0323***
		(-5.87)
_cons	0.320***	0.297***
	(21.52)	(18.05)

5. Conclusions and Implications of the Study

The article investigates the impact of intellectual capital on corporate financialization by analyzing a sample of non-financial A-share listed companies in Shanghai and Shenzhen from 2016 to 2022. Empirical results indicate that intellectual capital can inhibit corporate financialization. The findings suggest that governments could implement policies to reduce taxes and fees, helping lower production costs for businesses and narrow the profit gap with the financial sector. However, due to limited data availability for unlisted companies, these conclusions may not generalize to all enterprises, and further research is encouraged to build upon this study.

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Digitalization and Management Innovation III
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A Study of the Impact of ESG Performance on Firms' New Quality Productivity

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Abstract. In this paper, we choose a sample of A-Listed companies from 2012 to 2022 and use a fixed-effect model to analyze the direct influence of ESG performance on QOL and the moderating role of digital transition. It has been found that both the performance of ESG and the digital transition can significantly affect the new productivity of companies; digital transformation can also make an effective contribution to the performance of ESG and ESG performance's impact on new productivity.

Keywords. ESG performance, digital transformation, new quality productivity

1. Introduction

The use of ESG as an important indicator for assessing a company's future growth potential and risk management has gained international recognition in the face of rapidly changing international market conditions [1]. More and more companies are beginning to incorporate ESG criteria into their management strategy and risk management frameworks [2]. The performance of ESG means the performance of a company in protecting the environment, contributing to society and managing efficiently. The Political Bureau of the Communist Party of China (CPC), for the first time, put forward the concept of "New Quality Productivity". New-quality productivity is based on the basic connotation of the leap of workers, labor materials, labor objects and their optimal combinations, with a significant increase in total factor productivity as the core symbol, featuring innovation, with the key to quality and excellence, and is essentially advanced productivity.

In this paper, Chinese A-share listed companies in Shanghai and Shenzhen were selected as sample from 2012 to 2022 to investigate the relationship between ESG performance and NQF, and the moderating role of business digital transformation in order to help firms to increase their own level of productivity.

2. Theoretical analysis and hypothesis formulation

2.1. Corporate ESG performance and new quality productivity

Enterprise ESG performance and new quality productivity are both aimed at achieving enterprise sustainable development. The resource base theory holds that the key to a firm's sustainable competitive advantage lies in its internal resources and capacities, particularly

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those that are rare, valuable, and hard to replicate and replace [3]. ESG can be regarded as a kind of unique resource of an enterprise, which can enhance the enterprise's brand image, strengthen the trust of its stakeholders, and ultimately increase the enterprise's overall operational efficiency and productivity [4]. The measures taken by the enterprises to protect the environment can reduce the waste of resources, increase energy efficiency, and reduce the cost of resources and environment [5]. CSR can contribute to the establishment of stable supply chain relations and customer loyalty, increase corporate social capital and increase economic and social efficiency by means of positive corporate social interaction [6]. By optimizing the corporate governance structure, it can effectively reduce conflicts within the company, lower the company's risk and improve the efficiency of the company's resource allocation [7].

2.2. The moderating role of digital transformation

Digital transformation can optimize an organization's ESG through the introduction of new technologies [8], which in turn affects the new qualitative productivity of organizations. Resource dependency theory states that organizations rely on external resources to sustain their operations. Digital transformation provides organizations with new technologies and tools that help them to better achieve their ESG goals [9]. The Dynamic Capacity Theory stresses companies' capacity to adapt to changing circumstances, and digital change enables companies to adapt rapidly to market and societal changes, enabling them to better respond to ESG requirements [10], Institutional theory focuses on how organizations are affected by the external institutional environment, and digital transformation helps firms to better interact with external stakeholders by providing new communication and collaboration platforms. These interactions help firms understand and comply with ESG-related regulations and standards, while also enhancing their market position and productivity through increased transparency and trust. Finally, digital transformation helps to achieve ESG goals by optimizing a firm's value chain activities, where firms reduce their environmental impacts through supply chain management while improving efficiency and quality, thus contributing to new quality productivity. So, the following hypotheses are proposed:

H1: Good ESG performance of firms can contribute to new quality productivity gains.
H2: Digital transformation of the enterprise can contribute to new qualitative productivity gains.
H3: Digital transformation plays a positive moderating role.

3.Sample selection and research design

3.1. Samples and data

The research sample of this paper is listed companies in Shanghai and Shenzhen A-shares from 2012 to 2022, and the following treatments have been made to the data to ensure the reliability of the research results: (1) financial sector companies are excluded; (2) companies that are ST and *ST during the sample period are excluded; (3) companies with missing key data such as ESG ratings are excluded; and (4) tailing adjustments are made on all continuous variables, with the tailing object being the top and bottom 1% of the observations.

3.2. Definition and description of variables

3.2.1. Explained variables:

New Prime Productivity (NPRO). This paper adopts the entropy value method to measure the new quality productivity. Firstly, we choose the strategic industries and future industries which are closely related to NQF as samples. Secondly, based on the Two Factors Theory of Productivity, we construct a new Quality Productivity Index System.

3.2.2. Explanatory variables:

Corporate ESG (ESG). CSI ESG ratings are selected as a measure of corporate ESG performance, with the higher the score rating, the better the ESG performance.

3.2.3. Moderating variables:

Digital transformation (DCG). This paper uses text analysis method and based on python crawler technology to construct the index system of enterprise digital transformation.

3.2.4. Control variables:

To reduce the empirical bias, this paper refers to previous literature to select equity concentration (Share), firm age (Age), firm size (Size), return on equity (ROE), return on assets (ROA), and assets and liabilities (LEV) as control variables

3.3. Modelling

$$NPRO_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_j \sum Controls_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (1)$$

$$NPRO_{i,t} = \beta_0 + \beta_1 DCG_{i,t} + \beta_j \sum Controls_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \quad (2)$$

$$\begin{aligned} NPRO_{i,t} &= \beta_0 + \beta_1 ESG_{i,t} + \beta_2 DCG_{i,t} + \beta_3 ESG \times DCG_{i,t} \\ &+ \beta_j \sum Controls_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \end{aligned} \quad (3)$$

4. Empirical analysis

4.1. Descriptive statistics

Table 1 presents descriptive statistics for all variables. From the statistical results, The level of new quality productivity of the enterprises in the sample varies greatly, and there is still a lot of room for improvement on the whole; the sample enterprises likewise show large differences in ESG, but the overall level of attention to and practice of ESG is at a moderately high level; and the digitalization process of the enterprises, although it has variability among the different sample enterprises, does not have an extreme value, indicating that the majority of the sample enterprises' digital transformation level is relatively concentrated.

Table 1. Descriptive statistics

variant	sample size	average value	standard deviation	minimum value	maximum values
NPRO	11620	5.314	2.861	0.062	35.006
ESG	11620	4.419	1.109	1	8
DCG	11620	1.454	1.386	0	5.011

4.2. Correlation analysis

This chapter uses Pearson correlation analysis and the data obtained are shown in Table 2, which initially shows that there is a significant positive correlation between the performance of corporate environmental responsibility and the company's new quality productivity; the correlation coefficient between DCG and NPRO is 0.167, which passes the significance test of 1 per cent, indicating that the digital transformation of the company has the same positive effect on the improvement of new quality productivity. The correlation coefficients between the variables are all below 0.85, indicating that there is no significant covariance between the variables.

Table 2. Correlation analysis

variant	NPRO	ESG	DCG	Share	Age	Size	LEV	ROA	ROE
NPRO	1.000								
ESG	0.006***	1.000							
DCG	0.167***	0.082***	1.000						
Share	0.004	0.085***	-0.038***	1.000					
Age	0.038***	-0.003	0.082***	-0.204***	1.000				
Size	0.056***	0.191***	0.060***	0.257***	0.177***	1.000			
LEV	-0.091***	-0.016*	-0.075***	0.013	0.135	0.508***	1.000		
ROA	-0.012	0.135***	0.039***	0.182***	-0.111***	-0.097***	-0.438***	1.000	
ROE	-0.038***	0.151***	0.021**	0.183***	-0 073***	0.047***	-0.222***	0.812***	1.000

4.3. Regression results and analyses

Table 3 reports the regression results of models (1), (2), and (3). In column (1), the coefficient of corporate ESG performance on firms' new quality productivity is 0.104, which is significantly positive at the 1 per cent level, which indicates that good corporate ESG performance can enhance firms' own new quality productivity, and Hypothesis 1 is verified. In column (2), the coefficient of digital transformation on new quality productivity of enterprises is 0.116, which is significantly positive at 1% level, which indicates that enterprises with faster digital transformation process are more able to promote the new quality productivity of enterprises, and hypothesis 2 is verified. In column (3), the coefficient of the cross-multiplier term on firms' new quality productivity is 0.035, which is significantly positive at the 1% level, suggesting that digital transformation plays a positive moderating role in the impact of ESG on firms' new quality productivity, and Hypothesis 3 is verified.

Table 3. Benchmark regression results

variant	(1) NPRO	(2) NPRO	(3) NPRO
ESG	0.104***		0.047***
	(4.95)		(1.75)
DCG		0.116***	-0.041
		(4.86)	(-0.54)
ESG×DCG			0.035**
			(2.11)

4.4. robustness check

In this paper, we use the method of replacing explanatory variables to conduct the robustness test, using the BloombergESG indicator to replace the CSI ESG indicator, naming the reclassified and assigned ESG ratings as BloombergESG, and repeating the empirical process above, and the results are shown in Table 4. The empirical results of this reassignment are consistent with the previous section, and the empirical results of this paper are robust.

Table 4. Regression results with replacement of explanatory variables

variant	(1) NPRO	(2) NPRO	(3) NPRO
Bloomberg ESG	0.022***		0.007**
	(4.50)		(0.15)
DCG		0.116***	-0.196***
		(4.86)	(-2.43)
BloombergESG×DCG			0.010***
			(3.97)

5. Conclusion

It is found that both ESG performance and digital transformation can significantly affect firms' new quality productivity. This implies that in the context of digital transformation, companies should pay more attention to ESG practices in order to achieve sustainable development and long-term competitive advantage. Since new quality productivity is a newly proposed concept, the measurement of it is still immature, and it is hoped that future generations will continue to improve the study on this basis.

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Digitalization and Management Innovation III
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Analysis of Elderly Care Community Models Under the Background of Urban Rural Integration

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Abstract. In the context of urban-rural integration, exploring models for elderly community care has emerged as a critical issue in addressing the challenges posed by China's aging population. This paper analyzes the disparities in elderly care service needs between urban and rural areas, along with their developmental trends. The findings indicate that establishing interconnected elderly care communities can optimize resource allocation, enhance service quality, and foster social harmony and stability. However, this model encounters several challenges, including funding for sustained development, high construction costs, a shortage of professionals, and insufficient medical facilities. To address these issues, this paper proposes multi-dimensional strategies encompassing scientific planning, industrial integration, technological innovation, and community governance to facilitate the development of urban-rural linked elderly care communities. It is recommended that the government implement preferential policies to encourage participation from social capital while strengthening professional talent cultivation to achieve balanced development in urban and rural elderly care services.

Key words. Urban-rural linkage, elderly care provision, community

1. Introduction

In the 21st century, China is experiencing a significant increase in its aging population, leading to increasingly prominent pension issues and a diversification of service demands. Relevant state departments have begun to focus intensively on home care solutions. In 2019, the CPC Central Committee and The State Council issued the National Medium- and Long-term Plan for Actively Responding to Population Aging

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(hereinafter referred to as 'the Plan'). This Plan emphasizes the necessity of actively promoting the construction of a Healthy China by establishing and enhancing a comprehensive and continuous health service system for the elderly, which includes health education, preventive healthcare, disease diagnosis and treatment, rehabilitation services, long-term care, and hospice care. Concurrently, it aims to improve a multi-tiered elderly care service system that prioritizes home-based support while being bolstered by community resources and well-developed institutions that integrate medical care with social services. Furthermore, it seeks to expand product offerings suitable for older adults through diverse channels across multiple sectors while enhancing overall quality.

However, despite rapid advancements in pension services systems, imbalances persist. According to data from China's seventh national census, individuals aged 65 years or older reached 190.64 million—accounting for 13.50% of the total population—with an upward trend observed in urban demographics compared to previous censuses; during this latest census cycle, urban residents constituted 63.89% of the population [1]. These statistics indicate an increasing migration of younger individuals from rural areas into cities while leaving behind an aging populace in townships—a demographic shift that places substantial pressure on governmental and societal pension frameworks.

To effectively address these challenges, it is necessary to prioritize the construction of rural-urban aged care communities. A recent study by Yang et al. (2024) [2] found differences in preference for elderly care service demand among urban and rural populations in the Pearl River Delta region. Specifically, among locally registered older persons living in rural areas, there is a preference for institutional or community-based elder care options, while there is a trend in favour of integrated rural-urban pension services.

This paper conducts an in-depth analysis of representative urban-rural integrated elderly care communities such as Tangshan Hot Spring Elderly Care Town in Nanjing, Beijing Ruicheng Suyuan Elderly Care Center, and Xinhua Home Yizhuang Elderly Care Community, systematically summarizing their successful experiences in planning design, facility configuration and operational management. These experiences provide valuable references and lessons for the construction and development of other regional elderly care communities. In the context of this investigation, a case study method approach is adopted to scrutinize the repercussions of urban-rural integration on the paradigm of elderly care communities. By examining the exemplars of Tangshan Hot Spring Retirement Town, Beijing Vanke Suiyuan Elderly Care Center, and Yixiang Retirement Community, we distill the collective insights of various entities in the construction of elderly care communities. This analysis elucidates the inherent strengths and extant challenges of the elderly care community model, thereby facilitating the formulation of efficacious strategies for addressing these concerns.

In addition, based on summarizing practical experience, the study puts forward a series of comprehensive strategies, including industrial integration, technological innovation, ecological protection and community governance, aiming to promote the high-quality development of urban-rural integrated elderly care communities by integrating multi-industry resources, improving the level of intelligence, strengthening ecological protection and optimizing community management.

2. Related works

At present, the main pension methods in urban and rural areas are independent pension, home pension, community pension, institutional pension. Lu and Chen (2024) has found that home care and community care mainly focus on objective indicators in existing research [3]. Relevant policies can significantly improve the satisfaction of the elderly with life by increasing the total amount of household consumption, optimizing the consumption structure and enhancing the degree of social participation. The change of community home care service policy has a difficult process. Fan and Qiu (2024) has found that in the study of social security, the change of relevant policies is not only affected by the institutional background such as economic system reform and social welfare socialization, but also promoted by policy release and law revision [4]. At the same time, path dependence plays an important role in self-strengthening and sustainable development of the policy. Xing and Li (2024) have found that the promotion mechanism of the pilot reform of home-based community elderly care services should pay attention to the close cooperation and mutual learning between the central and local governments, to stimulate the enthusiasm and innovation ability of local governments and achieve efficient promotion and implementation of policies [5]. Chen (2024) has found that social organizations and market forces should be encouraged to participate in pension services, to form a pattern of diversified participation of government, market, society and family. It is necessary to provide guarantee for community home care services by giving play to the hub role of community in elderly care services [6]. Liu and Song (2024) has found that as a representative city in Northeast China, the construction of community elderly care service system in Changchun is of typical significance [7]. It is necessary to ensure the perfection of the old-age service system from the system, change the previous concept of old-age care, encourage social capital investment, improve the professional quality of old-age service personnel, and strengthen talent training. Under the background of accelerating aging in China, the problem of pension in large cities has become increasingly prominent. The main contradiction lies in the diversified demand for pension services brought by the surge of the elderly population and the insufficient supply of urban pension services. Li and Tan (2022) have found that the problem of elderly care service needs to be optimized and solved from multiple dimensions such as localization, intelligence and precision to explore a Chinese path that can not only relieve the pressure of elderly care in big cities but also help rural revitalization [8]. In addition, the construction of rural elderly care services should implement differentiated governance strategies according to the development stages and characteristics of different regions. Du and An (2023) has found that it is necessary to strengthen the social governance capacity of rural elderly at the grassroots level, realize the modernization of governance, ensure the high-quality development of community elderly care under the background of urban-rural integration, and improve the operation capacity and service level of rural community elderly care service centers [9].

3. Case study of urban-rural integrated elderly care community

With China’s rapid economic development, the deepening of urbanization process, the gap between urban and rural areas is increasingly widening, leading to the imbalance of urban and rural development. Under this background, the pension community gradually appears into the public field of vision, the project also arises in our country. Table 1 is about the three successful constructions of urban and rural combined pension communities in China.

Table 1: Comparison table of three urban-rural linkage pension communities

	Tangshan Hot Spring Retirement Town, Nanjing, Jiangsu	**Beijing Vanke Suiyuan Elderly Care Center**	**Xinhua Home · Yixiang retirement community**
Background	It is the first health town jointly built by China Jinmao, local government and provincial state-owned enterprise SOHO Holdings in Jiangsu Province which was included in the major projects of Jiangsu Province for three consecutive years in 2016, 2017 and 2018. Also, it was awarded the second batch of provincial characteristic towns approved by the Provincial Development and Reform Commission in 2018.	It is a public and private CCRC project cooperated by Beijing Vanke and the government, which has high credibility and cost performance.	Funded and operated by New China Insurance and built in the suburbs of Beijing, Xinhua Home · Yixiang Retirement Community is committed to the ultimate exploration of the elderly's new lifestyle and retirement satisfaction. With health and happiness as the theme, to create an ideal retirement life for the elderly.
Basic Information	The town's overall planning area is 2.5 square kilometers, and the core area is about 2017 mu. The project is the first health care town in Jiangsu province, which makes full use of Nanjing's booming economy and Tangshan's unique hot spring characteristics to give the elderly a perfect sense of belonging and experience.	Located at No.48 Fusheng East Street, Fangshan District, Beijing, outside the Fifth Ring Road in the southwest of Beijing, the project covers an area of about 50,000 square meters, with a total construction area of 40,000 square meters. Its green rate is as high as 35%.	The community is located in Yanqing District of Beijing, and the total construction area of the community reaches 284,000 square meters, with a total investment of 3.6 billion yuan, and 2,000 + sets of nursing homes are provided.
Surrounding environment	The surrounding natural environment is beautiful, surrounded by three mountains, Tangshan, Qinglong Mountain and Huanglong Mountain, and 150,000 mu of mountains and forests. The green coverage rate is as high as 80%, which is an ideal dwelling place for many Nanjing people.	Close to the Wan Mu Binhe Forest Park, country ecological Park, Changyang Park and Haotian Park, and close contact with Beijing urban area, but also make full use of Beijing's unique science and technology, medical and other resources.	The community is close to East Lake Park and Xiadu Park, with fresh air and four distinct seasons, which provides a good living environment for the elderly.
Internal facilities	The town is planned and designed with the "4+2" industrial model, which integrates six functional clusters of "medical rehabilitation cluster, Yi Le cultural and museum cluster, tourism and vacation cluster, elderly trade cluster, ecological leisure cluster and CCRC life apartment".	The town has a professional health management center and infirmary, equipped with geriatric internal medicine, Traditional Chinese medicine, rehabilitation and other departments.	More than 2,000 sets of nursing homes are provided. At the same time, the community also pays attention to greening and landscape construction, with a green rate of 51%.
Community service	The "Happy Life +" service system has been released, which includes three major service	The catering service is equipped with a team of professional dietitians	In the community there are cultural activities center, nutrition and food center,

	systems: life service, health service and happiness service, covering five sub-systems: travel, food, housing, transportation and shopping.	and caterers, as well as a professional service team.	intelligent health management center and other functional areas.
Features	With a long history of more than 1,500 years, containing more than 30 kinds of minerals and trace elements, and has extremely high medical and health care value.	The government enterprise cooperative pension project, established in cooperation with the Fangshan District Civil Affairs Bureau.	Advanced technologies such as the Internet of Things will be used to provide more convenient service experiences for the elderly.

This table gives an in-depth description of the background, surrounding environment and other information of the three urban-rural linkage pension communities. It has seized the opportunity of urban-rural linkage, integrated urban and rural resources, and realized the complementary advantages of resources. From a macro point of view, these urban-rural linkage pension communities aim to respond to the concept of urban-rural linkage pension and promote the balanced development of urban and rural pension services. At the same time, it emphasizes the characteristics of sustainable development and personalized experience. More importantly, it promotes the development of urban-rural integration and helps to break down the urban-rural divide. Compared with other pension models, these characteristics make the urban-rural linkage pension community stand out in the pension market.

4.The Integration Trend and Opportunities of Urban-Rural Linkage Elderly Care Communities

As the population structure ages, the demand for elderly care services is intensifying. Concurrently, with ongoing national economic development and urbanization processes, the government is actively promoting models of urban-rural integration and linkage. To address this increasing demand for elderly care services while fostering integrated development between urban and rural areas—and to rectify existing imbalances—the establishment of “urban-rural linkage pension communities” emerges as a viable solution.

4.1 Integrated Urban-Rural Development as a Future Trend

With an aging population structure, traditional pension models struggle to meet diverse individual requirements among seniors effectively. Developing urban-rural linkage pension communities has been regarded as an effective solution which allows full utilization of advantages both in rural and urban areas—to deliver comprehensive high-quality services tailored specifically toward older adults. Meanwhile, China has formulated significant strategies such as “The State Council’s Guidance on Promoting Rural Industry Revitalization” and directives from the Central Committee of the Communist Party regarding learning from successful projects like “Thousand Village Demonstration”, aimed at advancing urban-rural integration based on actual developmental realities. These efforts provide robust institutional guarantees and policy support for constructing urban-rural linkage pension communities. As China transitions into this new era characterized by evolving social contradictions—specifically "the disparity between unbalanced inadequate growth versus citizens' escalating aspirations"—this issue becomes particularly pronounced when comparing cities against townships. Thus, integrated developments necessitate not only economic convergence but also societal, cultural, and lifestyle integrations across multiple dimensions. Constructing these cohesive elderly care environments serves as tangible manifestations reflecting broader objectives surrounding holistic progress achieved through collaborative endeavors bridging gaps separating various demographic groups.

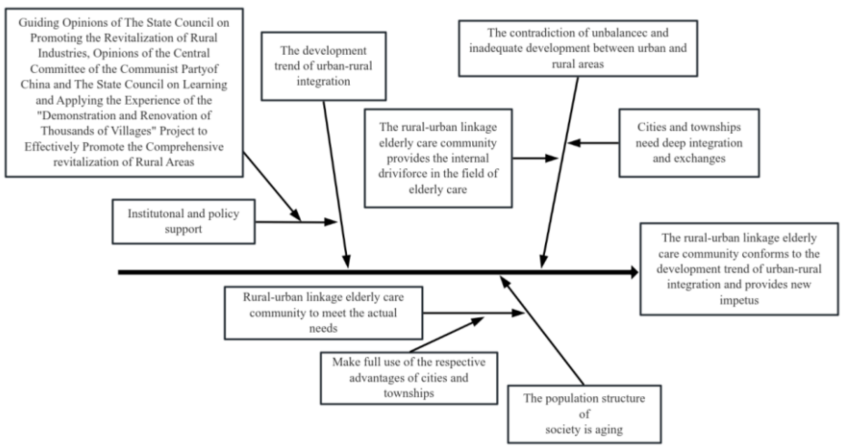

Figure 1: The general trend of future development of urban and rural integration

Figure 1 profoundly reveals the increasingly significant development trend of urban-rural integration, the global challenge of an aging social and demographic structure, and the profound contradiction of unbalanced and inadequate development between urban and rural areas. Based on these key social and economic phenomena, it strongly demonstrates how the urban-rural linkage pension community, as an innovative model, closely conforms to the development trend of urban-rural integration, injecting new impetus and vitality into this grand social change process.

The analysis process is carried out from three core levels: First, at the national strategy level, it discusses how the national policy orientation, resource allocation and strategic planning provide policy support and institutional guarantee for the development of urban-rural linkage elderly care communities; This includes initiatives to promote the sharing of resources and benefits between urban and rural areas. The second is the level of social structure. With the rapid development of social economy, the boundary between urban and rural areas is gradually blurred, residents' general demand for high-quality elderly care services and the necessity of interaction and cooperation between urban and rural communities are analyzed. This trend emphasizes the integration of services and infrastructure across urban and rural spaces. Finally, on the level of population demand, it elaborated on the growth of diversified demands of the elderly for living environment, medical services, social activities, etc. under the background of population aging, and how to meet these needs through urban-rural linkage pension communities to improve the quality of life of the elderly, highlighting the importance of a holistic approach to eldercare.

Within each level, more detailed influencing factors are further explored, such as the innovation of the service model of the elderly by technological progress, the impact of social and cultural changes on the concept of the elderly, the demand for the support system of the elderly by changes in family structure, etc. These factors are interwoven together to form a complex and rich analytical framework. It fully demonstrates the unique advantages and strong support of the concept of urban-rural linkage elderly care community in the current complex and changeable social environment and development trend.

4.2 Multi-Factorial Opportunities Across Multiple Levels

First, it is critical that policies and market dynamics align to support the construction of interconnected retirement facilities. According to the Guideline on Joint Elderly Care Services, Beijing is now emphasizing strong promotion of unified regional development using local assets/resources to promote collective prosperity of neighboring villages. In addition, the increase in the number of elderly population and the trend of continuous growth of the service market also provide favorable conditions for the construction of elderly care community models, bringing broad opportunities.

Second, scientific innovation plays a key role in the construction of aged care networks. As technology advances, modern tools such as big data analytics/blockchain applications/artificial intelligence/IoT are becoming more prevalent in various fields; The work plan of the Beijing Integrated Service Platform, for example, highlights the potential benefits that can be generated by adopting innovative solutions to ensure superior experiences for seniors who require specialized support/services.

Thirdly, the active engagement participation stemming from social capital injects renewed vigor vitality fueling efforts directed towards building sustainable connections linking together disparate elements comprising overall framework supporting healthy living arrangements designed accommodate growing demands placed upon society due rising number retirees seeking adequate accommodations suited their unique lifestyles. Underpinned by guiding policies driven primarily through market forces, more investors now focus attentively directing funds' investments geared toward creating supportive ecosystems capable of meeting challenges faced contemporary world.

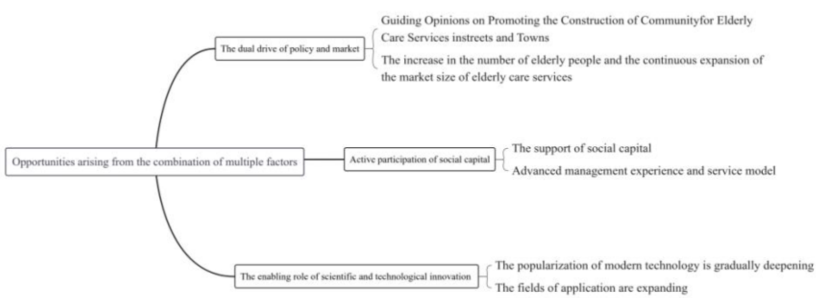

Figure 2: Multi-factor, multi-level, multi-faceted opportunity

4.3 Exploring Parallel Practical Pathways through Innovation

Firstly, the construction of urban-rural linkage pension communities should prioritize scientific planning and rational layout. The living needs and habits of the elderly must be thoroughly considered, with actual construction plans formulated based on the natural environment and resource advantages inherent in rural areas. Additionally, coordinated development with surrounding cities and villages is essential to avoid redundant constructions and minimize resource wastage. In overall layout planning, emphasis should be placed on human-centered zoning designs and supporting facilities to ensure that seniors can access convenient, efficient, and comfortable eldercare services. In the process of pursuing these goals, we will showcase the multi factor, multi-level, and multi-faceted opportunities brought by the urban-rural linkage elderly care community in Figure 2.

Second, the development of urban-rural linkage elderly care service communities needs to promote the deep integration of multi-industries and multi-resources. On the one hand, to promote the synergy between the elderly care industry and agriculture and other departments to form a diversified comprehensive elderly care service model; On the other hand, it must be effectively combined with the technical expertise of the city capital. For example, “Tangshan Hot Spring Elderly Care City” successfully integrated the hot spring assets and elderly care industry, established a comprehensive community covering hot spring treatment, health management, leisure activities, and finally improved the quality of service, to achieve regional economic diversification.

Third, we must acknowledge the critical role that technological innovation plays in aged care. For example, the “intelligent elderly service platform” established in Minhang District of Shanghai integrates health supervision, rescue operations, lifestyle assistance and other functions to provide a higher standard of living for the elderly.

Fourth, it is necessary for us to responsibly create a healthy lifestyle that is conducive to environmental protection. It should be implemented where feasible, utilizing green conservation technologies/products, such as eco-friendly buildings and incorporating renewable energy sources throughout the process.

Finally, strengthening community governance resident engagement remains paramount ensuring elders feel included decision-making processes enhances sense belonging fosters harmonious livable environments cultivated collectively encouraging feedback loops allowing continuous improvements made responsive evolving needs expressed individuals residing therein ultimately enriching overall experience enjoyed everyone participating journey together collaboratively shaping future ahead us all. At the same time, these policies encourage the participation and investment of social forces and promote the marketization and professionalization of elderly care services. By introducing social capital and advanced technology, the construction and operation level of elderly care communities has been significantly improved, providing more quality and efficient elderly care services for the elderly.

5.Challenges in the Construction of Urban-Rural Linkage Pension Communities

China is among the earliest developing countries facing significant aging challenges globally. Effectively addressing pension issues is crucial for maintaining social stability and promoting harmony within society. Currently, the construction of urban-rural linkage pension communities encounters several obstacles, including high construction costs, a shortage of skilled service personnel, insufficient participation from broader societal forces, and inadequate medical facilities within these communities.

Firstly, substantial funding is required throughout the construction process; typically, financing for general pension services primarily derives from government allocations alongside community donations. Despite governmental initiatives aimed at encouraging private investment through preferential policies related to retirement community development, such support often falls short in covering extensive expenditures associated with these projects.

Moreover, pension institutions registered as private non-enterprise units may benefit from relevant government incentives but are prohibited from generating profits. Consequently, these entities face difficulties not only obtaining dividends but also bearing responsibilities should any issues arise within their operations. This regulatory environment further exacerbates market access barriers hindering private capital involvement while complicating construction operational aspects surrounding these vital facilities.

In addition, a robust workforce comprising various professionals—including healthcare providers, social security experts, and community workers—is essential within every successful pension community. Currently, however there exists notable shortages across multiple disciplines pertinent directly towards supporting senior citizens' well-being. Ao (2012) has found that there remain acute deficits concerning nursing staff, social security specialists, and other allied professions particularly those focused upon delivering basic medical care necessary safeguarding life health older adults [10]. The absence of adequate healthcare provisions significantly undermines visibility appeal surrounding local eldercare offerings thus limiting potential clientele attracted seeking quality services rendered therein [11].

6. Conclusions and Suggestions

In overall layout planning, emphasis should be placed on human-centered zoning designs along with supporting facilities to ensure that elderly residents can access convenient, efficient, and comfortable eldercare services.

First, it is imperative to fully leverage both natural human resources while effectively integrating them with urban capital technical expertise. Our goal is not only to enhance quality standards within eldercare services via industrial and resource integrations but also stimulate growth prosperity local economies. For instance, "Tangshan Hot Spring Pension Town" located Nanjing Jiangsu Province exemplifies successful amalgamation hot spring assets alongside retirement sector establishing holistic community encompassing spa recuperation health management leisure activities which ultimately elevates both service quality & economic diversification regionally.

Second, technological innovation plays a crucial role in the field of elderly care initiatives. Intelligent senior support represents critical component underpinning effective establishment interconnected systems thus maximizing utilization contemporary information technologies enhancing overall performance levels associated respective offerings available throughout entire spectrum provided therein. Examples include platforms designed specifically cater online conveniences targeting demographic segments facilitating seamless interactions ensuring necessary supports required daily lives including emergency response mechanisms enabled through wearable devices monitoring real-time conditions alerting caregivers promptly whenever needed.

Finally, strengthening community governance resident engagement remains paramount ensuring elders feel included decision-making processes enhances sense belonging fosters harmonious livable environments cultivated collectively encouraging feedback loops allowing continuous improvements made responsive evolving needs expressed individuals residing therein ultimately enriching overall experience enjoyed everyone participating journey together collaboratively shaping future ahead us all.

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Impact of Institutional Factors and Tax Revenue on Firm Performance Across Provincial Localities in Vietnam

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Abstract. This research aims to examine the impact of the institutional factors and tax revenue on firm performance in 63 provinces and cities in Vietnam. The authors select data of the period 2015-2021 and run the regression model using GMM with the population and public investment in localities as instrument variables. The results show positive effects of Provincial Competitiveness Index (PCI), Provincial Information and Communication Technologies (ICT) Index, labor productivity, and tax revenue on firm performance, while there is a negative impact of firm investment on performance. There exists a negative interaction effect of PCI and labor productivity on firm performance, which might be due to the lack of policies from the local governmental bodies aiming to enhance the knowledge and skills of the labor force. These results suggest both governmental policymakers and business managers have proper strategies to boost the firm performance in the next period.

Keywords. Institutional factors, Tax revenue, Provincial firm's performance, Vietnam

1. Introduction

Institutional theory was New Institutional Economics (NIE) introduced by Ronald Coase [1] and Oliver Williamson [2], the authors documented that in developed countries where the institutions are well organized and legal, the resources might be allocated and used effectively, creating stability and growth. Institutions also frequently affect overall human welfare and distribution outcomes. Desalegn Abraha Gebrekidan [3] has summarized the main and common institutional factors in emerging markets, which include government structures, legal regulations, finance, and political factors. Roting [4] believes that governmental factors play an important role in firm performance. In addition, Narooz and Child [5] argue that legal regulations are crucial elements of an institution. Ward et al [6] and Johan [7] studied the institutional factor proxied by the Provincial Competitiveness Index (PCI) and presented that good

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institutions (good PCI) help improve firm efficiency. Studies using ICT index to represent institutional factors such as Salwani et al [8] and Berrio et al [9] also support positive results between institutional factors and firm efficiency and productivity.

In Vietnam, since 2015, local governments have started to use the indicators of PCI, Provincial Governance and Public Administration Performance Index (PAPI), and Information & Communication Technologies (ICT) Index to evaluate competitiveness and government efficiency in matters of governance and administration. Therefore, the institutional factors represented through these indicators play an increasingly important role in assessing the impact of the government authorities on business and individual. However, how they impact the firm performance in each locality, thereby increasing local budget revenue, is an issue that needs to be examined to have appropriate policies. In this research, the authors study the impact of institutional factors measured through PCI and ICT indicators on the financial performance of businesses in 63 provinces and cities in Vietnam, as well as the role of tax revenue.

2. Literature Review

2.1 Studies using market institutional reform (measured by the economic openness index) as a proxy for the institutional factor

These kind of studies result in three different streams of arguments about the relationship between market institutional reform and firm performance, these are positive relationships Cuervo-Cazurra and Dau [10], non-linear relationships Chari and Banalieva [11], and negative associations Chari & David [12]. Studies showing that institutional reforms enhance firm performance suggest that the external monitoring processes resulting from the reforms reduce agency and transaction costs for firms thereby increasing their profits Cuervo-Cazurra and Dau [13]. Studies showing negative impacts of reforms on firm performance argue that the policies to early open the national economy could bring difficulties for domestic firms as they have not been well-established and prepared to compete with their foreign rivals Chari & David [12].

2.2 Studies using the PCI as a proxy for the institutional factor

Most of the research on this branch currently supports the argument that increasing institutional efficiency will increase firm performance typically, Hallward - Dreimeier et al [14] showed that the ROA of Chinese businesses is positively correlated with rapid site clearance, reliable infrastructure, and good financial services. Ward et al [15] investigated the impact of economic institutions on the success of companies in the Philippines, they show that when economic institutions improve, companies' gross profits will increase. Johan [7] also studied the impact of institutional quality on productivity and growth of businesses in 42 developing countries, the results confirmed that good economic institutional quality is a condition for businesses to increase productivity and growth. In Vietnam, although research on this topic is still limited, there have been several studies on the role of institutions and institutional quality expressed through the PCI index on enterprise productivity and efficiency. Studies examining the impact of PCI on labor productivity in Vietnamese non-state-owned enterprises show that improvements in market information support, safe land use, and labor training have a positive effect on business performance, whereas weaknesses in the judicial system and lack of administrative reform will hinder business development Nguyen Phuong Le [16]. This study has not provided a straight theoretical model, mainly applying the model of previous authors, specifically those of Kane et al [17]. Similarly, Nguyen Van Thang et al [18] also used the PCI index set, examining the impact of these indexes on the performance of small and medium enterprises over two years (2005- 2006), the results also show that improving economic institutional indicators will increase the efficiency of the firms in the sample. This research was only conducted on a small sample size (a specific type of business within a province, for a certain industry) and over a short period thus it is not highly representative.

2.3 Studies using the ICT index as a proxy for the institutional factor

Currently, scholars generally study the impact of ICT in two directions, which are macro and micro impacts, in which micro impacts are those on businesses and individuals. There have not been many studies examining the impact of ICT on firm performance because of the lack of a proper approach and a sufficient set of data. However, there are still some studies confirming the positive relationship between ICT and firm productivity such as those of Berrio et al [19]. Recently, the study by Dang Thi Viet Duc [20] investigated the impact of ICT on the Vietnam economy in terms of macro economy, industry, and businesses. The results show that ICT has a positive impact on the economy, though its contribution to economic growth and labor productivity is quite low compared to other countries in the region. In addition, the spillover effect of ICT on firm performance when it is considered as a technological input of production and business is not economically significant. This is also true when it comes to its impact on changing firms' business and organizational models.

2.4 Studies on the impact of tax revenue on firm performance

Taxes affect firm performance in two aspects. On the one hand, taxes can be seen as a disincentive to innovation and investment, since every additional tax dollar is a dollar not spent on production Auerbach et al [21]. Empirical studies testing this theoretical prediction in developed countries find that taxes have negative effects on capital accumulation Cummins et al [22] and firm growth Carroll et al [23], and entrepreneurship, especially for the tax targeting entrepreneurs at the highest income levels Gentry and Hubbard [24]. On the other hand, taxes are the main source of revenue for governments to fund public infrastructure development projects, which in turn facilitate business activities. Similarly, the performance of the private sector depends heavily on the accessibility to infrastructure such as electricity, transportation and telecommunications Lisa Chauvet et al [25]. In addition, Aghion et al [26] argued that the positive effect of tax revenue on firm performance only exists when tax revenue is allocated to infrastructure projects, this requires governmental transparency and accountability.

2.5 Studies on impact of labor productivity and investment on firm performance

Regarding labor productivity, there are some different approaches to measuring this indicator. Csáfordi et al [27] used the value added per worker as a measurement, while Hintzmann et al [28] measured it as the real value added per working hour, another measurement is sales per worker by Liu et al [29]. Additionally, the positive relationship between company performance and labor productivity has been documented by many researchers Liu et al [29]

Secondly, firm performance and asset growth are considered important criteria for the sustainable and effective development of a country Fareed et al [30]. There have been many studies examining the association between firm investment and efficiency with disagreeing results. Several studies found a positive relationship Akron et al [31], while others presented negative ones Nguyen Trong Nghia [32].

3. Data, Model and Methodology

In this study, firm financial performance is measured by the return on total assets (ROA). The impact of institutional factors and tax revenue on firm performance is studied by the regression Model (*). The coefficients are determined using the GMM regression method in which instrumental variables are used to fix the endogeneity issue Hansen [33]. The variables is described thoroughly in Table 1 below.

$$\mathbf{ROA_{it} = b_o + b_1PCI_{it} + b_2ICT_{it} + b_3\,(Tax\ revenue/GRDP)_{it} + b_4(PCI^*\ LP)_{it} + b_5Size_{it} + b_6LP_{it} + e_{it}\quad (*)}$$

Table 1: Descriptions of variables at model (*)

Descriptions	Variables	Measurement
Dependent variable		
Return on total assets	ROA	ROA(it) is the average ROA of firms within province (or city) i for year t, where ROA for a specific firm is calculated by dividing the firm's after-tax profit by the firm's ending total assets.
Independent variables		
Provincial Competitiveness Index	PCI	PCI index of province or city i in year t
Provincial Information & Communication Technologies	ICT	ICT index of province or city i in year t
Tax revenue to income (GRDP)	Tax revenue/GRDP	Calculated by dividing total tax revenue by gross domestic product (GRDP) of province or city i in year t
Interaction variable between labor productivity and provincial competitiveness index	PCI*LP	Formed by the multiplication of labor productivity and competitiveness index of province or city i in year t
Control variables		
Investment capital	Size	The natural logarithm of the average total assets of enterprises in province (or city) i in year t
Labor productivity	LP	LP(it) is the average LP of firms in the province (or city) i for year t, where LP for a specific firm is calculated by dividing the firm's net sales by the firm's total employees.

Source: Compiled from the authors

3.1 Research data

The data is collected for the period 2015 - 2021, which includes the reports on the ICT index and PCI and operational and financial data of firms in 63 provinces and cities. Additionally, the authors also use data on the population and annual public investment of provinces and cities for the instrument variables. A more detailed explanation of each kind of data is presented in the following.

The PCI (Provincial Competitiveness Index) is an index that assesses and ranks the provincial authorities of Vietnam on their performance, capacity and willingness to build a business-friendly regulatory environment for private sector development. The Index is published annually by the Vietnam Chamber of Commerce and Industry (VCCI) in collaboration with the U.S. Agency for International Development (USAID). The data is available and accessible on the website at https://pcivietnam.vn/du-lieu-pci.

The ICT Index is a measure of the development of information and communication technologies and is used to evaluate the readiness for the development and application of information and communication technologies of a province (or city). The data is collected from the Report on Assessing and Ranking the Readiness for IT Development and Application in Vietnam which is published on the website of the Ministry of Information and Communications.

Regarding firm data, the author collected information from two sources to ensure consistency and sufficiency. The sources are the White Paper of Vietnam Enterprises by the Ministry of Planning and Investment and the statistics reports of the General Statistics Office of Vietnam. The data fields are sales, total assets, profits, and number of employees.

4. Results and Discussion

Table 2. Statistical description of variables

Variables	Obs	Mean	Min	Max	S.D
ROA	441	2.17	-5.61	19.32	3.16
PCI	441	62.47	48.96	75.08	3.86
ICT	441	0.42	0.08	0.94	0.14
Tax revenue/GRDP	441	0.09	0.0001	0.59	0.64
Size	441	17.04	14.32	19.91	0.87
LP	441	1328.01	98.82	5002.36	711.11

Source: Author's calculations

Table 2 shows the descriptive statistics of the variables in the study. The average value of ROA of 63 provinces and cities over 6 years is 2.17%, the lowest and highest value is -5.61% and 19.32% respectively. A negative ROA means that, on average, firms in a specific province in a specific year incur a loss. We carefully examined the sample and found that the majority of loss businesses are located in the central and northern mountainous provinces, in years of Covid19 epidemic (2020, 2021).

The Provincial Competitiveness Index or PCI (Provincial Competitiveness Index) was first announced in 2005 for 42 provinces and cities on a pilot basis. From the second time (2006) onwards, all Vietnamese provinces and cities have been included in the ranking, and the component indices have also been added. There are ten component indexes (with a 100-point scale) used to assess and rank provinces and cities in the areas of economic management under their authority. PCI is considered a policy tool, aiming at changing practice. Therefore, provinces with a low PCI index are considered not very good in terms of transparency, administrative costs, and competition environment, which suggests that provincial authority needs to be more dynamic and determined in creating a favorable business environment for the private sector development. Table 2 presents that during the period 2015-2021, across 63 provinces and cities, the highest value of PCI is only 75 points and the lowest value is 48.96 points.

The ICT (Information and Communication Technologies) Index is a measure of the development of Information and Communication Technologies (ICT) and the readiness to develop and apply ICT in sectors, countries and localities. The ICT Index of Province and City is an index of the readiness for ICT application and development of a Province or City, which includes three main groups of indicators including technical infrastructure, human resources and IT application, with a scale score ranging from 0 to 1. Table 2 shows that the average ICT index for the provinces over the period is 0.42, the highest is 0.94, and the lowest is 0.08. In general, low ICT indexes are those of provinces whose economies rely on agriculture and forestry, where the industrial production and service enterprises are less competitive and there are not many of these kinds of firms. Consequently, firm performance in these localities is quite low compared to other regions.

The descriptive statistics results from Table 2 show the average values of variables including: LP, Tax/GRPD and firms' investment capital. Similar to the average values of variables such as: PCI and ICT Index, it shows that the province with high indexes of these indicators has a tendency to have better business performance results.

Table 3. Correlation matrix of variables

Variables	ROA	PCI	ICT	Tax revenue/ GRDP	Size	LP
ROA	1					
PCI	0.0715	1				
ICT	0.1279	0.4013	1			
Tax revenue/GRDP	0.1940	0.3416	0.4865	1		
Size	0.1268	0.4519	0.5332	0.5462	1	
LP	0.2685	0.3482	0.1496	0.3096	0.2852	1

Source: Author's calculations

Table 3 presents the correlation matrix of variables in the model. In general, all variables have a positive relationship with the dependent variable of ROA. The striking point is the correlation coefficients between some variables in the model are quite high (approximately 0.5), which raises concern about the possibility of multicollinearity. Consequently, conventional regression methods such as Pooled OLS, REM or FEM may produce invalid estimates.

Table 4. Results of testing stationarity of variables

Variables	Statistic	p-value	Stationary
ROA	-12.24	0.0000	Yes
PCI	-37.47	0.0000	Yes
ICT	-31.62	0.0000	Yes
Tax revenue/GRDP	-64.25	0.0000	Yes
Size	-9.39	0.0000	Yes
LP	-8.44	0.0000	Yes
PCI*LP	-29.24	0.0000	Yes

Source: Author's calculations

Table 4 shows the results of testing stationarity according to the method of Levin-Lin-Chu unit-root test, the t statistic values of all tested variables are significant at all the usual testing levels. Therefore, we reject the null hypothesis and conclude that the series is stationary. Since variables are stationary, estimation using the GMM method becomes effective.

Table 5. Quantitative results of impact of institutional factors and tax revenue variables on local firm financial performance

ROA	Coef.	Robust Std. Err.	t-test	P-value
LP	0.0617	0.0254	2.42	0.016
ICT	2.4370	1.3837	1.76	0.079
PCI	1.1356	0.5284	2.15	0.032
TaxGRDP	3.8848	5.7479	0.68	0.499
Size	-0.1072	0.2834	-0.38	0.705
PCI*LP	-0.0009	0.0004	-2.37	0.018
Const	-70.2839	33.8794	-2.07	0.039

Source: Author's calculations (Note: Quantitative results using the GMM method, with the endogenous variable being the LP and instrument variables being the local population (Pop) and total local public investment capital (Total investment))

Table 5 shows the impact of local institutional factors and tax revenues on firm performance in provinces or cities in Vietnam. Firstly, PCI has a positive impact on local business financial performance with a marginal impact of 1.13%. The result is consistent with those of Hallward-Dreimeier et al [14], Nguyen Phuong Le [16]. This implies that when local governments make sound policies and act in a transparent, integrity, supportive manner to create a fairly competitive and favorable business environment, businesses will benefit, as they will be able to reduce administrative costs, increase initiative, and develop more accurate business plans. The ultimate result is better financial performance for them.

However, the interaction impact of competitiveness index and labor productivity on firm financial performance is negative with a marginal impact of -0.09%. Although it is not very economically significant, it reveals issues about the policy of training the local labor force, which is a sub-index in PCI. It appears that there has been a lack of suitable policies for developing the labor force from the local governments. Practically, the current policies put more focus on reforming administrative procedures to help businesses reduce costs. Therefore, more policies enhancing skills and knowledge for the local workforce should be implemented in the next period.

Secondly, the Information and Communication Technologies Index (ICT Index) also has a positive impact on local enterprise performance with a margin effect of 2.43%. This result is similar to those of Berrio et al [9], and Dang Thi Viet Duc [20]. The Provincial ICT Index is calculated based on three component indices including three main groups of indicators, which are technical infrastructure, human resources, and IT applications. Thus the result implies that local investment in technical infrastructure, human resource quality, and information technology application helps improve local firm performance.

Regarding tax revenue, according to current regulations, a portion of local government tax revenue is contributed to the central budget to fund disbursements as per budget allocation regulations, the rest is retained to reinvest in local infrastructure and support the local private sector. Recent local investments in infrastructure have contributed significantly to the development of the private economic sector, especially the businesses located in the area. It is believed that when the government has a large tax revenue and invests it in areas that effectively support the private sector, the local businesses will be more profitable. Furthermore, large tax revenue for a period could lead to even more tax revenue in the next periods, as when businesses have more profits they pay more taxes, providing that the tax revenue is used to support enterprises efficiently. Table 5 shows that the marginal impact of tax revenue on firm financial performance is 3.88%, which is consistent with previous studies by Aghion et al [16] and Lisa Chauvet et al [25].

In addition to PCI, ICT index and tax revenue, labor productivity (LP) also positively affect firm performance. This is consistent with studies by Liu et al [29]. However, there is a negative impact of firms' investment on their performance with a marginal impact of -0.11%. This implies that firms in localities are not efficiently employing their assets or overinvesting under the local government investment stimulation policies. This result is quite similar to the research results of Nguyen Trong Nghia [32].

5. Conclusion and Recommendation

This study aims to evaluate the impact of institutional factors and tax revenue on firm performance in different provinces and cities in Vietnam. The results show the positive impacts of the provincial competitiveness index (PCI), ICT index, labor productivity, and taxes revenue on the performance of enterprises in 63 provinces and cities in Vietnam during the period of 2015 - 2021. However, there exists a negative interaction effect of PCI and LP on firm financial performance, which is explained by the lack of improving labor capability policies of local governments. In addition, firm financial performance does not vary in the same direction as firm investment. These results bring several policy implications for both local governmental authorities and businesses. Firstly, the authorities should take actions aiming to continuously improve the PCI and ICT index, especially in provinces and cities where these indicators are still low. In addition, a greater portion of tax revenue should be invested in technological infrastructure development projects and supporting activities improving labor capabilities in the context of digital transformation. Secondly, businesses need to comprehensively review and reassess investment projects to avoid spreading and overinvestment which causes waste and ineffectiveness. In addition, both local governments and businesses need to implement measures to develop a workforce that is proficient in using information technology and equipped with up-to-date knowledge and skills.

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Research on the Impact of Fiscal Subsidies on the Performance of High-Tech Enterprises – Empirical Evidence Based on High-Tech Listed Companies in Guangdong Province

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Abstract. This paper relies on the data of high-tech listed companies in Guangdong Province during the period from 2012 to 2022. With the return on total assets as the explained variable, financial subsidies as the explanatory variable, and enterprise age, enterprise scale, asset-liability ratio, and enterprise growth as control variables, a panel data regression model is constructed to empirically examine the influence of financial subsidies on the performance of high-tech enterprises. The findings indicate that financial subsidies exhibit a notable positive impact on the performance of high-tech enterprises within Guangdong Province and have passed the robustness test. Based on the research conclusions, targeted suggestions and countermeasures are proposed from both the government and enterprises to jointly propel the high-quality development of high-tech enterprises.

Keywords. fiscal subsidies; high-tech enterprises; enterprise performance; empirical research

1.Introduction

High-tech enterprises are marked by features like substantial investment, elevated risk, high value-added, and a high degree of technological sophistication. As the global economy evolves rapidly and technology advances continuously, high-tech enterprises are exerting an ever more significant role in driving economic growth and innovative development, emerging as a vital economic growth engine. To boost the development of high-tech enterprises, governments around the world have introduced numerous financial subsidy policies. Guangdong Province, being one of the most economically developed areas in China, its high-tech enterprises are highly representative across the

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country. In recent years, the Guangdong provincial government has implemented a series of policies in support of high-tech enterprises. How fiscal subsidies affect the performance of high-tech enterprises in Guangdong Province has become a question worthy of attention.

There is still some controversy and unresolved issues in the academic field regarding the impact of financial subsidies on the performance of high-tech enterprises. On the one hand, scholars believe that the financial department providing direct or indirect financial subsidies to high-tech enterprises can promote enterprises to increase investment in technological innovation, alleviate the problem of enterprise capital shortage, improve their own competitive advantages, and thereby improve enterprise performance (Shuyu Wei et al., 2021; Xingwu Luo et al., 2021; Ye Yang et al., 2015; Hewitt-Dundas et al., 2009)[1][2][3][4]. On the other hand, financial subsidies may make enterprises overly dependent on financial funds, easily making enterprises fall into a mentality of "waiting, relying, and asking for", weakening enterprises' independent innovation ability. Financial subsidies may also lead to market distortions, making resource allocation deviate from the optimal path, thus causing problems such as waste of resources (Xuyun Bai et al., 2019; Ying Chen, 2016; Catozzella and Vivarelli, 2016) [5][6][7].

Therefore, conducting in-depth research on the influence of financial subsidies on the performance of high-tech enterprises is beneficial not only for uncovering the results of financial subsidy policies but also has crucial referential significance for the sustainable development of high-tech enterprises. This paper is dedicated to comprehensively dissecting the effect of financial subsidies on the performance of listed high-tech enterprises in Guangdong Province. By carrying out an empirical analysis of the empirical evidence from listed high-tech enterprises in Guangdong Province, it clarifies the function of financial subsidies in enterprise development, offers a foundation for the government to formulate more scientifically rational subsidy policies, and simultaneously provides guidance for high-tech enterprises to better utilize financial subsidies to improve their own performance.

2. Research Design

2.1. Theoretical Analysis and Research Hypothesis

Based on the government intervention theory, when an enterprise receives financial subsidies provided by the government, other enterprises will think that this enterprise has good development prospects, thus attracting the attention and participation of investors (Feldman and Kelley, 2006) [8], improving the enterprise's credit level, driving sales, increasing enterprise profits, and improving enterprise performance. Next, under the government intervention theory, financial subsidies are of utmost importance in boosting enterprise performance. For one thing, as the R & D activities of high-tech enterprises frequently encounter pressure due to capital shortage, the government's provision of financial support to high-tech enterprises via financial subsidy policies can help ease the capital strain on enterprises and thereby drive the technological innovation of high-tech enterprises. Additionally, it can also lower the operating costs and financial expenses of enterprises, playing a positive role in enhancing the overall performance of enterprises. For another, financial subsidies can expedite the transformation of innovation achievements of high-tech enterprises. Innovation achievements are one of the core tasks for high-tech enterprises to achieve industrialization. Financial subsidies can reduce the cost of enterprise achievement transformation and help stimulate the enthusiasm of enterprises to transform scientific research results, essentially realizing the goal of cost reduction and efficiency increase. Hence, this paper presents research hypothesis H1.

H1: Financial subsidies have a positive impact on the performance of high-tech enterprises.

In recent years, with the aim of spurring the development of high-tech enterprises, the Chinese government has provided copious amounts of financial backing. However, the increase in financial subsidy funds may not necessarily lead to an improvement in the performance level of enterprises. Instead, it may trigger a series of negative impacts. First, although the financial subsidy policy does alleviate the financial pressure of high-tech enterprises to a certain extent, excessive financial subsidies may cause enterprises to develop a sense of dependence. Enterprises may devote more energy to obtaining subsidies rather than focusing on technological innovation and market expansion. This excessive dependence phenomenon will weaken the self-development ability and competitiveness of enterprises. Secondly, according to the information asymmetry theory, due to the government's insufficient understanding of the real situation of enterprise projects, after enterprises obtain financial subsidies, they use the funds for non-productive expenditures instead of using them to improve the enterprise's performance level. Finally, based on the principal-agent theory, enterprise managers may be overly pursuing short-term interests and disregarding the long-term development of the enterprise. They may invest resources in areas with large financial subsidies rather than making reasonable layouts according to market demand. This phenomenon of obtaining financial subsidies may lead to an imbalance in resource allocation. This phenomenon may lead to industry overcapacity and excess production capacity, resulting in an increase in corporate financial risks, such as a rise in debt levels and a decline in profitability, further affecting the enterprise's performance level. Therefore, this paper puts forward research hypothesis H2.

H2: Financial subsidies have a negative impact on the performance of high-tech enterprises.

2.2 Sample Selection and Data Sources

This paper takes the high-tech enterprises listed on Shanghai and Shenzhen A-shares in Guangdong Province as the research subject and chooses the data during the period from 2012 to 2022 as the initial sample. The data of the required variables are sourced from the CSMAR database. To ensure the coherence and validity of the sample data and the authenticity and reliability of the obtained research findings, this paper excludes high-tech enterprises with missing important data, ST and *ST enterprises, and high-tech enterprises that have been listed for less than one year or have been delisted. Statistical software is used to clean and sort the initial data. Finally, 450 high-tech enterprises are selected, with a total of 4034 observation samples.

2.3 Research Variables

2.3.1 Explained Variable

Enterprise performance is taken as the explained variable. When evaluating enterprise performance, multiple financial ratios are usually used as measurement standards. This paper uses return on total assets (Roa) as the standard for measuring the performance of high-tech enterprises (Jie Wu et al., 2024) [9].

2.3.2 Explanatory Variable

Financial subsidies are taken as the explanatory variable. Considering that the government mainly provides government subsidies to high-tech enterprises in the form of direct subsidies, by calculating the total amount of government subsidies, the financial support received by enterprise performance can be accurately evaluated, thereby better stimulating its innovation vitality (Chunmei Zheng and Pei Li, 2015) [10]. Therefore, the natural logarithm of the number of financial subsidies is selected as the government subsidy intensity.

2.3.3 Control Variables

Combining existing literature, this paper selects enterprise scale (Size), asset-liability ratio (Lev), enterprise age (Age), and enterprise growth (Growth) as control variables. The detailed definitions of specific variables are shown in Table 1.

Table 1. Variable Definition

Variable Type	Variable Name	Symbol	Variable definition
Explained Variable	Return on total assets	Roa	Net profit / total assets
Explanatory Variable	Financial Subsidy	Sub	Take the natural logarithm of the amount of government subsidy
Control Variable	Enterprise Scale	Size	The natural logarithm of the total assets of the enterprise at the end of the period
	Asset-liability Ratio	Lev	The ratio of total liabilities at the end of the period to total assets of the enterprise
	Enterprise Age	Age	The natural logarithm of the years of enterprise existence
	Enterprise Growth	Growth	(Current year's operating income - previous year's operating income) / previous year's operating income

2.4 Model Design

To explore the impact of financial subsidies on the performance of high-tech enterprises, this paper constructs a panel data regression model:

$$Roa_{i,t}=\alpha_0+\alpha_1 Sub_{i,t}+\alpha Control_{i,t}+\varepsilon_{i,t}$$

In the above research model, Roa is the explained variable; Sub is the explanatory variable; Control represents a series of control variables, ε represents random error, i represents the enterprise, and t represents the year.

3. Empirical Test and Analysis

3.1 Descriptive Statistics

This paper selects 450 high-tech listed enterprises in Guangdong Province from 2012 to 2022 as data samples and uses SPSS statistical analysis software for descriptive analysis. The results are shown in Table 2:

Table 2. Descriptive statistical analysis

Variables	N	Mean	sd	Median	min	max
Roa	4034	0.0406	0.0719	0.0432	-0.3821	0.2552
Sub	4034	16.3694	1.4936	16.3436	8.2940	21.7885
Size	4034	22.0378	1.1966	21.8931	19.5701	26.4523
Lev	4034	0.4003	0.1903	0.3997	0.0349	0.9268
Age	4034	2.9222	0.3554	2.9444	1.6094	3.6109
Growth	4034	0.1701	0.3613	0.1162	-0.6535	3.8940

From Table 2, it is observed that the average value of Roa is 0.0406, suggesting that the overall total asset profitability of sample enterprises is rather weak. The maximum and minimum values are -0.3821 and 0.2552 respectively, demonstrating a large disparity in Roa among enterprises. There is a significant difference between the maximum and minimum values of financial subsidies, and the standard deviation is 1.4936, indicating a large variation in the number of financial subsidies received by sample enterprises. The median of enterprise asset scale is 21.8931, suggesting that the asset scale of most high-tech listed enterprises in Guangdong Province is relatively large. The average asset-liability ratio is 0.4003 and is close to the median, indicating that the liabilities of most sample companies are at a reasonable level. The average enterprise growth is 0.1701, indicating that the overall sample enterprises possess certain development potential.

3.2 Correlation Analysis

To understand the influence relationship between financial subsidies and the performance of high-tech enterprises, this paper conducts Pearson correlation analysis on the relationship between various variables. The results are shown in Table 3.

The correlation coefficient between financial subsidies (Sub) and return on total assets (Roa) is 0.0713, and it is positively significant at the 1% confidence level. When enterprises obtain more financial subsidies, the performance level of sample enterprises can be improved. This preliminarily verifies the first research hypothesis H1 proposed. Enterprise scale (Size) and enterprise growth (Growth) also have a significant positive effect on the performance of sample enterprises. However, asset-liability ratio (Lev) and enterprise age (Age) have a negative and significant effect on the performance of sample enterprises. That is, the higher the debt-to-operation ratio of enterprises and the longer the business cycle time is, the less conducive it is to the improvement of enterprise performance.

Table 3. Pearson correlation analysis

Variables	Roa	Sub	Size	Lev	Age	Growth
Roa	1					
Sub	0.0713***	1				
Size	0.0360**	0.7161***	1			
Lev	-0.3096***	0.3412***	0.5108***	1		
Age	-0.0914***	0.1731***	0.2636***	0.2028***	1	
Growth	0.2789***	0.0243	0.0661***	0.0712***	-0.1170***	1

Note: ***, **, and * respectively indicate significance at the 1%, 5%, and 10% confidence levels.

3.3 Collinearity Diagnosis

In the research process, when the sample data is subjected to regression analysis, there cannot be obvious collinearity problems. Therefore, to evaluate the degree of collinearity between variables in the regression model, the variance inflation factor (VIF) is used as the evaluation criterion, and collinearity diagnosis is performed using SPSS statistical analysis software. The obtained results are shown in Table 4.

Table 4. Collinearity analysis

Variables	VIF	Tolerance
Sub	2.0591	0.4856
Size	2.5307	0.3951
Lev	1.3684	0.7308
Age	1.1055	0.9046
Growth	1.0288	0.9720

The VIF values of each variable in Table 4 are far below the empirical thresholds of 5 or 10, and their tolerance values also exceed 0.2. Therefore, there is no serious collinearity problem in the model of this paper.

3.4 Regression Analysis

To further examine the influence of financial subsidies on the performance of high-tech enterprises, this paper conducts regression analysis. The results are shown in Table 5. Column Roa (1) is before adding control variables. The regression coefficient value of financial subsidies is 0.0034, showing a significant positive effect on enterprise performance. Column Roa (2) is after adding relevant control variables. The regression coefficient becomes 0.0040, also showing positive significance. And the adjusted R^2 is greater than 0.2, indicating that the model fits well and the results of regression analysis are statistically meaningful. The regression results show that financial subsidies have a significant positive effect on the performance level of sample enterprises, and hypothesis H1 has been further verified.

Table 5. Results of regression analysis and robustness test

	Regression analysis	Regression analysis	Robustness test	Robustness test
	(1)	(2)	(3)	(4)
VARIABLES	Roa	Roa	Roe	Roe
Sub	0.0034***	0.0040***	0.0111***	0.0057***
	(4.5419)	(4.2296)	(7.4268)	(2.9217)
Size		0.0118***		0.0299***
		(8.9790)		(11.1227)
Lev		-0.1710***		-0.2725***
		(-28.1389)		(-21.9465)
Age		-0.0064**		-0.0127**
		(-2.1895)		(-2.1209)
Growth		0.0582***		0.1166***
		(20.9578)		(20.5648)
Adjust-R^2	0.0048	0.2367	0.0133	0.1956
N	4034	4034	4034	4034

Note: ***, **, and * respectively indicate significance at the 1%, 5%, and 10% confidence levels.

3.5 Robustness Test

In this paper, a robustness test is carried out by replacing the explained variable. Using return on equity (ROE) as the replacement variable for enterprise performance, robustness test is conducted on the full sample. The results are presented in Table 5. Column Roe (3) is before adding control variables. The regression coefficient of financial subsidy Sub is 0.0111 and is positively significant at the 1% level. Column Roe (4) is after adding control variables. The regression coefficient of financial subsidy Sub is 0.0057 and is also positively significant at the 1% level. This shows that the results of robustness test can further confirm hypothesis H1. Therefore, the research in this paper passes the robustness test, and the research results are reliable and stable.

4.Research Conclusions and Countermeasures

4.1 Research Conclusions

This paper takes high-tech enterprises listed on Shanghai and Shenzhen A-shares in Guangdong Province from 2012 to 2022 as the research sample. After data cleaning and sorting, 4034 valid samples are obtained, and empirical analysis is carried out using SPSS software. The research results show that financial subsidies have a significant positive impact on the performance of high-tech enterprises in Guangdong Province, and this research result has passed the robustness test. High-tech enterprises are the key driving force for economic development, injecting vigorous vitality into economic growth and laying a solid foundation for scientific and technological innovation. The government's financial subsidy policy can provide financial support for high-tech enterprises, reduce the operating pressure of enterprises, and fully stimulate the enthusiasm of enterprises to carry out technological upgrading and product research and development. At the same time, it also helps to open emerging markets and cultivate emerging demands, further enhance their own competitiveness, and then promote the increase of enterprise performance. For high-tech enterprises to better use financial subsidies to improve the enterprise performance level and promote the high-quality development of enterprises, the government and enterprises must implement necessary measures and management strategies.

4.2 Countermeasures and Suggestions

According to the research findings, this article offers countermeasures and suggestions from the aspects of government and enterprises.

(1) Government level. For the government to attach importance to the development of high-tech enterprises strategically, it cannot do without the policy guiding function of financial subsidies. On the one hand, as the unit that issues subsidy funds, the government should formulate unified issuance standards, strictly examine whether the enterprises applying for subsidies meet the subsidy standards, and strictly regulate the rent-seeking behavior of high-tech enterprises. Once discovered, the punishment for "pseudo-high tech" companies should be increased to exert the deterrent effect of policies. On the other hand, the government should vigorously strengthen the efficiency evaluation and subsequent supervision of the use of subsidy funds by high-tech enterprises. Set up a scientific and perfect evaluation system to comprehensively and precisely measure the actual benefits created by enterprises while using subsidy funds. For enterprises with high benefits generated by using subsidy funds, give positive incentives. At the same time, it is also necessary to strengthen subsequent supervision and build a tight supervision network to ensure that enterprises use subsidy funds in strict accordance with regulations, resolutely prevent enterprises from unilaterally changing the use of funds, put an end to possible adverse selection behaviors of enterprises, and severely crack down on illegal phenomena such as misappropriation of funds.

(2) Enterprise level. While receiving government financial subsidies, enterprises should rationally plan the use of funds, establish and improve internal financial management systems, and build a flexible and efficient resource allocation mechanism to ensure that subsidy funds can be accurately invested and generate the greatest benefits. Enterprises should boost investment in research and development, focus on core technologies and product innovation, and improve the quality and competitiveness of products or services to adapt to market changes and technological development trends. In addition, enterprises also need to strengthen internal management, optimize project operation processes, reduce management costs, and at the same time pay attention to the intelligent upgrading of production processes and intellectual property protection. In terms of talent cultivation, enterprises should establish a perfect talent introduction, cultivation and incentive mechanism, and strive to build a high-quality and professional team of scientific and technological talents to provide solid and reliable intellectual support for the long-term development of enterprises.

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The Importance Analysis of Network Edge Connection Under Dilution Poisson Shock Process

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Abstract. This study focuses on the robustness of the network system in the face of external random factors (such as heavy rain, high temperature and earthquake), especially considering the effective and ineffective shocks that the connected edge may suffer. In this paper, the dilution Poisson process is introduced to describe the impact of external random factors on the network, and the network reliability model is constructed. We propose a Bayesian inference-based edge importance calculation formula to quantify the impact of each edge on the overall network reliability and design the corresponding numerical algorithm to identify the weak link of the network. Theoretical analysis shows that the network with one side path or one side cut is the most vulnerable link. To verify the effectiveness of the proposed method, we carried out simulation experiments on IEEE39 power grid system. The numerical results show that the proposed method can fully and accurately identify the weak links of the network under the condition of sparse Poisson shock process and provide accurate decision support for network maintenance and reliability optimization. This study promotes the progress of traditional network reliability analysis by introducing the dilution Poisson process and Bayesian inference method. The proposed method is not only applicable to power systems, but also can be widely applied to many artificial intelligence fields such as intelligent Internet of Things and autonomous driving systems. Therefore, the research results of this paper have important guiding significance for the reliability optimization of network system and the development and application of artificial intelligence technology.

Keywords. Dilution Poisson process; artificial intelligence; network reliability; bayesian importance; Weak link

1. Introduction

In modern society, network systems play a key role, but faced with the impact of external random factors, the robustness and reliability of network systems has become a hot issue. This paper focuses on the assumption of absolute reliability of network nodes, taking several key nodes as research objects, and the situation that the edge will fail with a certain probability. Generally, the network will operate in a random environment, and the connected edge may fail due to the impact of external random factors, which will cause the operation of the whole network system to be blocked or even collapse, which will bring serious consequences to real life. Therefore, the combination of artificial

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intelligence and network edge importance analysis can provide a more accurate and scientific decision basis for the reliability of network system. Based on this, this paper analyzes the importance of network connection under the impact process through the importance theory, quantifies the relative importance of different connections to the reliability of the whole network, to help identify the weak link of the network system.

In this paper, the diluted Poisson process is used to describe external random shocks, including effective and ineffective shocks. By constructing the network reliability model, we develop the edge-connected Bayesian importance formula and carry out theoretical analysis to determine its maximum value and design an algorithm to identify the weak link of the network. The aim of this paper is to provide more accurate and efficient methods and decision support for reliability analysis and optimization of network systems. The combination of artificial intelligence technology and network edge importance analysis is expected to promote the application and development of artificial intelligence in the network field.

2. Index selection

To explore the impact of external random shocks on the system, Shock Model is commonly used to simulate the state changes of the system under unexpected random shocks. At present, there are mainly four types of shock models: cumulative shock model[1], extreme shock mode[2],δ-shock model[3]and operational shock model [4]. Although various shock models have been studied and applied in the field of reliability over the years, they only focus on the mechanism of the change of the overall reliability of the system and fail to quantify and analyze the impact of component failures on the system, and thus fail to accurately identify the weak links of the network.

Importance[5] is used to quantify the contribution of network components (such as nodes or connected edges) to the overall reliability. It is a basic method to find the weak link of the system and is widely used in reliability analysis. In recent years, there are two main methods to calculate the importance of network components (nodes or connected edges). One is the component centrality index measurement method determined by the location of nodes or connected edges in the network, such as degree centrality[6], intermediate centrality[7], proximity centrality[8], K-Shell centrality[9] and other indicators. Based on these single index methods, some scholars combined different centrality measures to put forward a new importance calculation method or improve it. Hu Gang et al.[10] established an importance transmission matrix based on the transmission capabilities of paths and information between associated nodes, and comprehensively evaluated the importance of nodes by combining local and global attributes. Another major method to calculate the importance of network components (nodes or edges) quantifies the impact of edge reliability on the reliability of the entire network based on the failure Angle of the network system. For example, Birnbaum Reliability importance[11], Bayesian reliability importance[12], Reliability Achievement Worth[13]and redundancy importance[14].

In reviewing the existing studies, it is found that these methods of evaluating the importance of network components mainly assume the stability of the external operating environment, but the current research has not considered the case of ineffective shocks. Therefore, considering the invalid shock and quantifying the importance of the network edge is very important to accurately identify the weak link of the network and provide decision basis for network reliability optimization and maintenance.

3. Model building and testing

3.1. Dilution Poisson shock process

3.1.1. Sparse Poisson shock process

We treat the shock process as an external, instantaneous, and potentially harmful event that can cause a system or its components to fail. We assume that the network system is subject to orderly, independent external shock processes, and that the network is subject to at most one shock at any given time, disregarding the case of multiple shocks. Each shock will cause one of the randomly selected operating connected edges to fail with probability p, while the probability of no failure is 1-p. These shocks that cause a connected edge to fail are called "effective shocks"[15]. It is assumed that the external random total shocks obey a Poisson process with an arrival rate of λ, and according to the Poisson process decomposition theorem, the effective shocks {N(t), t≥0} are p-sparse processes of the total shock process, that is, N(t) obees a Poisson process with a strength of pλ. Therefore, the random variable N(t) represents the total number of effective shocks suffered by the network in the time period [0, t], and also represents the total number of connected edges that fail due to random shocks, which satisfies the following conditions:

(1)N(0)=0, that is, the network and all connected edges in the initial state operate normally;

(2){N(t),t0} indicates an independent incremental process;

(3) For any 0s<t, there are N(t)-N(s)~P(p(t-s));

(4) N(t)=0,1,... ,n,t≥0, that is, when all n connected edges fail, the external impact process ends.

Suppose a network system with n connected edges, where k represents the number of failed connected edges at time t. According to the above shock process, when the effective shock {N(t), t≥0} reaches saturation at k=n, then the probabilistic mass function of N(t) at time t can be expressed as the following piecewise function:

$$P\left(N(t)=k\right)=\begin{cases}\dfrac{e^{-p\lambda t}}{k!}(p\lambda t)^k, & k=0,1,\dots,n-1,\\ 1-\sum_{k=0}^{n-1}\dfrac{e^{-p\lambda t}}{k!}(p\lambda t)^k, & k=n.\end{cases} \quad (1)$$

Both hereλ and p represent the strength parameter of this effective shock process.

3.2. Analysis of the importance of network edge connection

Bayesian reliability importance refers to the probability that a component will fail when a system fails, and is calculated as follow[16]:

$$BAY_i(t)=P\left(x_i(t)=0\,|\,\varphi(t)=0\right) \quad (2)$$

Given a network system containing n connected edges, under the background of the effective shock process {N(t),t≥0}, the Bayesian reliability importance calculation formula of the network connected edge i at time t is derived.

Using the conditional probability formula P(A ∣ B)=P(A,B)/P(B), and substituting formulas (1) and (2) into (3), the Bayesian reliability importance of connected edge i is expressed as:

$$\begin{aligned} BAY_i(t) &= P\left(x_i(t)=0 \mid \varphi(t)=0\right) \\ &= \frac{P\left(\varphi(t)=0, x_i(t)=0\right)}{P\left(\varphi(t)=0\right)} \\ &= \frac{\sum_{k=0}^{n} P\left(N(t)=k\right) D\left(k, 0_i\right)}{\sum_{k=0}^{n} P\left(N(t)=k\right) D(k)} \end{aligned} \quad (3)$$

Further, using the total probability formula, P(xi(t)=0) can be expressed as:

$$\begin{aligned} P\left(x_i(t)=0\right) &= \sum_{k=0}^{n} P\left(N(t)=k\right) P\left(x_i(t)=0 \mid N(t)=k\right) \\ &= \sum_{k=0}^{n} P\left(N(t)=k\right) \frac{k}{n} \end{aligned} \quad (4)$$

Theorem for the network G=(V, E,T) containing n connected edges, assuming that its connected edges are subjected to an external impact process, of which the effective impact process {N(t),t≥0}, at a fixed time t, then the following conclusion holds:

① When the network has a unilateral path {r}, the maximum value of BAYi(t) (i=1,2,· · ·,n) is 1, and BAYi(t)=1 if and only if the connected edge i is a unilateral path r;

② When the network has a unilateral cut {r}, the maximum value of BAYi(t) (i=1,2,· · ·,n) is $\frac{\sum_{k=0}^{n-1} P\left(N(t)=k\right)\frac{k}{n}}{\sum_{k=0}^{n-1} P\left(N(t)=k\right) D(k)}$, and BAYi(t) reaches the maximum if and only if the continued edge i is a unilateral cut r′.

4. Analysis and explanation of model results

This section is demonstrated by IEEE39 power network system. Figure 1 shows the grid node system diagram of IEEE39, and Figure 2 shows the abstract network system model composed of 39 nodes and 46 connected edges[17]. The nodes represent major equipment such as generators and substations, while the connected edges represent power lines such as transmission lines and transformer branches. When any two key nodes in T={14,17,31} lose connectivity, the entire network system will fail. On the contrary, when no external shock occurs, the network system will maintain normal operation. The effective shock process {N(t), t≥0} of the network connected edges in Figure 2 follows the diluted Poisson process with arrival rate p, and the random variable N(t) represents the total number of effective shocks to the network at time t and the total number of faulty connected edges in the network at time t.

Observing Figure 2, you can see that the failure of edge 14 causes the key vertex 31 to lose connectivity with the other vertices, so 14 is a unilateral cut of the network. To further verify the advantage of the network connected edge importance analysis considering invalid shocks in identifying the weak link of the network, it is compared with the network connected edge importance analysis considering only effective shocks. Algorithm 1 is executed to obtain the D-spectrum of the network and the connected edge, and the Bayesian reliability importance of the connected edge BAYi(t) is calculated. Take λ=0.5, and at t=0.1, 10, 40, 100, Table 1 shows the comparison of the top 10 edges ranked by the importance of the connected edge under the condition of considering only effective shock (p=1) and invalid shock (p=0.5).

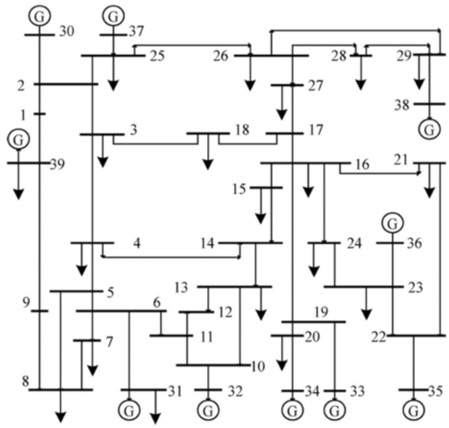

Figure 1. IEEE39 node system.

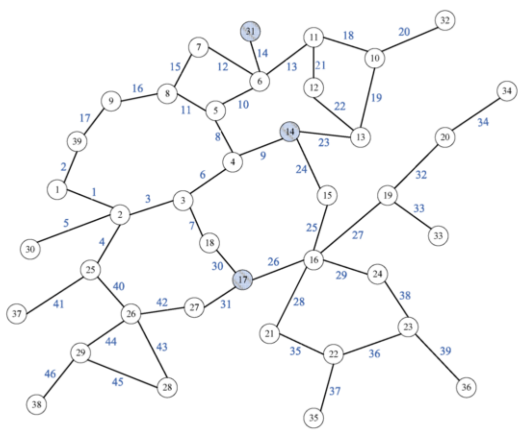

Figure 2. IEEE39 power network consisting of 39 nodes and 30 edges, T={14, 17, 31}.

Table 1. Comparison of importance ranking of edges under considering only effective shocks and ineffective shocks

	p=1				P = 0.5			
Sort	Straight edge *i* (*t*= 0.1)	Straight edge *i* (*t*=10)	Straight edge *i* (*t*=40)	Straight edge *i* (*t*=100)	Straight edge *i* (t = 0.1)	Continuing edge *i* (t=10)	Straight edge *i* (*t*=40)	Straight edge *i* (*t*=100)
1	14	14	14	14	14	14	14	14
2	20	26	9	16	20	26	8	9
3	4	24	8	46	38	25	9	8
4	38	25	26	11	4	24	26	26
5	28	6	24	18	28	6	6	24
6	44	7	25	27	44	30	25	25
7	22	30	6	38	22	7	24	6

8	11	8	30	10	11	8	30	10
9	30	9	10	12	46	13	7	30
10	46	23	7	45	30	23	13	7

From Table 1, the connecting edge 14 is always the most important connecting edge at all times, which is consistent with considering invalid shocks. By comparing the two cases, it can be found that only when t=40 is used in the short and medium term of network operation, the top 10 connected edges in the order of importance are consistent with that when invalid shocks are considered, and they are the connected edges of the two smallest paths forming the network, which further verifies the results of theoretical analysis. However, in the short term (t=0.1), short and medium term (t=10) and long term (t=100) of network operation, when only effective shocks are considered, the top 10 connected edges of importance ranking are inconsistent with the theoretical analysis results, resulting in the inability to determine the importance order of these connected edges, and thus the weak links of the network cannot be accurately identified. Nor can it provide decision-making suggestions for system reliability optimization.

5. Conclusions and Suggestions

In this paper, we study the actual network systems such as electric power and traffic, consider the cases of effective or ineffective shocks to the connecting edges of the network, use sparse Poisson process to describe external random shocks, and build a network reliability model. Through the simulation experiment of IEEE39 power grid system, the method of calculating the Bayesian importance of network connection under the condition of sparse Poisson shock process is demonstrated. The numerical results show that the method can fully identify the weak link of the network and provide a basis for the reliability optimization and maintenance decision of the power system. Combined with artificial intelligence, the method provides an intelligent scheme for the identification of network weak links and reliability optimization. In addition, the network reliability model under the shock process constructed in this paper assumes that each external random shock may cause a random operation of the edge failure, or no effect. However, the actual network may simultaneously cause two or more connected edges to fail when it is impacted. Therefore, in the future study, we will consider the impact process of multiple connected edges simultaneously failing for network edge importance analysis.

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Construction and Application of Knowledge Graph of Petroleum Industries Standards

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Abstract. Petroleum industry is currently undergoing a critical period of "digital transformation and intelligent development." As standards are an important component of national economic and social development, their digital transformation is an inevitable trend. To address the problems of the inability to systematically and efficiently utilize standard knowledge in the petroleum industry, as well as the barriers to knowledge transmission between machines and standard documents, this article takes petroleum industry standard documents as the data source. This article summarizes the model construction strategy, information extraction scheme, knowledge fusion and storage. Finally, the application of the standard document knowledge graph is discussed. To establish the foundation for the direct application of key indicators and other knowledge in standards by machines and provide reference ideas for other fields to conduct digital research on standards.

Keywords. Petroleum industries, Standards, Digital transformation, Knowledge graph

1. Introduction

On October 29, 2021, the China National Petroleum Corporation issued a notice titled "Digital Transformation and Intelligent Development", which clearly mandates the company to promote digital transformation and intelligent development. The development of the petroleum industry relies heavily on standards, which have evolved into an essential component of core competitiveness today. In order to achieve mutual compatibility between standard knowledge and petroleum industry technology and equipment undergoing digital transformation, the development of standard digitization has become an important direction for current standardization work. Currently, the related document clearly suggests that we should promote the transformation of standardization work towards digitization, networking, and intelligence.[1]

Standard digitization typically involves four stages. The first stage is using traditional standards that can automatically manage and display documents like WORD or PDF. The second stage involved machine recognizable standards, which process standard documents based on optical character recognition technology. They create double-layer PDFs with separate document editable layers and display layers. It is possible to export

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coarse-grained content including chapters, graphics, definitions, etc. The third stage is the machine executable standard, which extracts all significant information units and records their interrelationships, thereby enabling the machine to directly acquire standard knowledge and implement it. The fourth stage is the machine decidable standard, in which the information in the standard is linked to other information sources and used by the machine to automatically perform complex operations and decision-making processes.[2] Simultaneously, this stage requires real-time gathering of information, updating indicators and other knowledge according to actual conditions for standards. Ultimately, unmanned operation throughout the entire lifecycle of the standard will be achieved. Based on a large number of scientific research projects, the petroleum industry has achieved the second stage of storing standard documents in double-layer PDF format. However, this stage is unable to utilize standard knowledge efficiently, and data transmission barriers between machines and standard documents still exist. Knowledge graphs have a good expression of knowledge units and their relationships, which can be better organized and managed massive amounts of information. As a core technical means of the machine executable standard stage, it has received widespread attention.

The knowledge graph is a data structure based on graphs that was developed on the basis of conventional knowledge bases. It is comprised of nodes and edges, with each node representing an "entity" and each edge representing a "relationship" between entities. Knowledge graph is a type of semantic network.[3] The knowledge graph describes entities that exist in the real world and the relationships between them. The basic forms of "Entity 1-Relationship-Entity 2" and "Entity-Attribute- -Value" are shown in Table 1. The knowledge graph has been extensively utilized in various fields such as intelligent search, intelligent question answering, personalized recommendation, among others, due to its flexible form and high scalability.

Table 1 Elements of Knowledge Graph Composition

Entity	Something that is distinct and exists independently.
Attribute	The entity points to the value of the attribute.
Relationship	A function that maps graph nodes (entities, semantic classes, attribute values) to Boolean values.

The above-mentioned characteristics enable knowledge graph to handle various structured and unstructured documents in accordance with machine-recognizable standards. Performing knowledge graph processing on documents will provide an intelligent data foundation. Based on an analysis of the characteristics of petroleum industry standard documents, this article summarizes the model construction strategy, knowledge acquisition scheme, knowledge fusion, and storage methods of standard knowledge graph, and analyzes their advantages and disadvantages. It also explores the application of standard knowledge graph.

2. Related works

With the continuous development of computer technology and management science, knowledge graphs have been widely applied in semantic search fields such as Google, Baidu, Meituan. [4] In addition, it has been widely applied in some vertical fields such as finance, healthcare, etc. [5-8]

In the field of general standard documents, some research groups have constructed literature related knowledge graphs based on the "introduction" and "normative reference " of the standards.[9] At the same time, by defining the basic and key elements of standard documents, some research groups analyze the method of constructing a standard knowledge graph. [10] Relevant researchers analyze the characteristics and structure of standard texts, examine the knowledge associations of standard documents, and construct the RDM model of standard document knowledge graph.[11] Some researchers have also defined the relationship between standard element entities and standard documents by analyzing the application scenarios of standard document knowledge graphs, thereby confirming the process of constructing standard document knowledge graphs.[12] In terms of standard text format, the research team converts traditional standard text into XML documents for parsing, and then constructs its ontology layer to complete the construction of the knowledge graph. Due to the characteristics, there is little research involved in the petroleum industry.[13]

3. Characteristics of Petroleum Industry Standard

Petroleum industry standards include national, industry, group, and enterprise standards related to petroleum geology, petroleum geophysical exploration, petroleum drilling, logging, oil and gas field development, oil and gas production, oil and gas storage and transportation, oil and gas measurement and analysis methods, petroleum pipe materials, and other fields. This type of standard differs from general scientific papers in terms of technical content, structure, etc., and is mainly manifested in:

(1) Coordination. Each standard has a relatively central standardization object and a defined scope of application and will endeavor to avoid unnecessary variances as much as feasible. Only when it appears in different levels of standards, there may be differences in the relevant indicators of the standardization object. However, it must follow the principle of “the indicators of group standards must be higher than that of national and industry standards, and group standards with indicators lower than national and industry standards are invalid standards".

(2) Timely. Standard documents are subject to continual revision, replacement, or even elimination with the advancement of economic and technological levels, resulting in the knowledge contained within them being constantly updated.

(3) Standardized forms of expression. The names, levels, and elements of standard documents are strictly drafted in accordance with the guidelines of GB/T1.1 "Directives for Standardization- Part 1: Rules for the Structure and drafting of standardizing documents". The overall structure of the text is well-organized, and the expression form is standardized.

(4) The content is complex. The standard documents for the petroleum industry contain a wide variety of professional content and a wide range of specialties, with different standardization targets and tendencies for each specialty.

4. Construction of Standard Knowledge Graph

4.1 Construction of Standard Knowledge Ontology

The construction of the Ontology model of standard knowledge utilizes domain knowledge and standard application scenarios as inputs and generates a domain knowledge ontology comprising domain entity category system, entity attributes, domain semantic relationships, and relationships among semantic relationships through the utilization of key technologies such as ONTOLOGY ENGINE.

The ontology construction technology includes two directions, namely top-down and bottom-up. The top-down construction method generally involves domain related experts starting from top-level concepts and gradually refining them in order to construct a structure with a clear hierarchy. The bottom-up construction method is based on analyzing and organizing existing domain terminology sets and extracting upper level concepts.

Petroleum industry standards not only have differences in professional technical content, but also differences in standard categories, such as product standards, method standards, guidelines, etc. Different types of topics should have distinct ontology designs, and for the same type of topic, it is imperative to ensure that corresponding entities and relationships can be extracted from diverse documents. Based on the standards themselves and practical use, the top-down and bottom-up methods are usually combined to meet the universality of the standard ontology, while taking into account the characteristics of various professional branches and standard categories.

4.2 Standard knowledge acquisition

Standard knowledge is acquired through the acquisition of standard documents and output of domain knowledge, entity sets, and entity relationships/attributes.

Information extraction, which is the main technology for standard knowledge acquisition, is a text processing technique that extracts specified types of entities, relationships/attributes, and other factual information from natural language texts, and forms structured data output. The main tasks are to recognize entities and extract relationship and attribute.[14]

Entity extraction should be being with Chinese word segmentation, which involves using machines to add tags between words in Chinese text. It is possible to match the Chinese character string to an entry in a complete and comprehensive dictionary by following a certain strategy. If a string is found in the dictionary, it matches. This method is easy to do and doesn't require much language source. It doesn't require any lexical, syntactic, or semantic resources. However, this method has poor ambiguity resolution ability, and low segmentation accuracy. It heavily relies on the quality of the dictionary.[15] The development of machine learning and other technologies has led to the gradually research of statistical segmentation methods. Initially, establish a model for generating learning samples, and subsequently utilize the model to indirectly infer the predicted outcomes. This technique is capable of achieving high segmentation accuracy when the size of the training corpus is sufficiently large and the coverage area is extensive enough. The indicators commonly used to determine the results of information extraction include accuracy, recall, and F-value (the combined value of accuracy and recall). When the training corpus size is small, the segmentation model for information extraction relies too heavily on training samples, while annotation of large-scale training samples is time-consuming and laborious. This results in poor recognition ability of the segmentation system for new words and a significant decrease in performance on test sets that differ greatly from the training samples. At the same time, the recognition performance of entities and proper nouns is low, and it is also difficult to recognize situations where one word has multiple meanings or meanings. In the information extraction of standard documents, it is important to consider the sample size.

Professional terminology and literature databases can help with the limited number of standards in each field and the numerous professional terms.

Entity relationship extraction is the automatic recognition of related triplets composed of a pair of entities, and the relationships that connect them. To extract relationships from standards, the main sources are standard texts and encyclopedia websites. Standard text, as a pure text data type, is complex, diversified, large-scale, and exhibits significant noise. At present, machine learning methods are primarily used. Firstly, relationship instances are converted into feature vectors in high-dimensional space or directly represented by discrete structures through manually annotated corpora. Subsequently, classification models are trained on annotated corpora, and entity relationships are identified.[16] For some companies that have established universal professional knowledge websites, the website possesses a good information correspondence structure and is capable of recognizing information blocks by utilizing module learning to extract attribute values.

There are multiple fields of standards in the petroleum industry, and the directions and types of standards in different fields have different tendencies. Deep learning is the first choice for handling standard documents when construction methods don't require manual labor. [17] There are two issues to consider: 1) Sample problem. In order to obtain high-quality information extraction results and application accuracy, it relies on a substantial quantity of training corpus. (2) Time efficiency. Deep learning, especially recurrent neural networks, has a time complexity proportional to the square of the text length. This makes it difficult to implement in large-scale data usage scenarios. Therefore, when selecting techniques for constructing standard knowledge graphs, it is necessary to choose appropriate techniques based on the amount of standard text. Furthermore, the standard contains multimodal information such as text, tables, and images, all of which have key core indicators that guide production use. This makes it difficult to use universal information extraction methods to extract entities and relationships.

4.3 Integration and Storage of Standard Knowledge

Standard knowledge needs to balance autonomy and dynamism while having shareability. Based on feature expressions that combine contextual semantic information, extracted knowledge, existing databases, and knowledge ontologies are taken as inputs. It is essential to link and integrate the extracted standard information with each other. After eliminating contradictions and ambiguities, standard knowledge is stored as a unified knowledge base.

Standard knowledge integration is mainly used to merge multiple standard knowledge graphs and solve the matching between the ontology layer and the instance layer. Standards encompass multiple levels, such as national standard, industry standard, and group standard, as well as multiple types, such as products and methods. Each standard has its own specific knowledge base. In the absence of knowledge fusion, it is easy to form a knowledge island, which is unsuitable for future intelligent applications.[18]

Knowledge fusion involves the process of parsing and cleaning existing knowledge graphs and data from different sources, constructing basic data, and then performing matching calculations through the construction of matching clues and similarity calculations. The obtained results are extracted and evaluated, and the corresponding matching tuning is completed.

Knowledge graph has both table and graph characteristics. Knowledge graph is stored based on table structure or/and graph structure according to different usage scenarios. Table-based storage refers to the utilization of two-dimensional data tables to store data within a knowledge graph, such as triplet tables, type tables, and relational databases. Graph-based storage refers to the utilization of graphs to store data within knowledge graphs, such as graph databases. Most database systems give users with interfaces for accessing data through formal query languages, such as SQL, which is the standard query language for relational databases. SPARQL is the standard query language for graph databases. [19] Since knowledge graph is logically a graph structure, graph query techniques can also be used to search for specific query graphs. The primary concern is to ascertain whether the query graph is a subgraph of the graph dataset.

4.4 Application of Standard Knowledge Graph

The application of the standard knowledge graph is based on diverse stakeholders, such as design selection, product manufacturing, inspection and testing, among others. The main modes of usage include retrieval and intelligent question answering. Providing applications such as search and intelligent question answering based on knowledge graphs will improve the efficiency and quality of problem-solving for standard stakeholders. Empowering standard services and management by incorporating knowledge throughout the entire lifecycle of standards will enhance the automation capabilities of standard service systems/machines, enhance intelligence levels, and reduce labor costs.

The main types of retrieval are word retrieval, multi-word retrieval, and semantic retrieval. Retrieval in sentences and paragraphs is achieved mainly through recognition of entities and relationship extraction in knowledge graphs, and it's capable of quickly locating relevant data. By using a specific query language, correlation matching can be achieved.

Intelligent Q&A is mainly based on the knowledge base, which is the process of parsing natural inquiries and obtaining responses from the knowledge base. Intelligent Q&A differs from information retrieval in that it does not return a list of relevant documents (evidence of Q&A) that may contain answers, but instead provides directly accurate answers. Firstly, by parsing the question sentences, the referential relationships are clarified, and the entity links are completed. Then, the task is placed in the graph to analyze its text and structure. [20] After rearranging and filtering the answers, users can obtain the corresponding answers. For reasons such as incomplete knowledge in the knowledge base, knowledge base Q&A also requires the support of reasoning techniques, including inductive reasoning, deductive reasoning.[21]

5. Discussion

(1) Due to the diversity of standard knowledge, it is necessary to detect and correct possible errors in knowledge graph construction, including spelling errors in text, entity recognition errors, etc. At the same time, it is necessary to remove irrelevant or duplicate data to ensure that the information in the knowledge graph is clean and useful.

(2) To achieve the transformation of knowledge graph construction from semi-manual to unmanned, machine learning is indispensable. To obtain high-quality machine learning results, sample size is crucial. In addition to standard texts, academic journals,

technical reports, and other materials related to the field can be introduced as supplements.

6. Conclusion

This article proposes to combine the characteristics of standard documents with use the method of constructing standard knowledge graphs to continuously refine the granularity of standard knowledge, laying the foundation for the direct application of key indicators and other knowledge in standards by machines. It also provides a reference for other fields to carry out standard digitization research.

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The Research on Automatic Location Algorithms for Partial Discharge in Long Vertical Shafts GIL

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Abstract. Due to the long pipeline distance and weak signals, achieving precise localization of partial discharge occurring in GIL (Gas-Insulated Line) is challenging. This paper conducts key technological research on the automatic localization of partial discharge in GIL, developing an algorithm specifically for the automatic localization of partial discharge in GIL. This algorithm effectively overcomes the difficulties posed by the long distance and weak signals of GIL, enabling accurate identification and localization of defects, as well as assessing the risk levels of these defects. Hence, it ensures the safe and stable operation of power systems in the watershed.

Keywords. Partial discharge, gas insulated line, automatic location, rapid deployment

1. Introduction

GIL (Gas Insulated Transmission Lines), which utilize SF_6 gas for insulation, are metallic enclosed long-distance power transmission devices [1]. They play a crucial role in power transport due to their advantages, including high transmission capacity, flexible spatial arrangement, high reliability, long service life, and minimal environmental impact [2]. However, partial discharge is a primary factor leading to defects and hazards in GIL equipment, necessitating early detection and remediation of discharge sources to prevent severe failures, such as insulation failure [3].

Currently, mainstream partial discharge detection and localization devices have relatively singular functions. Some devices focus on the detection, diagnosis, and analysis of partial discharge but have limited localization accuracy, generally around 1 meter [4]. Other devices employ high-speed sampling oscilloscopes, requiring specialized personnel to connect and operate high-performance oscilloscopes on-site to measure the time difference of partial discharge pulse arrivals [5]. Consequently, the discharge source location is manually calculated, and variations in the operation methods of different personnel can lead to slight discrepancies in the localization of the partial discharge source [6-8].

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Regarding the application of long vertical shafts for GIL in certain hydropower stations, the UHF (Ultra-High Frequency) sensors installed on the GIL can reach a maximum distance of 250 meters [9]. At such distances, the electromagnetic wave signals experience significant attenuation. For effective localization, it is necessary to customize special cables exceeding 100 meters in length, which also leads to considerable signal degradation [10-15]. Therefore, it is crucial to enhance the performance of the UHF partial discharge signal acquisition front end in long vertical shafts.[16]

In practical applications, intermittent partial discharge in GIL can account for approximately 30% of occurrences [17]. Due to their sporadic nature, traditional detection devices are prone to missing these events as a result of sampling logic limitations, which adversely affects the detection rate of defects [18]. When intermittent discharges occur within GIL, the on-site presence of equipment specialists, multiple partial discharge manufacturers, and operational maintenance personnel for continuous monitoring are required, which sometimes extending over several hours or even days [19]. This process necessitates repeated monitoring to ascertain the specific development trends of partial discharge and locate their sources, resulting in substantial labor costs [20].

Meanwhile, to address the hazards posed by intermittent signals, it is often necessary to use high-performance oscilloscopes on-site for prolonged signal localization and the deployment of critical care equipment, resulting in additional equipment and service costs that lead to derivative economic losses.

Therefore, this paper conducts research on the key technologies for the automatic localization of partial discharge in GIL. An algorithm for the automatic localization of partial discharge in long vertical GIL has been developed, capable of overcoming challenges posed by the long distances and weak signals associated with GIL. The proposed algorithm can accurately identify and locate defects in GIL, assess the risk level of these defects, ensuring the safe and stable operation of the regional power system.

2. Ultra-high frequency time-difference localization method for partial discharge

When partial discharge occurs within GIL equipment, electromagnetic waves propagate from inside the equipment. Upon encountering solid metal or enclosures, these electromagnetic signals experience significant attenuation. To ensure the accuracy of live measurement and localization, it is essential to calculate the time delay between different sensors and to locate the position of the partial discharge. The principle of UHF positioning method is shown in Figure 1.

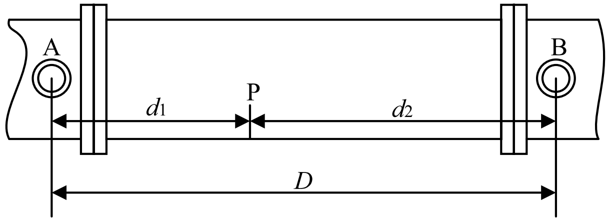

Fig. 1. The principle of UHF positioning method

Assuming that the discharge pulse arrives at points A and B at t_1 and t_2, respectively, and that the velocity of propagation of the discharge pulse in the GIL is the speed of light c, the distances d_1 and d_2 from point P to points A and B can be expressed as follows:

$$\begin{aligned} d_1 &= ct_1 \\ d_2 &= ct_2 \end{aligned} \tag{1}$$

From this we know that the formula for d_1 is:

$$d_1 = ct_1 = D - ct_2 = \frac{D - ct_2 + ct_1}{2} = \frac{D - c(t_2 - t_1)}{2} \tag{2}$$

As shown in Equation (2), as long as the time difference between t_1 and t_2 is calculated, d_1 can be obtained. The time difference between t1 and t2 is expressed as:

$$\Delta t = t_2 - t_1 \tag{3}$$

Thus, Equation (2) can be rewritten as:

$$d_1 = \frac{D - c\Delta t}{2} \tag{4}$$

This method imposes stringent requirements on the accuracy of the time difference. Additionally, in practical partial discharge scenarios, noise interference is common, and distinguishing between partial discharge signals within the GIL and noise signals is also a challenge that the time-difference localization method must address.

In response to the limitations of traditional time-difference location methods, the localized discharge localization technology proposed in this paper enhances positioning accuracy by leveraging microscopic information from pulse waveforms and statistical data from positioning results, building upon the foundation of time-difference methods.

3. Calculation of time difference of arrival based on microscopic information of pulses

Based on the principal analysis from the previous section, the key to improving the accuracy of time-difference positioning methods lies in accurately determining the pulse arrival time and correctly calculating the time differences. Considering that the pulse waveform contains rich microscopic information, this paper will utilize the microscopic information captured from the collected pulse waveforms to achieve the determination of pulse arrival times and the correction of time differences.

3.1 Determination of pulse arrival time

The waveform of the discharge pulse exhibits a rapid rise before the peak and a gradual decline after the peak. Therefore, the localized discharge localization technique proposed in this paper employs a rising edge trigger mechanism to determine the time at which the pulse arrives at the sensor. This time is defined as the moment when the pulse voltage detected by the sensor exceeds a preset threshold. Given that the peak value of each pulse varies and the degree of attenuation differs when reaching different sensors, the established threshold should not be fixed. The specific method for setting this threshold is as follows: when the pulse reaches the sensor, the voltage amplitudes of the first *m* points collected by the sensor are recorded, and the threshold is set as twice the maximum value among these *m* voltage amplitudes, which can be expressed as:

$$T_i = 2\max\left|x_{qi}(n)\right| \tag{5}$$

In the equation, $x_{qi}(n)$ represents the amplitude of the *n*-th sample point among the first *m* sample points of the *q*-th pulse waveform collected by the *i*-th sensor, where *i* ranges from 1 to 2, and *n* ranges from 1 to *m*. The moment when the voltage of the *q*-th pulse first exceeds the set threshold is recorded as the arrival times t_{q1} and t_{q2} at sensors 1 and 2, respectively.

3.2 Calculation and correction of arrival time difference

After recording the arrival times t_{q1} and t_{q2} of the *q*-th discharge pulse at sensors 1 and 2, respectively, the time difference of arrival can be initially defined as:

$$\Delta t_q = t_{q2} - t_{q1} \tag{6}$$

To correct the calculated time difference, a window with a width of 2p is applied around the two arrival times t_{q1} and t_{q2}. This allows us to extract the most relevant segment of the pulse waveform, whose amplitude expression is given by:

$$y_{qi}(n) = x_{qi}\left(\Delta t_q - (p+1) + n\right) \tag{7}$$

In the equation, the range of values for *n* is defined as n = 1, 2, …2p + 1n=1,2, …2p+1.

To calculate the correlation of the *q*-th pulse waveform collected by two sensors within a window of width 2p:

$$R_{q12}(j) = \sum\nolimits_{n=0}^{2p-j} y_{q1}(n+j)\, y_{q2}(n) \tag{8}$$

In the formula, Rq12（j） represents the correlation of the *q*-th pulse waveform collected by sensor 1 and sensor 2 within the range of -p–p to pp, where the values of *j* are defined as j=-p, -p+1, …p.

3.3 The correction of positioning results based on statistical information.

According to the Central Limit Theorem in probability theory, when a large number of repeated experiments are conducted on random variables, the probability distribution will approach a normal distribution. In a normal distribution curve, there is a single peak, and the curve is symmetrical around the peak. The x-coordinate at the peak represents the mean of the experimental results. The reason the normal distribution exhibits this pattern is that, when the number of experiments is large, the points representing results equal to the mean are the most numerous, while the points representing results below and above the mean are approximately equal in number. Moreover, as the distance from the mean increases, the number of points decreases. Therefore, the peak of the distribution of random experimental results can be used to estimate the mean.

Using the time-difference positioning method to conduct multiple localizations of partial discharge is equivalent to performing repeated experiments on the variable of the localization results. When the number of experiments reaches a certain threshold, the distribution of localization results will theoretically approximate a normal distribution. Based on this principle, this paper plots the localization results on the x-axis and the number of localizations on the y-axis. The peak of the distribution of the localization results is utilized as the final localization result.

The online localization of partial discharge sources based on time-difference positioning methods is primarily influenced by the error in time difference. Specifically, this is manifested when complex devices, such as circuit breakers, are present; the electromagnetic waveforms can undergo a certain degree of distortion. This distortion affects the accuracy of time measurement for the arrival of electromagnetic waves at the sensors, leading to discrepancies between the localized position of the PD source and its actual location.

On the other hand, the dependability of online localization is also affected by disruptions, as well as the number and type of local discharge sources. Sometimes noise interference is a significant issue that cannot be overlooked. When multiple discharge defects exist within a GIL, discharge signals characterized by low pulse amplitude and infrequent discharges can easily be obscured by signals with high pulse amplitude and frequency. This may result in the localization process focusing solely on the discharge pulse from one defect, while neglecting others. It is important to note that noise signals are not generated by partial discharge and therefore their localization results do not exhibit a normal distribution. Conversely, different discharge defects do not discharge simultaneously, and their discharge pulses do not interfere with one another, allowing for separate localization.

In summary, when partial discharge signals are accompanied by noise signals, or when multiple discharge defects exist simultaneously, plotting multiple localization results on the same graph can yield a distribution that resembles the superposition of several normal distribution curves.

4. Case analysis

4.1 Case introduction

In August 2024, a partial discharge alarm signal was generated by an online monitoring system at a certain GIL. Sensors a are spaced 126.6 meters apart. The amplitudes detected by sensors a# and b# were -49.2 dBm and -53 dBm, respectively, with the spectrum displaying characteristics indicative of discharge in the insulation gap. The left image depicts the PRPD spectrum detected by sensor a#.

4.2 Case analysis

The signals from Sensor a and Sensor b are connected to Channel a and Channel b of a high-speed oscilloscope via 100-meter coaxial cables, utilizing a 30 dB preamplifier for signal amplification. Figure 2 presents the partial discharge waveforms detected by the GIL automatic localization device.

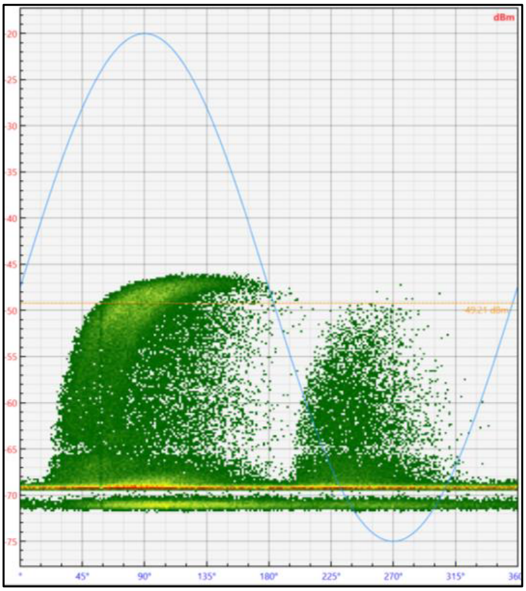

Fig. 2. Partial discharge PRPD

The signals from sensor a# and sensor b#, transmitted through a 100-meter optical fiber transmission component, are respectively connected to channels 1 and 2 of the GIL high-precision, long-distance, portable partial discharge automatic positioning device in the vertical shaft. Within 2 minutes, the device detected 5,074 partial discharge pulse signals. A typical original pulse waveform is shown in Figure 3. After automatic positioning by the device, the results indicate that the discharge source is located between measurement points a# and b#, approximately 34 meters from sensor a#.

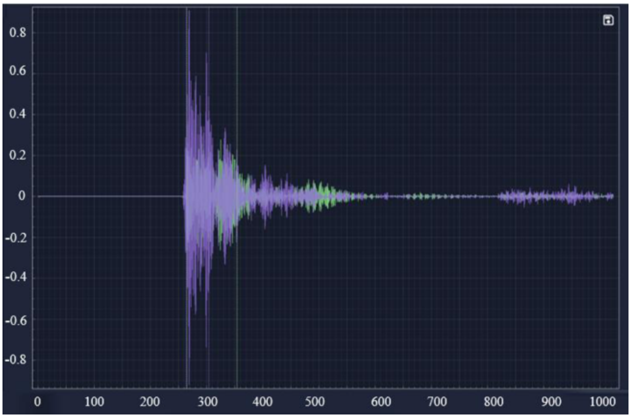

Fig. 3. Original pulse waveform

During the return factory testing using the pulse current method for partial discharge, no abnormal signals were observed during the gradual voltage increase at lower voltages. When the voltage reached 220 kV, signals began to appear with strong phase correlation, and the measured partial discharge quantity was 1.5 pC. As the voltage increased to 380 kV, the signals became significantly stronger and more distinctive, with the measured partial discharge quantity rising to 2.9 pC. The shape of the PRPD spectrum was largely consistent with the results from on-site testing. As the voltage continued to rise to 600 kV, the signals disappeared, and no further activity was detected even at the maximum voltage of 750 kV.

5. Conclusion

This paper develops an automatic positioning algorithm for GIL partial discharge. Compared with traditional ultra-high frequency positioning methods, considering that the pulse waveform contains rich microscopic information, this article will use the collected microscopic information in the pulse waveform to complete the verification of pulse arrival time and the correction of arrival time difference. The experimental case verified the effectiveness of the algorithm, which can accurately locate the partial discharge source in the GIL pipeline.

Acknowledgments

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Portable Long-Distance Partial Discharge Detection Device for Vertical Shaft GIL

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Abstract. GIL (Gas Insulated Line), known for its advantages such as high transmission capacity, flexible spatial arrangement, high reliability, long service life, and minimal environmental impact, has been widely used in various large hydropower stations. Existing online partial discharge monitoring devices and offline localization systems face the challenge of insufficient localization accuracy when identifying partial discharge in long vertical GIL This paper develops a high-precision, long vertical shaft GIL automatic partial discharge localization device based on the single-channel sampling rate of up to 20 GS/s and multiple channels with adjustable sampling rates for ultra-high-frequency synchronous triggering. Through an automatic threshold-triggering determination algorithm and a noise recognition algorithm, it can reliably capture the ultra-high-frequency original pulse waveform of intermittent partial discharge signals in GIL, achieving automatic localization with an accuracy of within 10 cm. This facilitates precise identification and localization of partial discharges in long vertical shaft GIL systems.

Keywords: Partial discharge, gas insulated line, online monitoring, fault diagnosis

1. Introduction

In recent years, gas-insulated metal-enclosed transmission lines (GIL) have increasingly been utilized as a type of metal-enclosed long-distance power transmission equipment in large hydropower stations, booster stations, and high-voltage power grids [1]. GIL employs sulfur hexafluoride gas as its insulating medium and offers numerous advantages, including high transmission capacity, flexible spatial arrangement, high reliability, long service life, and minimal environmental impact [2]. As a result, it has been widely adopted in several large hydropower projects [3-5].

Due to the significant role of GIL in power transmission, the GIL equipment operated by the various power stations along the Yangtze River is currently equipped with ultra-high-frequency partial discharge monitoring and location systems [6]. These systems are utilized for monitoring, diagnosing, analyzing, and preliminarily locating the insulation status of the GIL [7-10].

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However, in practical operations, the existing online partial discharge monitoring devices and offline location systems face challenges regarding insufficient positioning accuracy when locating partial discharges in vertically oriented GIL.

The UHF detection systems for partial discharge monitoring in vertical long-distance GIL exhibit several limitations: 1) Signal Attenuation and Distortion: UHF signals generated by PD events experience significant attenuation and distortion during propagation in vertical long-distance GIL structures, reducing the sensitivity of the detection system and potentially leading to undetected weak signals. 2) Limited Localization Accuracy: The multi-path effects and signal reflections inherent to long-distance vertical GIL structures complicate the measurement of time-of-arrival differences, thereby impairing the accuracy of PD source localization. 3) Challenges in Installation and Maintenance: The structural characteristics of vertical GIL configurations increase the complexity of sensor installation and maintenance, potentially leading to suboptimal sensor placement and reduced detection effectiveness. 4) Susceptibility to Electromagnetic Interference: UHF detection systems are prone to interference from external electromagnetic signals, and the vertical long-distance design of GIL may exacerbate external signal coupling, resulting in false positives or missed detections.

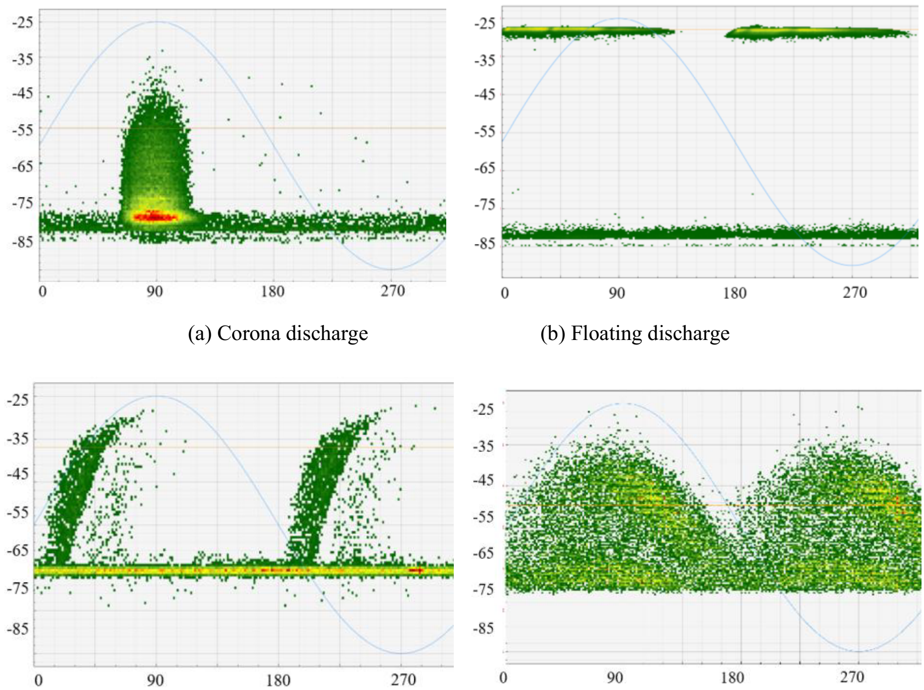
To better guide defect risk assessment and on-site maintenance work, this paper develops a high-precision, long-distance portable partial discharge automatic localization device for GIL in vertical shafts. This device aims to further understand the partial discharge signal characteristics of GIL defects, enhance the localization accuracy of partial discharge defects, assess the risk level of these defects, and provide more reliable technical support for maintenance decisions, thereby ensuring the safe and stable operation of power systems.

2. Research on Partial Discharge Type Identification

2.1 GIL Partial Discharge Type

In GIL, there are four main types of partial discharge that may occur: tip discharge, floating discharge, surface discharge, and metallic particle discharge [11]. The typical partial discharge PRPD (phase resolved partial discharge) pattern for these discharges are shown in Figure 1.

Corona discharge occurs when partial discharge is released through a sharp electrode, characterized by high current density and the production of significant light and sound [12]. Floating discharge takes place in a gas medium where the arc appears to be suspended, typically used for plasma generation. Surface discharge propagates along the surface of solid insulators, characterized by lower voltage and larger discharge area [13]. Metallic particle discharge results from the aggregation of metallic particles, which can adversely affect the insulation performance of equipment, leading to discharges and electrical breakdowns [14-15].



(a) Corona discharge (b) Floating discharge

(c) Surface discharge (d) Metallic particle discharge

Fig. 1. Partial discharge PRPD pattern

2.2 The preprocessing of PRPD pattern data

To enable neural network models to learn the characteristics of the PRPD spectrum and effectively train the model, the PRPD data is first converted into a local discharge grayscale image. This grayscale image transforms the parameters and their relationships, such as phase ϕ, pulse amplitude q, and pulse count n, into the grayscale values, spatial positions, and intrinsic structural relationships of image pixels. Thus, the original three-dimensional spectrum of ϕ, q, and n is mapped into a two-dimensional grayscale image [16]. By training the neural network model with this grayscale image data, it is possible to effectively extract the identifying features embedded within the grayscale image, thereby achieving the representation learning of discharge characteristic "fingerprints." The specific process is as follows:

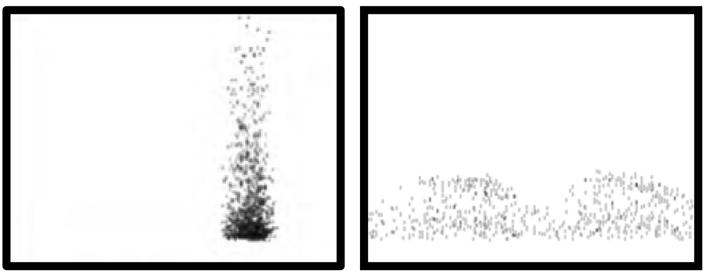
To import PRPD data, we can define the horizontal axis as the frequency phase ϕ divided into N intervals and the vertical axis as the pulse signal amplitude q divided into MM intervals. This results in a $\phi - q$ plane segmented into M×N intervals. We then count the number of pulses n within each interval, constructing the $\phi - q - n$ map. Following this, we normalize the pulse counts n as follows:

$$n'_{u,v} = \frac{n_{u,v}}{n_{max}} \tag{1}$$

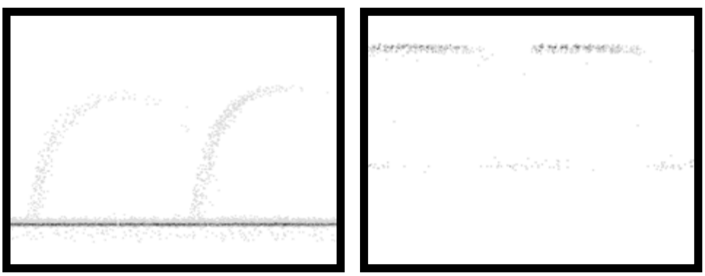
To enhance the visualization of grayscale images, the maximum and minimum values of n should correspond sequentially to the minimum and maximum grayscale levels of the image. Specifically, the deeper the pixel color, the more frequently discharge events occur at that point. Consequently, the grayscale values of the pixels in the partial discharge grayscale image are obtained as follows:

$$k_{u,v}(1 - n_{u,v})x255 \tag{2}$$

Based on the above steps, four types of partial discharge (tip discharge, particle discharge, air gap discharge, and floating discharge) can be visualized through grayscale images. The four typical grayscale images of partial discharge in GIS are illustrated in Figure 2.



（a）Grayscale image of Corona discharge （b）Grayscale image of Corona discharge



（c）Grayscale image of Corona discharge （d）Grayscale image of Corona discharge

Fig. 2. Grayscale image of PRPD pattern

3. Development of a Portable Local Discharge Detection Device for GIL at Long Distances

The device primarily consists of system hardware and system software, which include: UHF (Ultra high frequency) sensors, a photoelectric conversion module, field optical cables, a device host (which contains a signal acquisition and processing unit, a high-speed sampling component, a storage module, and a synchronization module), as well as analysis software.

3.1 Signal acquisition and processing unit

The signal acquisition and processing unit comprises an analog front-end amplification module and a synchronization module. This paper categorizes the unit into two types of circuit boards based on their functions: the analog front-end board (PD_SCOPE_AFI) and the synchronization board (PD_SCOPE_SYNC), with the analog front-end board supporting eight channels. It enables bandpass filtering, RF amplification, and demodulation within the detection frequency range of 300 to 1500 MHz [17].

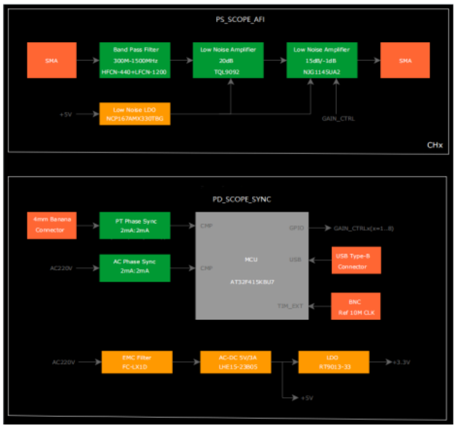


Fig. 3. The signal acquisition and processing unit

The fundamental function of the filtering circuit is primarily to select the frequency range of the signal; signals within this range can pass through, while those outside the range cannot. In practical applications, the signals received by the system may not be genuine partial discharge signals, but rather include interference from sources such as mobile phone signals, radio signals, and so on. Therefore, it is necessary to use a filtering circuit to eliminate some of the external noise interference. The electromagnetic wave signals undergo a series of amplification: the first-stage amplifier achieves a gain of 20 dB, while the second-stage amplifier achieves a gain of 15 dB. The gain is controlled by automatic adjustments through software. The design block diagram for the signal acquisition and processing unit is shown in Figure 3.

3.2 High-speed sampling component

The role of the high-speed sampling component is to utilize high-speed sampling rates exceeding 5 GS/s to directly capture processed raw pulse signals [18]. Through market research, the LeCroy WavePro 254HD-MS oscilloscope and the PDS high-speed acquisition card have been selected as development platforms, is shown in Figure 4. Based on this platform, each channel can perform real-time calculations on no fewer than 1,000 discharge pulse waveforms, enabling the implementation of four advanced functional modules: FIR (Finite Impulse Response) filter, pulse amplitude calculation, pulse waveform feature extraction, and pulse arrival time verification. Among these, the FIR filter and pulse arrival time verification will be used for subsequent anti-jamming capabilities and automatic positioning functions, while pulse amplitude calculation and pulse waveform feature extraction will facilitate automatic diagnostic functions for discharge types.

Fig. 4 High-speed sampling component

3.3 Signal transmission module

The signal transmission module is divided into two parts: the synchronization module and the fiber optic transmission module.

The synchronization module uses a 50Hz signal as a trigger to control the operation of the measurement and analysis software system. During testing, a 50Hz industrial frequency signal can be conveniently obtained on-site and fed into the circuit for processing, which then provides the circuit board with the trigger signal [19].

Internal synchronization refers to the use of an internal crystal oscillator within the device to achieve industrial frequency synchronization, with a frequency adjustable in the range of 20 to 300 Hz [20].

The external ports utilize 4 mm banana plugs to synchronize the phase with the PT secondary interface and other output devices.

Fiber optic transmission modules typically consist of two components: the transmitter module and the receiver module. The transmitter module receives radio frequency (RF) signals from RF devices, such as antennas and radio transceivers, converts these signals into optical signals, and transmits them through fiber optic cables. Conversely, the receiver module receives the optical signals and converts them back into RF signals for use by RF devices at the receiving end.

4. Case analysis

4.1 Case introduction

In August 2024, a Level 1 partial discharge alarm signal was generated by an online monitoring system at a certain GIL (gas-insulated line). Sensors 1# shown in Figure 5, are spaced 126.6 meters apart. The amplitudes detected by sensors 1# and 2# were -49.2 dBm and -53 dBm, respectively, with the spectrum displaying characteristics indicative of discharge in the insulation gap. The left image depicts the PRPD (Phase Resolved Partial Discharge) spectrum detected by sensor 1#.

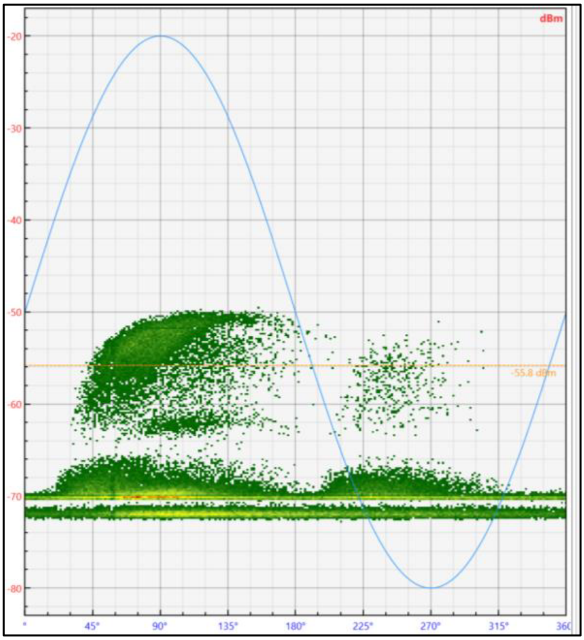


Fig. 5. Sensors 1# PRPD pattern

4.2 Case analysis

The signals from Sensor 1 and Sensor 2 are connected to Channel 1 and Channel 2 of a high-speed oscilloscope via 80-meter coaxial cables, utilizing a 20 dB preamplifier for signal amplification. Figure 6 presents the partial discharge waveforms detected by the high-speed oscilloscope.

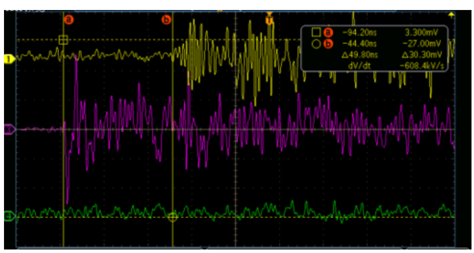


Fig. 6. Partial Discharge Trend Graph

By conducting statistical calculations on dozens of pulses, the time difference between the two channels is approximately 44.77 ns. The calculation yields the following result: (126.6-44.77×0.3)/2 =56.5 m. This indicates that the partial discharge source is located between measurement points 1# and 2#, at a distance of approximately 56.5 m from Sensor 1.

During the return factory testing using the pulse current method for partial discharge, no abnormal signals were observed during the gradual voltage increase at lower voltages. When the voltage reached 318 kV, signals began to appear with strong phase correlation, and the measured partial discharge quantity was 1.5 pC. As the voltage increased to 381 kV, the signals became significantly stronger and more distinctive, with the measured partial discharge quantity rising to 2.9 pC. The shape of the PRPD spectrum was largely consistent with the results from on-site testing. As the voltage continued to rise to 600 kV, the signals disappeared, and no further activity was detected even at the maximum voltage of 740 kV.

5. Conclusion

This paper develops a high-precision, long vertical shaft GIL portable automatic localization device for partial discharge detection. The device is based on a single-channel sampling rate of up to 20 GS/s and multi-channel adjustable sampling rates for ultra-high-frequency synchronous triggering and data acquisition. By utilizing an automatic threshold-triggered judgment algorithm and noise recognition algorithm, it can reliably capture the ultra-high-frequency raw pulse waveforms of intermittent partial discharge signals in GIL, achieving automatic localization with an accuracy of within 10 cm. The synchronization of power frequency phase enables accurate statistics of Partial Discharge PRPS and cumulative PRPD. Even in situations where pulses are rare, the localization results can be confirmed through spectrum analysis to ensure they originate from partial discharge pulses, thus facilitating precise identification and localization of partial discharges in long vertical shaft GIL systems.

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Research on Intelligent Monitoring of Illegal Sand Mining in Yangtze River Based on Deep Learning Algorithm

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Abstract. This paper proposes an intelligent monitoring system of illegal sand mining ships in the Yangtze River based on deep learning algorithm. By combining the generative adversarial network (GAN) algorithm with the YOLOv8 object detection technology, the system aims to effectively detect and monitor illegal sand mining ships [1]. The proposed system combines advanced image processing and target detection techniques to provide real-time monitoring and early warning for illegal sand mining ships. The results show that the system achieves high detection accuracy and has great potential in environmental protection and resource management. At the same time, the paper also explores the application of YOLOv8 in target trajectory analysis, which further enriches the function and practicability of the system.

Key words: GAN; YOLOv8 algorithm; deep learning; target detection

1 Introduction

Sand is an essential natural resource, and its illegal extraction, particularly through sand mining, has become a growing environmental and societal concern. Illegal sand mining not only leads to severe ecological damage, but also threatens the structural integrity of riverbanks and bridges, posing safety risks to infrastructure. In regions such as the Yangtze River basin, illegal sand mining has escalated into a serious problem that requires immediate intervention and monitoring to prevent further ecological degradation and ensure the protection of critical infrastructure.

Deep learning has shown great potential in various fields, including environmental monitoring. Deep learning-based object detection algorithms can accurately identify and locate objects in images, providing a powerful tool for environmental monitoring. Recently, the YOLO (You Only Look Once) series of algorithms have been widely used in target detection tasks due to their high detection speed and accuracy. At the same time, the generative adversarial network (GAN) is also applied to image generation and data enhancement, which can improve the performance of the target detection algorithm.

The main goal of this study is to develop an intelligent monitoring system for detecting sand theft in the Yangtze River basin by integrating the GAN algorithm with

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YOLOv8 target detection technology. This system aims to leverage the strengths of both approaches to improve detection accuracy, reduce false positives and negatives, and enhance the system's generalization ability across different conditions. The specific objectives of this study include:

A. Design and implement an intelligent monitoring system architecture that integrates image acquisition, processing, and target detection [2].
B. Train and optimize the YOLOv8 model for detecting illegal sand mining in the Yangtze River basin.
C. Use GAN-based data augmentation to improve the model's detection performance and generalization ability.
D. Evaluate the performance of the proposed system and analyze its strengths and limitations.
E. Explore the application of YOLOv8 in target trajectory analysis to provide more comprehensive information for monitoring illegal sand mining behavior.

By combining these techniques, this research aims to contribute to the development of a more effective and reliable system for monitoring and combating illegal sand mining in the Yangtze River basin, ultimately helping to safeguard both the environment and critical infrastructure.

2 Theorecital Principle

2.1 Image Dehazing

In our intelligent monitoring system of sand theft behavior in Yangtze River basin, GAN consists of generator and discriminator. The generator is typically built using Convolutional Neural Networks (CNNs), leveraging upsampling and convolutional layers to create high-resolution images from random noise. In this study, the generator's task is to produce synthetic images that include both real sand mining boats and the surrounding environmental background. These images may be generated from random noise or conditional inputs representing specific sand mining scenarios, with the output being similar in distribution to real images [3].

The discriminator is also built on a CNN architecture and is responsible for distinguishing whether the input image comes from the real dataset or is a synthetic image generated by the generator. The discriminator continuously optimizes its ability to recognize and precisely differentiate between real and fake images. Its output is a binary classification indicating whether the image is real or fake, and through the backpropagation process, it guides the generator's optimization.

In terms of specific model architecture, the generator uses a Deep Convolutional Generative Adversarial Network (DCGAN), which not only generates high-quality images but also adapts well to changing environmental conditions. The discriminator uses a PatchGAN structure, which improves the accuracy and granularity of discrimination by evaluating small patches of the image rather than the entire image.

The objective function of the GAN is a minimax game (Minimax Game). For both the generator and the discriminator, the objective function is:

$$\min_G \max_D V(D,G) = E_{x\sim P_{data}(x)}[\log D(x)] + E_{z\sim P_z(z)}[\log(1 - D(G(z))] \quad (1)$$

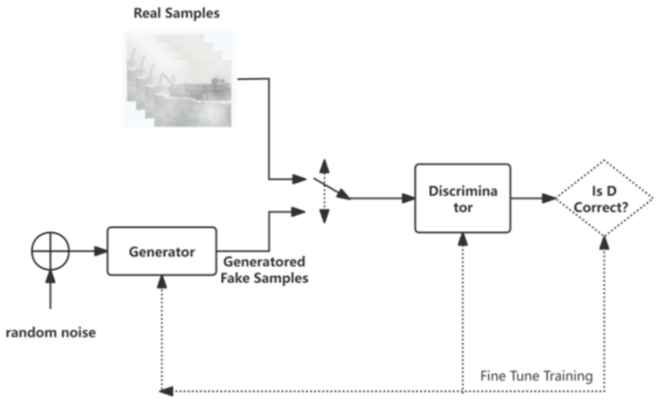

Figure 1. GAN Algorithm Principle

$P_{data}(x)$ is the real data distribution, $P_z(z)$is the random noise distribution, $D(x)$is the judgment probability of the discriminant to the real data, $G(z)$is the data generated by the generator, and $D(G(z))$ is the judgment probability of the discriminant to the generated data. This objective function leads the generator to continuously generate more realistic images, and the discriminator is also constantly improving its discrimination ability. Finally, the generated image can well simulate the real sand theft scene in Yangtze River Basin and provide more data samples for subsequent target detection [4].

The training process of GAN is based on minimizing the difference between the generated images and the real images. In our monitoring system, by constantly adjusting the parameters of the generator and the discriminant, the generated image is getting closer and closer to the real Yangtze River basin scene. The objective function is usually defined as a binary cross-entropy loss function, used to measure the similarity between the real image and the generated image distribution. This loss function can help us to evaluate the performance of the generators and discriminators and guide their training process.

GAN has many strengths in our program. First, it is able to generate high-quality synthetic images that can increase our training dataset and improve the generalization ability of the model. For example, we can use GAN to generate images of sand stealing scenes in Yangtze River basin under different light conditions and weather conditions, so that the model can learn more changes, so as to better deal with various situations in the actual monitoring. Second, GAN has the potential to improve the performance of other machine learning algorithms, and in our system, it can be combined with the YOLOv8 target detection technology to improve the detection accuracy of sand-stealing behavior.

2.2 Object detection

YOLOv8 Is a single-stage target detection algorithm, which uses a single neural network to predict the bounding box and category probability of objects in an image in our intelligent monitoring system of sand stealing behavior in Yangtze River Basin. The architecture of YOLOv8 includes the backbone network for feature extraction and a detection head for target prediction. The backbone network is responsible for extracting features from the input Yangtze River watershed images that contain information about possible sand-stealing activities and objects. The detection head predicts the bounding box and category probability of objects according on these features, so as to determine whether there is sand stealing activity and related objects in the image [5].

YOLOv8 not only performs well in target detection, but also has potential application in target trajectory analysis. By detecting and tracking targets in consecutive frames, the movement trajectory of targets can be constructed to provide more comprehensive information for the monitoring of sand-stealing behavior. For example, the trajectory of the sand boat can be analyzed to determine whether it is active in the illegal sand mining area and whether there is sand theft. In addition, target trajectory analysis can also help us understand the patterns and trends of sand stealing activities and provide a basis for developing effective regulatory strategies.

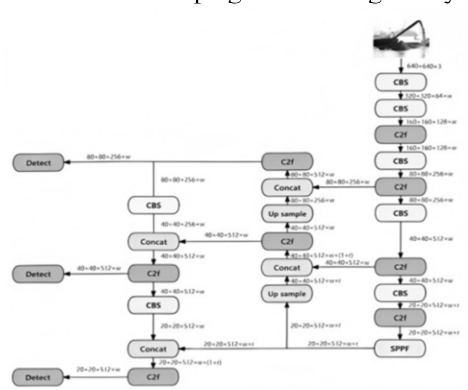

Figure 2. YOLOv8 Network Architecture Diagram

2.3 The Combination of GAN and YOLOv8 Models

To improve the detection accuracy of illegal sand dredging vessels, a combination of Generative Adversarial Networks (GAN) [6] and the YOLOv8 object detection model was used. First, data augmentation was performed by generating synthetic images using GAN to enhance the training dateset. By generating synthetic images of sand mining scenes, the dateset was expanded to include various weather conditions, lighting, and types of vessels. This approach allows the YOLOv8 model to learn more diverse features, improving its ability to detect sand mining activities in different scenarios. The GAN-generated synthetic images were then added to the YOLOv8 training dateset, enhancing the model's generalization capability. The model can detect illegal dredging vessels and other relevant objects, outputting corresponding bounding boxes and class probabilities [7].

The images generated by GAN not only provided YOLOv8 with diverse training data but also improved its robustness in real-world scenarios by enhancing data variety. By combining GAN with YOLOv8, the model's generalization ability was enhanced. Through the use of GAN to generate diverse images, [8] YOLOv8 learned more types of illegal sand dredging activity features, maintaining high accuracy in different environments. Additionally, the synthetic data generated by GAN enriched the training set, preventing YOLOv8 from over fitting due to insufficient data during training.

2.4 Experimental Results and Analysis

This project uses the deep learning framework PyTorch for experimental training. In terms of hardware configuration, the GPU is RTX 4090 (24GB), and the CPU is 22 vCPU AMD EPYC 7T83 64-Core Processor. In this training, the epoch was 750, batch size was set to 8, IOU threshold was set to 0.7, and image size was set to 640. The training environment configuration is shown in Table 1.

Table 1. Experimental training environment configuration

project	model
operating system	Ubuntu 18.04.6
programming language	Python 3.8.10
CPU	22 vCPU AMD EPYC 7T83 64-Core Processor
GPU	RTX 4090
GPU memory	24GB
frame	PyTorch

2.4.1 experimental result

Precision, Recall, and mAP were used as evaluation indicators to evaluate the performance of our improved model.

The confusion matrix is an important tool for evaluating the classification model performance, as shown in Table 2.

Table 2. Experimental evaluation indicators

	Positive (Positive prediction result)	Negative (Prediction result is reverse)
True (positive sample)	TP	FN
False (Back example)	FP	TN

Where TP (True Positive) is the true example, refers to the number of target being correctly detected; FN (False Negative) is the false reverse example, the number of target being detected as background; FP (False Positive) is the false positive case, the number of background being detected as a target; TN (True Negative) is the true reverse example, and the number of background being correctly detected.

By analyzing the four key elements in the confusion matrix, the precision, recall, accuracy, F1 value and other algorithms can be calculated.

Accuracy: the ratio of the number of correct model predictions to the total number of samples, formula (2):

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \quad (2)$$

Recall: represents the proportion of the model correctly predicting positive samples, namely formula (3):

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

Precision: represents the proportion of true examples in the sample with predicted positive examples, namely formula (4):

$$Precision = \frac{TP}{TP+FP} \quad (4)$$

F1: Combining accuracy and recall, namely formula (5):

$$F_1 = \frac{2 \times Precision \times Recall}{Precision+Recall} \quad (5)$$

AP: Only the accuracy and recall rate to judge the model is too one-sided, and the comprehensive index AP is used to measure the detection performance of the model, that is, formula (6):

$$AP = \int_0^1 P(R)dr \quad (6)$$

mAP: used to detect the mean value of the target accuracy value AP, the larger the mAP value, the better the comprehensive performance of the algorithm, namely formula (7):

$$mAP = \frac{1}{n}\sum_{i=1}^{n} A\,P_i \quad (7)$$

2.4.2 Evaluation of experimental results

2.4.2.1 convergence analysis

The convergence curve refers to the curve where the model performance index changes with the increase of training times during training. Usually, as the number of training times increases, the performance of the model will gradually improve until a stable state is reached. During training, the convergence curve can be drawn by monitoring the performance metrics of the model on the training and validation sets. Common performance indicators include loss function, accuracy, precision, recall and so on. By observing the convergence curve, we can judge whether the model has converged, and whether there are problems such as overfitting or underfitting. However, after our model is trained many times, the convergence curve has leveled off, indicating that the model has converged, and the training purpose of the model can be stopped, as shown in Figure 3.

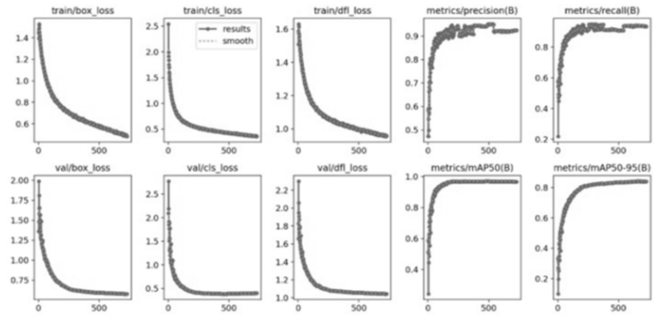

Figure 3. YOLOv8n the convergence curve on the dateset

2.4.2.2 Classification accuracy assessment

In a confusion matrix, the rows represent the predicted categories by the model, and the columns represent the true categories of the data. Through the confusion matrix, we can intuitively see the model's prediction accuracy across different categories and identify the types of errors made. Ideally, a classification model will show higher values along the diagonal, indicating that the model is accurately classifying data points into the correct categories. Values off the diagonal represent the proportion of misclassifications. During our model training process, through multiple iterations and optimizations, we achieved a stable confusion matrix. The model demonstrated a high prediction accuracy, performing well in identifying "sand stealing boats" and "ordinary boats," with an accuracy rate of 93% for each. The results of the confusion matrix are shown in Figure 4 [9].

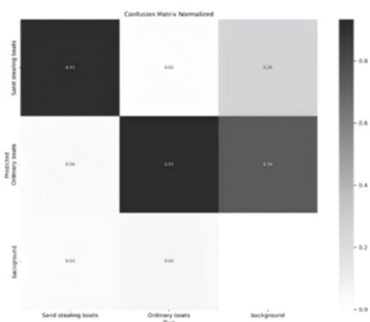

Figure 4. YOLOv8n the confusion matrix generated on the dataset

2.4.2.3 mAP trace analysis

The precision-recall curves curve is a two-dimensional curve with precision as the ordinate and recall as the abscissa, called the P-R curve. This figure is drawn by the corresponding precision and recall at different thresholds. Accuracy, precision and recall are a pair of contradictory indexes. It is impossible to make both indexes particularly high, while one side is high, and the other side index is low. The area enclosed by the P-R curve is the AP value, and usually, the better a detector, the higher the AP value. And in general, the more the P-R curve is to the right, with the left curve, the right one is a better detector. Figure 5 shows a confidence level above 0.96 with very good accuracy.

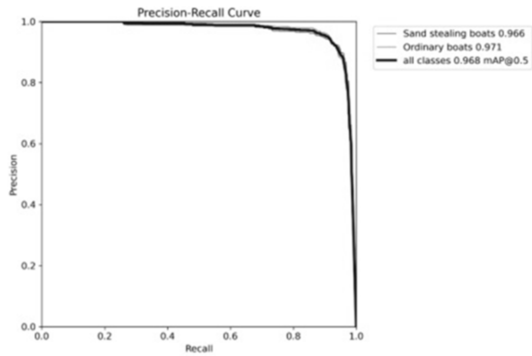

Figure 5. P-R curves and the mAP plots

The precision rate refers to the proportion of the positive category sample that is really a positive category, and the formula is:

$$Precision = \frac{TP}{TP+FP} \quad (8)$$

2.4.2.4 Comparison of experimental results

Before we found that the direct use of YOLO8 algorithm and conventional defogging means to identify illegal boats had the disadvantages of instability and lack of accuracy, we adopted the initially proposed method of adding generative adversarial network to the head of the backbone network to conduct experimental training and detection on the data set, and the results are shown in the figure below.

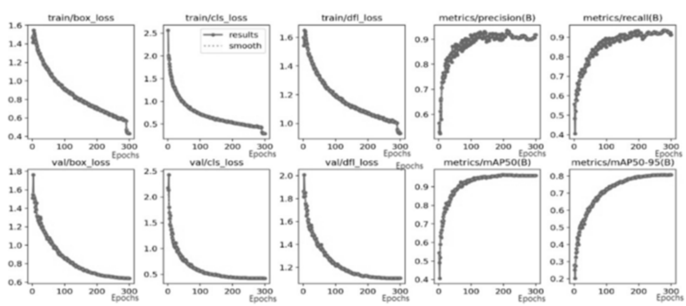

Figure 6. Convergence curve

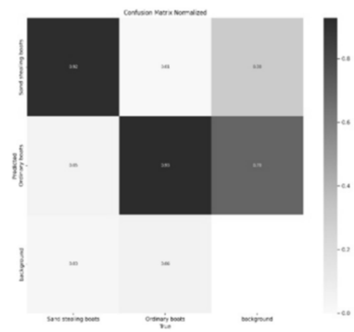

Figure 7. Confusion matrix

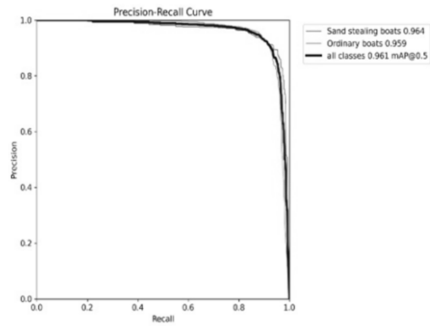

Figure 8. P-R curves and the mAP plots

Through the comparison of two experimental results, it can be found directly in the backbone network head to join the generative against network as illegal boat identification error, and using our improved GAN algorithm and then through the YOLOv8 algorithm is obviously more accurate, the accuracy of illegal boat identification has significantly improved.

Display of the experimental training results

The experiment confirmed that the YOLOv8 model has good detection and identification ability for both types of boats, and the detection and identification results of the training part of this experiment are shown in Figure 9.

Figure 9. Part of the test identification results

3 SYSTEM DESIGN

3.1 Dataset

3.1.1 Hardware components (camera, sensor, etc.)

The intelligent monitoring system used for sand theft in the Yangtze River basin consists of hardware components such as cameras, sensors and communication equipment. Cameras are used to capture images of the watershed, which are distributed in key locations in the Yangtze River watershed and can fully cover areas where sand theft may occur. Sensors are used to detect environmental parameters such as water level and flow rate, which can assist in determining whether sand theft has an impact on the ecological environment of the basin. The communication device is used to transfer captured images and sensor data to a central server for processing.

3.1.2 Software module (image processing, object detection, etc.)

The software modules of the system include image processing, target detection, and data analysis. The image processing module is responsible for the pre-processing of the captured images, such as noise reduction and enhancement. The target detection module uses the YOLOv8 model to detect sand-stealing activity and objects in the image. The data analysis module analyzes the detected data and generates reports and alerts.

3.2 System functional structure

3.2.1 Images and sensor data were collected from the Yangtze River

The system uses cameras and sensors to collect images and sensor data from the Yangtze River basin. Images were taken at fixed time intervals and transmitted to a central server for processing. Sensor data includes water level, flow rate and other environmental parameters to assist sand theft detection. For example, if there are abnormal changes in the water level and flow rate, it may mean that sand theft occurs.

3.2.2 Data cleaning and normalization techniques

The collected data were preprocessed using the data cleaning and normalization techniques. Data cleaning involves removing noise and outliers from the image and sensor data. For example, remove abnormal image data due to weather reasons or equipment failure. Normalization is used to scale the data to a common range to improve the performance of the target detection algorithm.

3.3 System interface design

3.3.1 YOLOv8 Model training and fine-tuning

The YOLOv8 model was trained using a large image dataset containing sand-stealing activities and objects. This dataset includes images taken from the Yangtze River basin as well as synthetic images generated through GAN. The training process involves optimizing the model parameters to minimize the loss function. Fine-tuning to adapt the model to specific characteristics of the Yangtze River basin, such as different light conditions, weather conditions and land forms.

3.3.2 Detection of sand-stealing activities and objects

The trained YOLOv8 model was used to detect sand-stealing activity and objects in images captured by the camera. The model outputs the bounding box and category probabilities of detected objects that can be used to identify and track sand stealing activity. For example, when a sand boat or sand mining equipment is detected, the system can issue an alarm and record relevant information.

3.4 Data enhancement and improvement based on GAN

3.4.1 Generate the synthetic images used for the training

Generate the synthetic images used to train the YOLOv8 model using GAN. The resulting images were added to the original training dataset to increase the diversity and size of the dataset. This can improve the generalization ability of the model and reduce the overfitting. For example, we can use GAN to generate images of sand-stealing scenes at different angles and under different conditions of illumination, so that the model can learn more changes.

3.4.2 Improve the detection performance and the generalization capability

Using GAN-based data augmentation can improve the detection performance and generalization capability of the YOLOv8 model. By generating synthetic images similar to real data, the model can learn more robust features and improve the ability to detect sand-stealing activity in different scenarios.

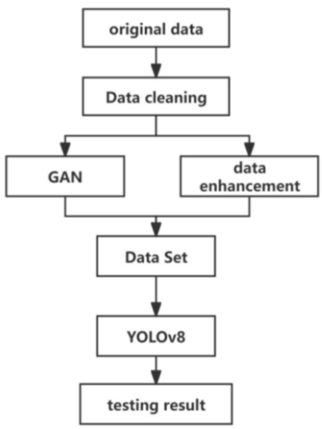

Figure 10. Simple project flow char

3.5 Construction of the visual platform system

To better display monitoring results and facilitate user operations, a visualization platform system has been constructed. [10] The platform presents real-time images captured by cameras, detected sand theft activities and the positions of objects, along with relevant statistical data. Users can use this platform to set parameters, query data, and handle alerts [11].

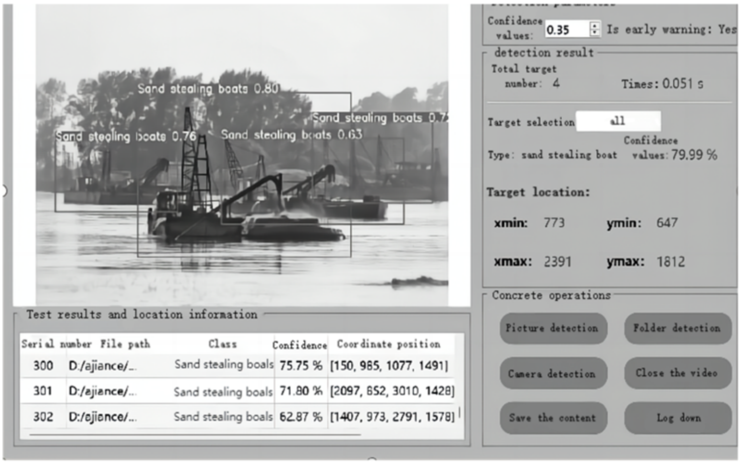

Figure 11. Visual interface

4 Application Case

4.1 Application Background

With the increasing illegal sand mining activities in the Yangtze River Basin, ecological damage and infrastructure safety risks have become more pronounced. Illegal sand mining not only threatens the ecological balance of water bodies but also poses a potential risk to the stability of bridges, dams, and other infrastructures along the riverbanks. Therefore, timely monitoring and detection of illegal sand mining activities have become an urgent need for environmental protection and resource management.

This intelligent monitoring system, based on YOLOv8 object detection technology and Generative Adversarial Networks (GAN) for data augmentation, can effectively monitor illegal sand mining vessels in the Yangtze River Basin, improving environmental supervision capabilities. The following case study demonstrates the effectiveness of the system in real-world applications within the Yangtze River Basin.

4.2 System Deployment and Real-Time Monitoring

Location: Key waterway of the Yangtze River, middle and lower reaches
Period: May 2024 to August 2024

For this case study, we selected typical water areas in the middle and lower reaches of the Yangtze River and deployed monitoring equipment with high-definition cameras and environmental sensors. The cameras capture images of the waterway, which are then transmitted to a central server for processing. The sensors monitor real-time environmental data such as water levels and flow speeds. The system uses YOLOv8 for real-time object detection of sand mining vessels and combines the synthetic images generated by GAN to enhance the training dateset, thereby improving the system's ability to detect sand mining activities under different environmental and weather conditions.

4.3 System Performance

Over the three months of actual monitoring, the system achieved the following remarkable results across multiple monitoring points in the Yangtze River Basin:

4.3.1 Real-Time Monitoring and Alerts

The system can automatically identify illegal sand mining vessels as they enter the monitoring area and send an alarm. Based on YOLOv8 object detection, the system categorizes the vessels and distinguishes between normal and mining vessels. Once a mining vessel is detected, the system generates relevant information and sends alerts to regulatory authorities.

4.3.2 High Accuracy and Low False-Positive Rate

By using GAN to augment the dateset, the detection accuracy of YOLOv8 improved significantly. During actual monitoring, the system achieved an accuracy rate of 93% and a recall rate of 91%. This indicates that the use of GAN for data augmentation significantly enhanced the system's generalization ability, especially in challenging environmental conditions such as fog or low light.

4.3.3 Trajectory Analysis of Targets

The system not only identifies individual illegal mining activities but also tracks the movement trajectories of mining vessels over consecutive frames. For instance, in one of the monitoring points, the system detected a mining vessel moving along the river and performed trajectory analysis, revealing that the vessel repeatedly entered the same water area, which confirmed its involvement in illegal sand mining. This provided regulatory authorities with timely intervention clues.

4.3.4 Enhanced Environmental Adaptability

The GAN-generated synthetic images, including different weather conditions, water levels, and vessel types, helped the system adapt to various real-world environments. For example, during low-light conditions, the synthetic image samples assisted the model in handling the lighting changes encountered in long-duration monitoring.

5 Conclusion

This application case demonstrates the effectiveness of the intelligent monitoring system based on YOLOv8 and GAN for detecting illegal sand mining activities in the Yangtze River Basin. The system provides high-precision detection capabilities for illegal sand mining, while trajectory analysis and data augmentation enhance its adaptability and generalization ability. In the future, as technology continues to develop, this system will play a significant role in broader environmental protection and resource management.

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Research on Trajectory Tracking of Robotic Arm Based on Inversion Control

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Abstract. With the rapid advancement of technology, robotic arms have played a significant role in enhancing production efficiency. Considering the highly nonlinear and strongly coupled characteristics of the dynamic equations of loading and unloading robotic arms, this study proposes a trajectory tracking strategy based on inversion control. Firstly, to simplify the design of the controller, the complex robotic arm model is decoupled into two independent subsystems. Then, using the inversion control strategy, control laws are designed for these two subsystems separately. Simulation results verify that the control laws based on inversion control ensure system stability and accurately track the trajectory, achieving the expected dynamic performance requirements.

Keywords. packaging manipulator; strong coupling; backstepping control; trajectory tracking

1. Introduction

Robotic arms, also known as robot arms, are highly automated and programmable tools widely used in industrial, medical, service, and research fields. Researching robotic arms not only helps advance automation technology and elevate the level of industrial automation but also aids in developing new applications such as disaster relief and complex surgeries, thereby expanding the functionalities and enhancing the intelligence level of robotic arms [1-3].

Inversion control, or inverse system control, involves designing controllers by reverse engineering the system's model[4]. However, inversion control is highly sensitive to model inaccuracies and external disturbances, necessitating effective compensation and adjustments to mitigate these adverse factors during implementation [5]. In reference [6], the issues encountered between the platform and the robotic arm are addressed by employing a combination of backstepping and sliding mode control, which improves stability and response to uncertainties. In reference [7], to address the issues of input vibrations and model limitations, a disturbance observer (DO) was designed to estimate system disturbances, and the idea of inverse control was integrated to improve the sliding mode control algorithm. In reference [8], proposed nonlinear feedback robot controller integrates the dynamics of both the robot manipulator and the joint motor.

The research, grounded in a comprehensive review of the literature, tackles the complexity and high coupling in flexible robotic arms used for loading and unloading by

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splitting the dynamic model into two independent subsystems, each governed by an inverse control-based law. The system's exponential convergence is confirmed through the application of Lyapunov stability theory, and numerical simulations further illustrate that this control strategy substantially improves the robustness and accuracy of the system.

2. Problem description

2.1. Dynamic model of loading and unloading manipulator

The rotation angle of the car body is influenced by the driving torque of the right wheel and the resistance torque of the left wheel. This can be explained by the principle of moment balance：

$$I_v\ddot{\phi} = D_r l - D_l l \tag{1}$$

According to Newton's law, (1) can be further written as:

$$M\dot{\upsilon} = D_r + D_l \tag{2}$$

Where, I_v represents the moment of inertia of the loading and unloading robotic arm around its center of mass, D_l and D_r represent the torque on the left and right sides of the robotic arm, respectively. ϕ is the pose angle of the robotic arm, l is the distance from the left and right wheels to the center of mass of the robotic arm, and M represents the mass.

Based on the above, the dynamic characteristics of the left and right wheels can be further described as follows:

$$I_w\ddot{\theta}_i + c\dot{\theta}_i = ku_i - rD_i \tag{3}$$

For the left wheel, represented as $i = l$, the equation is $I_w\ddot{\theta}_l + c\dot{\theta}_l = ku_l - rD_l$, and for the right wheel, represented as $i = r$, the equation is $I_w\ddot{\theta}_r + c\dot{\theta}_r = ku_r - rD_r$. Here, I_w is the moment of inertia of the wheel, k represents the drive gain, θ is the angular rotation of the robotic arm, r is the radius of the robotic arm around its center of gravity, c is the viscous friction coefficient, and u_i is the drive input.

2.2. Dynamic model conversion

According to literature[9], the kinematics principle of loading and unloading manipulator can be obtained:

$$\upsilon = \frac{\upsilon_r + \upsilon_1}{2} \tag{4}$$

$$l\dot{\phi} = \frac{\upsilon_r - \upsilon_1}{2} \tag{5}$$

The relationship between ϕ, υ, θ_i variables can be obtained from (5).

$$\begin{cases} \upsilon_r = r\dot{\theta}_r = \upsilon + l\dot{\phi} \\ \upsilon_1 = r\dot{\theta}_1 = \upsilon - l\dot{\phi} \end{cases} \tag{6}$$

From the formula (3), it can be further concluded that

$$I_w r\ddot{\theta}_i + cr\dot{\theta}_i = kru_i - r^2 D_i \tag{7}$$

Then

$$I_w r(\ddot{\theta}_r + \ddot{\theta}_1) + cr(\dot{\theta}_r + \dot{\theta}_1) = kr(u_r + u_1) - r^2(D_r + D_1) \tag{8}$$

From the formula (6), it can be further that

$$\begin{cases} r(\dot{\theta}_r + \dot{\theta}_1) = 2\upsilon \\ r(\ddot{\theta}_r + \ddot{\theta}_1) = 2\dot{\upsilon} \end{cases} \tag{9}$$

Then

$$2I_w\dot{\upsilon} + 2c\upsilon = kr(u_r + u_1) - r^2(D_r + D_1) \tag{10}$$

Substituting the formula (2) into the formula (10) can be obtained.

$$2I_w\dot{\upsilon} + 2c\upsilon = kr(u_r + u_1) - Mr^2\dot{\upsilon} \tag{11}$$

Then

$$\dot{\upsilon} = -\frac{2c}{(Mr^2 + 2I_w)}\upsilon + \frac{kr}{Mr^2 + 2I_w}(u_r + u_1)$$

From the formula (1) and (3), it can be further that

$$I_v r^2\ddot{\phi} = (D_r - D_1)r^2 l \tag{12}$$

$$I_w\ddot{\theta}_r + c\dot{\theta}_r = ku_r - rD_r \tag{13}$$

$$I_w\ddot{\theta}_1 + c\dot{\theta}_1 = ku_1 - rD_1 \tag{14}$$

Substituting (12) and (14) into the above formula, you can get

$$I_w \cdot l2l\ddot{\phi} + I_v r^2\ddot{\phi} = -cl \cdot 2l\dot{\phi} + krl(u_r - u_1) \tag{15}$$

$$\ddot{\phi} = -\frac{2cl^2}{I_v r^2 + 2I_w l^2}\dot{\phi} + \frac{krl}{I_v r^2 + 2I_w l^2}(u_r - u_1) \tag{16}$$

Define the state variables as $x = \begin{bmatrix} \upsilon & \phi & \dot{\phi} \end{bmatrix}^T$, the drive control inputs as $u = \begin{bmatrix} u_r & u_1 \end{bmatrix}^T$,and the output variables as $y = \begin{bmatrix} \upsilon & \phi \end{bmatrix}^T$.Then, from equation (16), we can derive:

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx \end{cases} \tag{17}$$

$$A = \begin{bmatrix} a_1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & a_2 \end{bmatrix},\ B = \begin{bmatrix} b_1 & b_1 \\ 0 & 0 \\ b_2 & -b_2 \end{bmatrix},\ C = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix},\ a_1 = -\frac{2c}{Mr^2 + 2I_w},$$

$$a_2 = -\frac{2cl^2}{I_v r^2 + 2I_w l^2},\ b_1 = \frac{kr}{Mr^2 + 2I_w},\ b_2 = \frac{krl}{I_v r^2 + 2I_w l^2}$$

3. Controller design and analysis

In this section, the complexity and nonlinearity in the dynamic system can be effectively managed and compensated by using the inverse controller, and the required control results can be achieved by performing mathematical inverse operation on the dynamics of the system, thus improving the stability and accuracy.

First, decoupling is performed:

$$\begin{bmatrix} u_r \\ u_1 \end{bmatrix} = \begin{bmatrix} 1 & -1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_r \end{bmatrix} \tag{18}$$

Then

$$\begin{cases} u_r = u_1 - u_2 \\ u_l = u_2 \end{cases} \tag{19}$$

Substituting equation (19) into equation (17) results in two independent subsystems, as shown below:

$$\dot{\upsilon} = a_1\upsilon + b_1u_1 \tag{20}$$

$$\begin{cases} \dot{\phi} = \omega \\ \dot{\omega} = a_2\omega + b_2u_1 - 2b_2u_2 \end{cases} \tag{21}$$

Control laws are then designed separately for the two independent subsystems (20) and (21). Let us assume the ideal linear speed v_d ,and the speed error is:

$$\upsilon_e = \upsilon_d - \upsilon \tag{22}$$

Define the Lyapunov function as:

$$V = \frac{1}{2}\upsilon_e^2 \tag{23}$$

Then

$$\begin{aligned} \dot{V} &= \upsilon_e\dot{\upsilon}_e \\ &= \upsilon_e(\dot{\upsilon}_d - a_1\upsilon - b_1u_1) \end{aligned} \tag{24}$$

The control law for (20) is as follows:

$$\dot{\upsilon} = a_1\upsilon + b_1u_1 \tag{25}$$

Then

$\dot{V} = -c_1\upsilon_e^2 = -2C_1V$ and $V(t) = e^{-2C_1t}V(0)$.

For equation (21), assuming an ideal angular velocity ϕ_d, the error is

$$z_1 = \phi - \phi_d \tag{26}$$

Introduce a virtual control variable

$$\alpha_1 = -c_2z_1 + \dot{\phi}_d \tag{27}$$

Where, c_2 is a non-negative constant. To ensure system stability, the Lyapunov function is defined as:

$$V = \frac{1}{2}z_1^2 + \frac{1}{2}z_2^2 \tag{28}$$

Deriving equation (28) results in:

$$\begin{aligned}\dot{V} &= \dot{V}_1 + z_2\dot{z}_2 \\ &= z_1z_2 - c_2z_1^2 + z_2(a_2\omega + b_2u_1 - 2b_2u_2 + c_2\dot{z}_1 - \ddot{\phi}_d)\end{aligned} \tag{29}$$

This leads to the control law for equation (21):

$$u_2 = \frac{1}{2b_2}(a_2\omega + b_2u_1 + c_2\dot{z}_1 - \ddot{\phi}_d + z_1 + c_3z_2) \tag{30}$$

Thus,

$$\dot{V} = -c_2z_1^2 - c_3z_2^2 \le -2C_mV \tag{31}$$

Where, $V(t) \le e^{-2C_mt}V(0)$, ensuring exponential stability of the system.

4. Numerical simulation

The controlled object is selected as described by equation (17), with parameters $a_1 = -0.05$, $a_2 = -0.1$, $b_1 = 0.25$, $b_2 = 0.6$. The ideal linear speed is $v_d = 1.0$, and the ideal angular command is $\phi_d = \sin t$. The control laws used are from equations (25) and (30). Below are some of the simulation results:

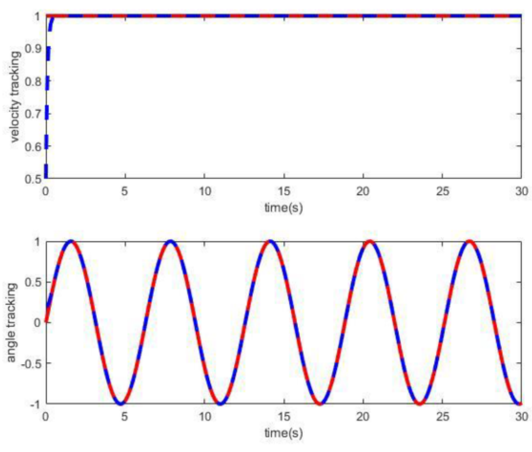

Figure 1. Speed tracking and angle tracking change diagram

Figure 1 shows the tracking of speed and angle, where the red solid line represents the preset commands, and the blue dashed line represents the actual tracking results of speed and angle. As seen in Figure 1, under the controller's influence, the system can accurately track the prescribed commands. Figure 2 displays the control input response curves for the left and right wheels, from which the stability of the system output can be observed.

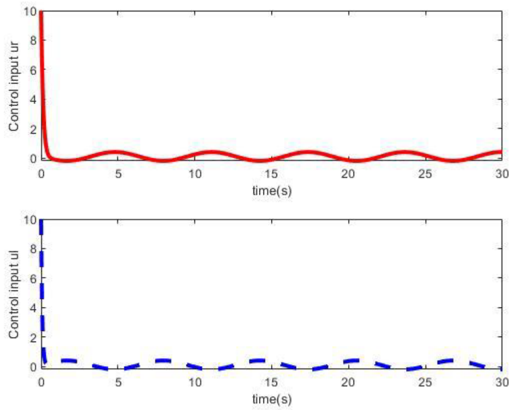

Figure 2. The response of left and right wheel control input

5. Conclusion

This study investigates the control difficulties in dynamic, integrated robotic arms used for loading and unloading, applying an inverse control approach. By breaking down a complex system into simpler subsystems with dedicated controllers, we significantly reduced design complexity. Simulations validated the efficacy of our method, and forthcoming research aims to tackle control input saturation to improve both the real-world utility and robustness of the system.

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Pipeline Standardization Issues: Reflecting Technological Challenges in Energy Transition

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Abstract. This article aims to provide a comprehensive overview of the current state of standardization in the energy industry, with a specific focus on pipeline transportation systems. It includes an examination of global pipeline projects relevant to low-carbon energy. The article also references existing standards established by various organizations and countries to address these issues. Based on direct involvement, the authors discuss the structural changes occurring within the technical committee of the International Organization for Standardization (ISO) Technical Committee 67 "Oil and gas industries including lower carbon energy" in the context of the energy transition. The conclusions drawn highlight key areas for research and development of regulations in the low-carbon energy sector to support the energy transition. The characteristics of carbon dioxide and hydrogen pipeline transportation are examined in the context of conventional oil and gas pipeline operations, along with their potential repurposing in light of the energy transition.

Keywords. International standardization, energy transition, low-carbon energy, pipeline transportation, hydrogen, carbon dioxide

1. Introduction

One of the UN goals of sustainable development to be reached by 2030 is to ensure access to clean and affordable energy, which is key to the development of agriculture, business, communications, education, health care and transportation [1].

The oil and gas industry is dedicated to bolstering resilience and tackling the urgent sustainability challenges facing the world. It is assuming an increasingly pivotal role in addressing issues related to climate change, environmental impact, as well as human health and safety.

The central theme of the plenary meeting of ISO Technical Committee 67, "Oil and Gas Industries, including Lower Carbon Energy," held on October 19-20, 2023, was the anticipated transformations in the energy sector over the next decade and their implications for standardization within the oil and gas industry.

The path along which the technical committee 67 has been moving in order to stick to the energy transition agenda is described below.

Following the plenary meeting of the technical committee, held in October 2020, it was proposed to change the name of the committee from "Materials, equipment and

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offshore structures for petroleum, petrochemical and natural gas industries" to "Oil and gas industries including lower carbon energy". After extensive discussion in a specially established advisory group, in September 2021, following a vote of national standards bodies, this decision was adopted by a majority vote and finally the ISO Technical Council approved this change at its meeting in Geneva on 13-14 June 2022.

In addition to the name of the technical committee, the official scope of the standards was also clarified, which now reads: Standardization in the field of the oil and gas industry, including petrochemical and lower carbon energy activities. Excluded:

—aspects related to the Petroleum and related products, fuels and lubricants from natural or synthetic sources being covered in ISO/TC 28;

—aspects related to Natural gas being covered in ISO/TC 193;

—aspects related to hydrogen technologies being covered in ISO/TC 197;

—aspects related to biogas being covered in ISO/TC 255;

—aspects related to Carbon dioxide capture, transportation, and geological storage being covered by ISO/TC 265;

—aspects of offshore structures subject to IMO requirements (ISO/TC 8).

The current organizational structure of the ISO TC 67 has been illustrated in Figure 1.

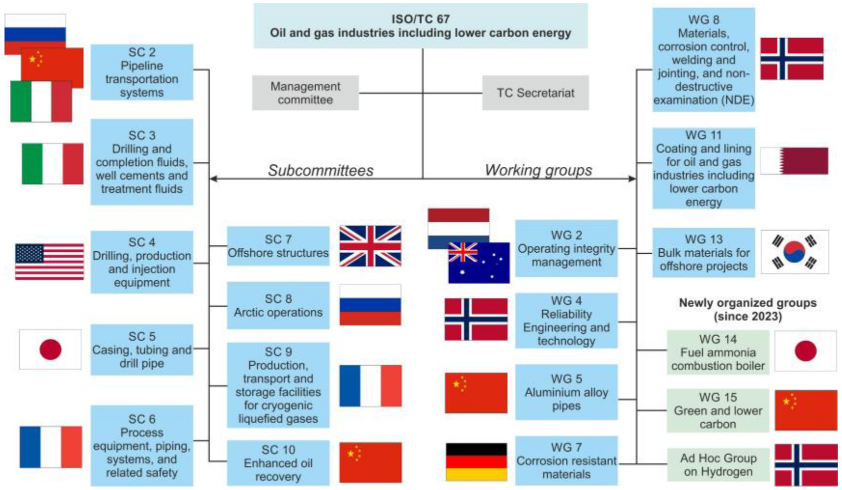

Figure 1. Organizational structure of the ISO TC 67

Contemporary evidence demonstrates that standardization is a potent mechanism for enhancing safety and productivity, as well as promoting economic efficiency and innovation. In order to further contribute to the attainment of sustainable development objectives, standards should incorporate measures aimed at reducing adverse environmental effects and optimizing resource utilization across the entire life cycle, while upholding quality and safety.

It is well known that hydrogen energy, as well as issues of carbon dioxide emissions, are regulated in the International Standardization System by the relevant technical committees – TC 197 "Hydrogen technologies", ISO/TC 207/SC 7 "Greenhouse gas and climate change management and related activities", TC 265 "Carbon dioxide capture, transportation, and geological storage", as well as some other ISO and IEC committees and subcommittees. ISO TC 67 maintains and develops liaisons with these subcommittees in order to harmonize the standards being developed and avoid duplication. Nevertheless, in order to fully meet the challenges of the energy transition period, structural changes are inevitable within the TC 67 dedicated to the oil and gas business itself.

A few working groups were created since 2023 (see Figure 1). On the initiative of the Norwegian national standardization body, under the auspices of ISO TC67, an ad hoc group on hydrogen energy was proposed, the purpose of which is to identify the topics and needs for standardization in the field of production, transportation, storage, distribution, conversion and domestic use of hydrogen and ammonia. Representatives of China initiated the creation of a working group "Green and lower carbon", and at the initiative of Japan, a working group "Fuel ammonia combustion boiler" was created.

These changes reflect broader processes occurring in the global economy, the energy sector as a whole, and the oil and gas sector in particular.

The Pipeline Transportation Systems Subcommittee, in alignment with its parent TC 67, has also developed a new and detailed scope for its standards. The recently approved scope of the Pipeline Transportation Systems Subcommittee is presented in Table 1.

Table 1. The scope of the "Pipeline transportation systems" subcommittee of ISO TC 67

Standardization in the field of pipeline transportation of fluids specific for oil and gas industries including lower carbon energy activities	
Objects of standardization comprise the following elements of the on-land and offshore pipelines: - pipeline system as a whole including gathering lines and distribution piping, - line pipe (excluding: ferrous metal pipes and metallic fittings related to ISO/TC 5, aluminium alloy pipes related to ISO/TC67/WG5), - valves and their equipment (including actuators and mounting kits), - bends, flanges, and fittings (including corrosion resistant ones), - pipeline connectors, - pipeline repair techniques and materials, - external protective coatings (including polyolefin, polypropylene, polyethylene, polyurethane, and epoxy), - external insulating coatings (including wet thermal insulation), - external weight coatings (including concrete coating), - internal anticorrosion coatings (excluding protective paint systems for steel structures related to ISO/TC 35/SC 14).	Aspects of standardization comprise the concepts relating to design, construction, operation, inspection, and maintenance of the pipeline systems, including: - integrity management, - fluid transfer modes, - life extension, - risk management including those risks initiated by geological hazards, - in-field coating repairs, - corrosion protection including cathodic protection and prevention of corrosion influenced by stray currents, - requirements for the transportation of fluids containing carbon dioxide, - requirements for the transportation of fluids containing hydrogen, - requirements for ammonia transportation, - test procedures of different elements of the pipeline systems, - non-destructive testing including in-line inspection, - repair methods, - terminology.

The scope of the subcommittee generally encompasses the topics addressed by the standards it develops. However, in addition to these, issues related to the pipeline transportation of hydrogen (H_2), carbon dioxide (CO_2), and ammonia (NH_3) have been incorporated into the scope. This expansion reflects the understanding that the transition to low-carbon energy will inevitably lead to a rise in the use of such pipelines. While there are existing pipelines worldwide designed to transport these fluids, none of them are associated with low-carbon energy. As the scale of these pipelines grows, and given their close integration with oil and gas infrastructure, new technological challenges will arise that will need to be addressed in the near future.

The oil and gas industry is relatively mature, characterized by its inherent inertia, and its diversification presents a complex challenge that demands a thorough justification of the steps taken. Given the current circumstances, it is crucial to understand the nature of the challenges engineers will face during the transition of the oil and gas sector to a new, low-carbon trajectory.

Technological processes in low-carbon energy involve the transportation of key products, such as hydrogen and carbon dioxide, from production sites to consumption or storage locations via pipelines. These pipelines differ in configuration and operational modes, possibly to an even greater extent than traditional oil and gas pipelines. The task of future standardization efforts will be to examine their specific characteristics and establish regulations for the design, construction, operation, and maintenance of such pipelines. The block diagram of technological processes in low-carbon energy has been illustrated in Figure 2.

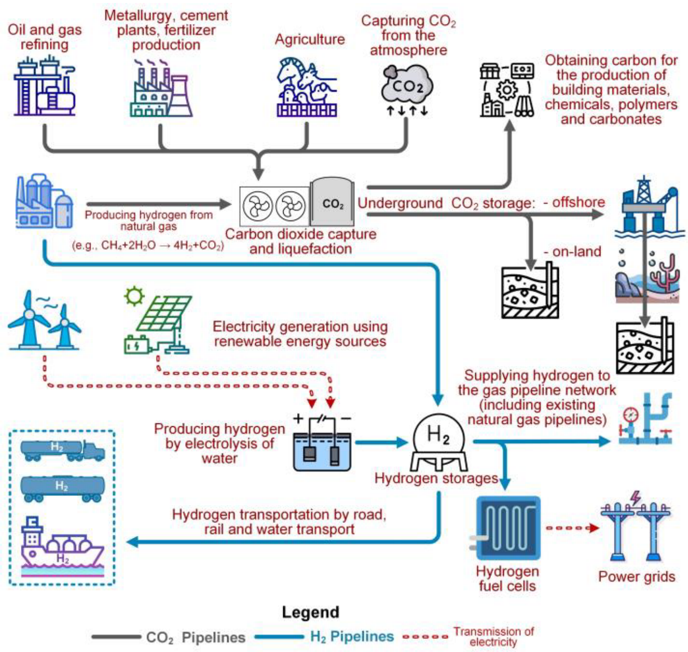

Figure 2. The block diagram of technological processes in low-carbon energy

Figure 2 illustrates that the main arteries connecting low-carbon energy facilities will be hydrogen and carbon dioxide pipelines. This indicates that, in the near future, it will be necessary to develop a corresponding regulatory framework for their construction, taking into account the specific characteristics and associated operational risks.

2. Global lower carbon energy trends

The goals of the Paris Agreement of 2015, are to significantly reduce global greenhouse gas emissions and limit the increase in average global temperature in this century to 2 °C while seeking means to further limit this increase to 1.5 °C.

Bearing this goal in mind, the world's energy giants, including British Petroleum, Shell, Total, ENI, along with Tesla Motors, Boeing, British Airways, Nippon Steel and many others, have committed to achieving carbon neutrality by 2050.

British Petroleum has been actively developing new business areas in recent years. Thus, in 2019, only about 3% of the company's capital investments accounted for drivers of transitional growth - bioenergy, development of an electric vehicle charging network, hydrogen and renewable energy, and in 2022 the share of these costs has already increased to 30%. After acquiring the American company Archaea Energy in 2022, British Petroleum is building one of the world's largest plants for the production of renewable methane, the technology of which is based on its production through anaerobic decomposition of waste with the participation of single-celled organisms [2].

Shell, in addition to comprehensively reducing carbon emissions at all stages of its technological chain, is actively involved in carbon capture, utilization and storage (CCUS) projects. This technology should become a key element of the transition to carbon-free energy, according to the International Energy Association [3].

Shell currently has interests in three operating CCUS projects – in Australia, Canada and Norway; 11 projects are in development and 6 more are in the investment feasibility stage [4].

The global annual volume of carbon dioxide emissions is estimated at approximately 40 billion tons [5], so projects similar to those given above are very numerous, and they are implemented not only by such well-known giants of traditional energy. In particular, in Iceland in September 2021, the world's largest CCUS plant was commissioned at a geothermal power plant, the energy of which is used to power the plant, while all carbon dioxide and hydrogen sulfide previously emitted by this power plant into the atmosphere are captured and buried [6].

These and other low-carbon energy projects currently underway and those being discussed are unthinkable without relevant pipeline facilities.

The global situation of this area, the aforementioned trends will be accompanied by a rise in the proportion of pipelines specifically engineered for the transportation of hydrogen and carbon dioxide.

3. Assessing the features of transporting hydrogen via pipelines

Using hydrogen as an energy source has been generally recognized as one of the main cornerstones of energy transition. According to the European Union's energy strategy, the target is to produce 10 million tons of renewable hydrogen by 2030 and import a further 10 million tons over the same time period [7].

For distances less than 3000 km the pipeline transportation of hydrogen is considered to be the most cost-effective way [8].

The establishment of a robust hydrogen transmission network is a critical priority for the expansion of a comprehensive hydrogen-based economy.

There are approximately 5000 km of existing hydrogen pipelines in the world [9]. As of the end of 2021, the length of pipelines for transporting hydrogen in the United States was about 2,500 km, approximately 85% of which were on three main lines, mainly having a diameter of up to 300 mm (in some sections the pipeline diameter is 450-500 mm). A set of forty projects managed by the transmission system operators of European countries, representing 31,500 kilometers of hydrogen pipelines, is expected to be commissioned before 2030 [10].

By 2030, it is planned to build about a thousand more kilometers of hydrogen pipelines in the United States. At the same time, the utilization of the current natural gas infrastructure for hydrogen delivery has been under deliberation for several decades.

As part of the US hydrogen strategy, the possibility of expanding the hydrogen delivery infrastructure by adapting part of natural gas pipelines to transport a mixture of natural gas and hydrogen (with a hydrogen share of up to 15%) is being closely studied, which may require only minor modifications of pipelines and equipment [11].

Similar projects are already being developed in other countries, including HyDeploy (UK), GRHYD (France), ARENA (Australia) and others. Using existing natural gas networks to transport hydrogen is four times more cost-effective than building new pipelines, research shows [12].

As a testament to this, we can observe the ongoing negotiations between the Algerian Minister of Energy and Mining and the German Federal Ministry of Economic Affairs and Climate Protection regarding the conversion and expansion of current gas transmission networks. This is aimed at facilitating the export of renewable hydrogen from Algeria to southern Germany through Tunisia, Italy, and Austria [13]. The South H_2 project will consist of converting existing gas pipelines to transport up to 4 million tons of green hydrogen per year. Gas transmission system operators SNAM (Italy), Gasconnect-Austria (Austria), Trans Austria Gasleitung (Austria) and Bayernets (Germany) have begun a feasibility study to assess technical export possibilities. In March 2023, Algeria presented its renewable hydrogen road map, which aims to meet 10% of Europe's renewable hydrogen needs by 2040.

However, the use of existing gas pipelines to transport hydrogen is associated with a number of technical problems, the root causes of which will be discussed below.

The first long distance hydrogen pipeline was constructed in 1938 in Germany (connecting Rhine with Ruhr, 240 km built of regular steel pipes 250-300 mm in diameter, transporting hydrogen at 10-20 bar pressure, still in operation). Hydrogen pipelines operating in the world today are highly specialized and connect specific enterprises with each other.

The hydrogen industry itself is quite mature; there are various standardization documents regulating the design and operation of hydrogen pipelines [14-16]. At the same time, they are usually rather particularized and apply mainly to small-scale pipelines located within industrial buildings and structures.

It has been quite a long time since different approaches were made towards systematizing the experience of constructing hydrogen pipelines with the aim of converting accumulated quantity into quality and further transition to long-distance pipelines like those that transport oil and gas [17-19]. However, there is still little experience on long-distance transport, and building of dedicated pipelines is expensive.

The first modern, thorough attempt to cover all the intricacies and nuances of the transition to pipeline transport of blended natural gas and hydrogen has been made in a technical report by the European standardization body [20].

The report contains a selection of valuable factual data, and provides a guideline on how the pipeline industry will develop in the future and in which areas additional research is needed.

In turn, ISO TC67 (the aforementioned working group 15) has published the technical specifications ISO/TS 20790:2024 “Oil and gas industries including lower carbon energy – Guidelines for green manufacturing and lower carbon emission of oil and gas-field equipment and materials”.

These specifications provide guidelines for green manufacturing and carbon emission reduction in oil and gas field equipment and materials. They include the establishment of a green attribute system and the implementation of best practices, such as green design, manufacturing, remanufacturing, evaluation, and management. This document applies to organizations involved in the design, construction, engineering, commissioning, operation, maintenance, decommissioning, and reuse of materials, equipment, installations, and process systems in the hydrocarbon industry.

Subcommittee 2 of TC 67 has published ISO 13623:2017/Amd 1:2024 "Petroleum and natural gas industries – Pipeline transportation systems – Amendment 1: Complementary requirements for the transportation of fluids containing carbon dioxide or hydrogen", specifying requirements and giving recommendations for the design, materials, construction, testing, operation, maintenance, and abandonment of pipeline systems used for transportation in the petroleum and natural gas industries.

There are two approaches to transporting hydrogen using pipelines: transporting pure hydrogen and its blending with natural gas transported via existing gas pipelines [21]. Some of these pipelines should be re-purposed into pure hydrogen pipelines later on. All of these prospects imply a number of technological challenges to be resolved.

The features of pipeline transportation of hydrogen are determined by its physical and chemical properties, such as extremely low density, high permeability, high chemical activity towards other materials, and some other properties (Joule-Thomson effect coefficient, explosive limits, high flammability, low ignition energy, etc.), significantly discrepant from those of natural gas. Physical properties of hydrogen, crucially important from the point of view of pipeline transport, in comparison with those of methane has been given in Table 2.

Table 2. Physical properties of hydrogen, crucially important from the point of view of pipeline transport, in comparison with those of methane

Properties		Hydrogen	Methane
Density, kg/m3 (@ 20 °C, 101 325 Pa) [22]		0.09	0.7
Molecular size, nm [22]		0.075	0.22
Sound speed, m/s (@ 20 °C, 101 325 Pa) [23]		1390	438
Joule-Thomson coefficient, K/MPa (@ 10 MPa, 230…355 K) [24]		-0.23…-0.42	3.8…2.3
Flammability limits in air (@101 325 Pa, 20 °C), % [25]	lower	4	5.3
	upper	75	15
Minimum ignition energy, mJ (@101 325 Pa, 20 °C) [25]		0.02	0.3

Blending hydrogen with natural gas and utilizing the existing natural gas transportation pipeline and distribution network for transmission is among the options being considered for transportation of hydrogen to end users.

That said, the data in Table 2 clearly shows how much the physical properties of these gases differ. It is enough to note that even the sign of the Joule-Thomson coefficient is different; and when Joule-Thomson coefficient is greater than zero, the post-throttling temperature decreases; when it is less, the post-throttling temperature increases.

In the light of re-purposing, additional testing of steels used in the old natural gas pipelines is needed to identify their limiting behavior in hydrogen environments.

The hydrogen-methane mixing ratio depends on the specific case and can vary over a wide range. Although hydrogen separation is a well-known technology, the process itself is rather expensive and must be the subject of an individual cost-benefit calculation. The economic assessment of hydrogen blending must take into consideration pressure de-rating of existing pipelines, increased compression energy, increased pipeline maintenance spends, overall capital investments, as well as economical effect from replacing natural gas with hydrogen as a fuel.

The penetration of atomic hydrogen into the material of pipes and equipment leads to the risk of steel embrittlement [26]. To avoid this on newly built hydrogen pipelines, it is important to pay special attention to the material properties or to protect the inner surface from hydrogen saturation by using coatings [27].

Repurposing existing natural gas pipelines for hydrogen or hydrogen blends, while more cost-effective than building new infrastructure, introduces several technical challenges. Pre-existing defects, such as corrosion, cracks, and dents, can trap hydrogen and exacerbate hydrogen embrittlement in pipeline steel. Older pipelines, constructed with legacy metallurgical methods, tend to have higher impurity levels, making them more vulnerable to hydrogen embrittlement compared to modern materials. Studies indicate that the prolonged exposure of these pipelines to underground conditions over decades may further degrade their mechanical properties, increasing the risk of brittle failure [28].

The small size of the hydrogen molecules leads to a significant increase in the risk of leaks from pipelines and equipment [29]. To prevent this, it is necessary to introduce more stringent tightness requirements for hydrogen pipelines than for natural gas pipelines, as well as to reconsider leak-detecting techniques, and, probably, improve quality and decrease quantity of threaded, flanged and welded connections.

As a part of the commissioning and decommissioning technologies, when purging and filling pipelines and equipment with hydrogen, it is necessary to prevent stratification during the purging process (to ensure complete emptying or filling of pipelines), as well as to exclude the formation of explosive hydrogen-air mixture through inertizing (for safety reasons). The approaches should also differ from those for natural gas.

Hydrogen blending is affecting the hydraulic and thermodynamic of the gas pipeline transportation [30]. The low molecular weight of hydrogen makes centrifugal compressors increase rotational speed with increasing hydrogen concentrations to maintain the compression ratio needed. The lower volumetric energy density of hydrogen results in reduction of energy transmission capacity at fixed pipeline pressures, and maintaining either consistent pipeline pressures or energy transmission capacity requires a significant increase in compression energy due to the lower molecular weight of hydrogen.

The blending of hydrogen with natural gas depends on various factors [31]. Different components of gas transmission equipment react differently to hydrogen levels. For example, gas coolers, filters, and vent stacks should not be significantly affected by hydrogen, while gas turbines, centrifugal and reciprocating compressors require specific consideration.

To prevent surge or choke, centrifugal natural gas compressors should exhibit flexible performance [32]. Gas mixtures that deviate from standard compositions can alter fluid density at the inlet, which in turn influences the volumetric flow rate and may lead to the compressor operating outside its intended parameters.

Centrifugal compressors with variable-speed drive electric motors offer flexibility to avoid surge and choke, while fixed-speed machines can adjust inlet guide vanes as an alternative solution.

Studies indicate that impeller speed exceeds safe limits when compressing natural gas mixtures with 10 % hydrogen content under constant throughput conditions [33]. Similarly, maintaining a constant outlet pressure results in the compressor exceeding safe rotation speeds at around 20 % hydrogen concentration [34].

It is important to note that these extreme values were obtained through experimental processes. For industrial applications, any hydrogen content in transported gas must be approved by the equipment manufacturer. Currently, research is focused on the feasibility of blending up to 10% hydrogen into natural gas for future use [35].

After hydrogen is mixed into natural gas, the gas characteristics are more complex, which has a complex impact on the pipeline, transportation equipment, fuel equipment and so on. To promote the development of hydrogen energy, it is desired to study and establish a series of applicable standards for the design, construction, operation and management of hydrogen-mixed natural gas pipelines, so as to form a targeted and integrated standard system for hydrogen-mixed natural gas pipelines.

Compared with steel pipes for hydrogen transport, non-metal pipes have many advantages, for example, strong design-ability, light weight, no risk of hydrogen embrittlement, and no welding, convenient and quick connection. That said, it should be taken into consideration that hydrogen can impact the physical properties of plastic and composite materials penetrating in their structure [36]. For example, the degradation of polymers in pipelines can be caused by such processes as permeation, absorption, oxidation, and hydrolysis [37]. The continuity, density, and resilience of materials can be heavily affected, as a result.

4. Risks and challenges associated with carbon dioxide pipelines

When implementing CCUS projects, the problem of transporting carbon dioxide obviously arises. And the more modern such projects are, the larger the scale they acquire.

In 2022, Equinor (Norway) together with Wintershall Dea (Germany) announced plans to build a 900 km pipeline by 2032 to transport CO_2 from northern Germany to an underground disposal site on the Norwegian shelf [38].

In October 2023 the final investment decision for Porthos project was taken [39]. Porthos has been recognized by the European Union as a Project of Common Interest. The construction will start in 2024, the system is expected to be operational from 2026.

Porthos is developing a project in which CO_2 from industry in the Port of Rotterdam is transported and stored in empty gas fields beneath the North Sea.

The CO_2 that will be transported and stored by Porthos, will be captured by various companies. The companies will supply their CO_2 to a collective pipeline that runs through the Rotterdam port area, where it will be pressurized and transported through an offshore pipeline to a platform in the North Sea, approximately 20 km off the coast. From this platform, the CO_2 will be pumped into an empty gas field. The empty gas fields are situated in a sealed reservoir of porous sandstone, more than 3 km beneath the North Sea. The total capacity of Porthos will be around 37 Mton CO_2 (approximately 2.5 Mton per year for 15 years).

An increasing number of both offshore and onshore projects involving carbon dioxide transportation are being developed. However, there remains limited experience with the construction and operation of large-scale carbon dioxide pipelines. The transportation of carbon dioxide via transmission pipelines presents unique challenges, similar to those encountered in hydrogen transport. However, the specific issues associated with carbon dioxide differ substantially from those encountered in hydrogen pipeline systems.

The United States has accumulated significant experience in the construction and operation of offshore and onshore carbon dioxide pipelines. Currently, there are about 50 such pipelines in operation there, with a total length of more than 8,000 km, through which about 70 million tons of CO_2 are transported annually. These pipelines link natural sources of carbon dioxide to oil fields, where it is used to enhance oil recovery, since

CO_2 is a super solvent. In the near future, it is planned to build more than 5.5 thousand km of pipelines to transport captured and utilized carbon dioxide produced at ethanol plants in the upper and mid-western regions of the United States [40].

The safe operation of CO_2 pipelines is caused by significant differences in the physical properties of carbon dioxide from hydrogen, oil, and gas. The phase diagram of carbon dioxide is shown in Figure 3, where we see that CO_2 can exist in one of three physical states in a range of pressures and temperatures that is commonly encountered in practical applications.

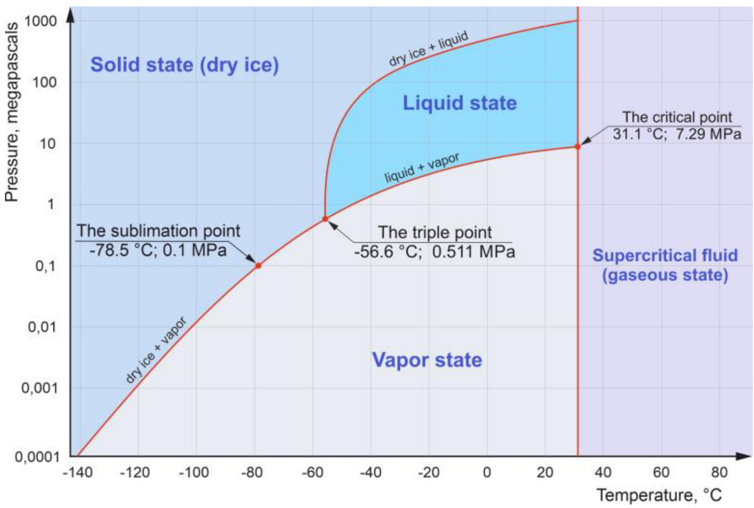

Figure 3. Phase diagram of carbon dioxide

Carbon dioxide pipelines designed for its capture and sequestration involve multiple gas sources, whose flow rates and pressures can vary rather unpredictably, complicating the maintenance of stable hydraulic conditions in the pipeline. CO_2 is usually transported in the liquid phase, and as shown in the phase diagram (Figure 3), the conditions for this phase are relatively limited.

While Figure 3 describes pure carbon dioxide, its behavior changes quite a bit according to very small amount of pollutants that the gas is carrying (such as hydrogen sulphide, sulphur dioxide and others), that are commonly found in exhaust gases. Not all of these properties are completely foreseeable and understandable.

The most sensitive impurity in carbon dioxide is water. Although dehydration of carbon dioxide is a very energy-intensive process [41], if it is not carried out, then even a single percentage can cause great trouble for the pipeline [42].

Free water, if it is not removed from carbon dioxide prior to its transportation, acts as an electrolyte directly impacting the CO_2 pipeline material, which causes corrosion [43]. Also, the interaction of free water with carbon dioxide can lead to the formation of carbonic acid, causing corrosion, as well [44]. Extensive research has been conducted on both types of corrosion mechanisms, resulting in well-documented data on corrosion rates. The susceptibility of carbon steel pipelines to corrosion is a significant concern, according to studies involving hydrocarbons with low CO_2 content [45].

These and related issues, such as the danger of hydrate formation, are described in the form of guidelines in existing documents [46].

Corrosion of CO_2 pipelines is not solely caused by water; studies have shown that the presence of small amounts of H_2S in the CO_2 stream can accelerate corrosion under dynamic flow conditions. Under these circumstances, the formation of a protective iron carbonate scale is hindered by the deposition of iron sulfide, which is unstable and prone to removal from the metal surface, reducing its protective effectiveness. The combination of CO_2 and H_2S creates a highly corrosive environment, significantly increasing the risk of damage to pipeline steel [47].

However, a number of issues still require detailed regulation, in particular those related to the safe operation and hydraulic modes of carbon dioxide transport.

The usual range of operation parameters lays within the liquid area (see Figure 3), but once the pressure is released, the product immediately turns into a normal CO_2 gas, with its volume increasing very rapidly, as pressure is released. In the event of an emergency, if CO_2 were to be released from a pipeline, it would rapidly cool (the Joule-Thomson coefficient of CO_2 is 11.1 K/MPa @ 5 MPa, 20 °C [21]) and spread along the pipeline right-of-way and surrounding area. Due to its specific gravity of 1.53 being higher than that of air, it will tend to move towards lowlands, following the actual topography of the area. A similar incident occurred on February 22, 2020, in the U.S. [48], when, as a result of a leakage, a CO_2 cloud covered the small town of Satartia (Yazoo County, Mississippi). That day, many unprepared inhabitants lost consciousness due to the high concentration of carbon dioxide (an asphyxiant with well-established toxicological risks) in the atmosphere, 200 residents surrounding the rupture location were evacuated, and 45 were taken to the hospital. What was even more daunting, people could not leave the zone of the CO_2 plume, since the internal combustion engines did not start at lack of oxygen in the atmosphere. Such cases underscore the need for thorough risk analysis associated with the operation of carbon dioxide transmission pipelines [49].

The existing CO_2 pipelines connect its natural sources to the oil producing facilities, which means that pressure distribution along the pipeline is almost the same through the whole operation period. Whereas the modern CO_2 main pipelines, dedicated to the CCUS industry, would have lots of intermittent sources, that vary up and down in their volume and pressure, sometimes unpredictably, which makes the operating such a pipeline really much more complicated, in order to maintain the optimal operational regime.

Other potential hazards associated with CO_2 pipeline transportation are as follows [50]:

- it has low surface tension and near-zero viscosity which can complicate sealing,
- release of CO_2 can cause rapid cooling, increasing the risk of embrittlement,
- pure carbon dioxide release lacks a significant initial sensory response in humans,
- liquid CO_2 release can create a large thermal cooling effect,
- explosive decompression may occur, with elastomer seals potentially failing after gas absorption under high pressure,
- carbon dioxide is a potent solvent, raising concerns for toxic contamination upon release.

The development of relevant standards is essential to establish the foundational guidelines necessary for the design tools that will support the success of the pipeline sector within the broader context of the global CCUS strategy.

5. Conclusion

The global oil and gas giants are presently in the process of metamorphosing into comprehensive energy entities, encompassing a diverse renewable energy portfolio.

These companies are initiating ambitious strategies to substantially diminish their carbon footprint as part of a concerted effort to combat climate change.

The composition of the technical committee within the domain of oil and gas technologies at the International Organization for Standardization (ISO) is acutely attuned to shifts in global energy policy. Pertinent subcommittees and working groups are established in due course, providing a platform for preeminent industry experts to share their cutting-edge expertise.

A pivotal facet of executing energy transition initiatives involves a substantial surge in the scale and extent of pipelines for transporting hydrogen and carbon dioxide. The magnitude of this expansion will surpass that of existing pipelines of the sort, necessitating technological innovations.

The challenges associated with standardizing hydrogen pipelines, including those re-purposed from natural gas pipelines, are rooted in the distinctive properties of the lightest element in the universe. Its minuscule molecular size, high permeability, as well as its combustible and explosive nature, present significant hurdles.

The complexities of standardizing carbon dioxide piping are intimately linked to the unconventional phase behavior of the substance and the safety concerns it engenders, alongside its chemical reactivity. These factors are also connected to the constraints on product purity and pipeline preparation.

The existing standards governing the design and operation of hydrogen and carbon dioxide pipelines are primarily tailored for specialized facilities or individual projects or provide general guidelines. These standards do not encompass the same scope as those for the oil and gas industry, owing to the differing scales of the two sectors. It is increasingly clear that a transition from general guidelines to more prescriptive standards is required. Such standards would establish precise and comprehensive requirements for the design of hydrogen and carbon dioxide pipelines. The issues addressed in this article highlight key directions for the development of standards within the energy sector. This is already reflected in the work program of the Pipeline transportation subcommittee of TC67.

The development of the technical report "Assessment techniques for determining fitness for service of pipeline steel for transportation of natural gas-hydrogen mixtures" commenced this year. The report is being developed under the auspices of the dedicated working group and is based on a thorough applied study of the behavior of pipeline steel in the presence of hydrogen. For this purpose, CNPC researchers are building an experimental rig consisting of pipes with diameters ranging from 300 to 650 mm, with a total length exceeding 50 m. A mixture of natural gas and hydrogen, with a variable composition ranging from 3% to 84% hydrogen, is pumped through this experimental pipeline. The pipe samples are easily replaceable due to flange connections and include girth welds, which are known to be particularly susceptible to the effects of hydrogen [51].

The results obtained from this study will enable the development of recommendations for the use of specific steel grades under particular conditions, taking into account the hydrogen content in the transported mixture.

As for the holistic approach to following standardization in the field of pipeline transportation for low-carbon energy, the following sequence appears to be reasonable. Particular factors are identified that are considered significant and potentially hazardous. Corresponding research is conducted to address these concerns. As a result, specific procedures are described, including the development of standards. These procedures are ultimately formalized in deliverables such as technical reports, specifications, and ISO standards. Throughout this process, the primary objective is to ensure the proper design, construction, and maintenance of pipelines. This goal is achieved through the development of well-founded, balanced, and appropriately calibrated standards, avoiding unnecessary conservatism.

Acknowledgments

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Numerical Simulation of Hypersonic HBS Standard Mode Dynamic Derivative Support Interference

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Abstract. In this paper, based on HBS (Hyper Ballistic Shape), the support interference study of the strut diameter was carried out. The influence of the diameter of the strut on the static aerodynamic forces and dynamic derivatives is given by the static/dynamic flow field calculation of the diameter of different strut diameters. The bowing shock wave of the leading edge of different strut diameters is consistent with the compression shock wave of the tail skirt, and the difference of the bottom flow field is the largest, so the support to the bottom resistance is also the most obvious. According to the simulation results, the tail branch of this design has less interference to the dynamic flow field of air-breathing hypersonic vehicle.

Keywords. Hypersonic, support interference, numerical simulation, dynamic derivative Introduction

1. Introduction

Support interference is one of the important sources of dynamic derivative error. It is important to study the support interference under dynamic conditions when nonlinear aerodynamic loads are generated by unsteady flow structures. [1-2].

In general, the test model and support form differ greatly from the actual situation, and some correction methods are not reliable in this case. In addition, the influence of the support rod on the model resistance is mainly concentrated in the rear body of the model, and the geometric shape of the model, the geometric parameters of the support rod, the incoming Mach number and Reynolds number will affect the resistance [3-5]. For this special case, there is no more suitable calculation program can be used [6-7].

In this paper, based on HBS (Hyper Ballistic Shape), the support interference study of the strut diameter was carried out. The influence of the diameter of the strut on the static aerodynamic forces and the dynamic derivatives is given by the static/dynamic flow field calculation of the diameter of different strut diameters. The bowing shock wave of the leading edge of different strut diameters is consistent with the compression shock wave of the tail skirt, and the difference of the bottom flow field is the largest, so the support to the bottom resistance is also the most obvious.

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2. Calculation method

Dynamic stability parameter is a significant parameter for aircraft control and unstable boundary analysis [8-10]. The aerodynamic coefficients C_λ can be defined as follows:

$$C_\lambda(t) = C_\lambda\big(\alpha(\xi), \beta(\xi), p(\xi), q(\xi), r(\xi)\big) \qquad -\infty < \xi \le t \tag{1}$$

Eq. (1) can be simplified as:

$$C_m(t) = C_m\big(\alpha(\xi)\big) \qquad -\infty < \xi \le t \tag{2}$$

Let the aircraft fly in a fixed attitude before time $\xi = 0$, the Angle of attack isα_0, and then change the motion state as follows:

$$\alpha_1(\xi) = \begin{cases} \alpha(\xi) & 0 \le \xi \le \tau \\ \alpha(\tau) & \xi > \tau \end{cases} \tag{3}$$

$$\alpha_2(\xi) = \begin{cases} \alpha(\xi) & 0 \le \xi \le \tau \\ \alpha(\tau) + \Delta\alpha & \xi > \tau \end{cases} \tag{4}$$

$\Delta C_m(t)$ is related to starting moment τ, observation time *t*, the $\Delta\alpha$ and attack angle α,

$$\Delta C_m(t) = \Delta C_m[\alpha(\xi); \Delta\alpha, \tau, t] \qquad -\infty \le \xi \le \tau \tag{5}$$

Based on Eq. (5):

$$A = A[\alpha(\xi); t, \tau] \qquad -\infty \le \xi \le \tau \tag{6}$$

Based on Eqs. (5-6), when *t>0*, $C_m(t)$ can be written as:

$$C_m(t) = C_m(0) + \int_0^t A[\alpha(\xi); t, \tau]\, \frac{d\alpha}{d\tau} d\tau \qquad (0 \le \xi \le \tau) \tag{7}$$

The initial condition of Eqs. (1-7) is: when $\tau < 0, \frac{d\alpha}{d\tau} = 0$. In fact, we can assume that $\alpha(\xi)$ expands to a convergent Taylor series around $\xi = \tau$, And then, the Eq. (7) can be equivalently deformed to:

$$A[\alpha(\xi); t, \tau] = A(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots) \tag{8}$$

In the Eq. (8), when $\tau, \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots$is given, the change of $\alpha(\xi)$ is also unique. The transition response is only related to $t - \tau$. Therefore, Eq. (8) can be deformed to:

$$C_m(t) = C_m(0) + \int_0^t A(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots)\, \frac{d\alpha}{d\tau} d\tau \tag{9}$$

Easy to know, when $t - \tau \to \infty$, indicial response $A(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots)$ rely on the $\alpha(\tau)$, its limit is $A\big(\infty; \alpha(\tau)\big)$. Redefine a new function F:

$$F(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots) = A\big(\infty; \alpha(\tau)\big) - A(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots) \tag{10}$$

As $t - \tau \to \infty$, $F \to 0$, substitute Eq. (10) into Eq. (9):

$$C_m(t) = C_m\big(\infty; \alpha(t)\big) - \int_0^t F(t - \tau; \alpha(\tau), \dot\alpha(\tau), \ddot\alpha(\tau), \cdots)\, \frac{d\alpha}{d\tau} d\tau \tag{11}$$

Easy to know $u = t - \tau$, Eq. (11) deformed to:

$$C_m(t) = C_m\big(\infty; \alpha(t)\big) - \int_0^t F(u; \alpha(t - u), \dot\alpha(t - u), \ddot\alpha(t - u), \cdots)\, \frac{d\alpha(t-u)}{du} du \tag{12}$$

According to the above assumptions about Taylor series, $\alpha(\xi)$ could expand at any point in $[0, t]$. Meanwhile, $t - u = \tau \in [0, t]$, $\alpha(t - u), \dot\alpha(t - u), \ddot\alpha(t - u), \cdots$ also could expand near t:

$$\begin{aligned} \alpha(t - u) &= \alpha(t) - \dot\alpha(t)u + \frac{\ddot\alpha(t)}{2}u^2 - \cdots \\ \dot\alpha(t - u) &= \dot\alpha(t) - \ddot\alpha(t)u + \frac{\dddot\alpha(t)}{2}u^2 - \cdots \\ \ddot\alpha(t - u) &= \ddot\alpha(t) - \dddot\alpha(t)u + \frac{\ddddot\alpha(t)}{2}u^2 - \cdots \end{aligned} \tag{13}$$

To substitute Eq. (13) into Eq. (12):

$$C_m(t) = C_m\big(\infty; \alpha(t)\big) + \sum_{i=1}^{\infty} C_i \frac{d^i\alpha(t)}{dt^i} \tag{14}$$

In Eq. (14)

$$C_i = \frac{(-1)^{i+1}}{(i-1)!}\int_0^t F(u;\alpha(t),\dot{\alpha}(t),\ddot{\alpha}(t),\cdots)\,u^{i-1}du \quad (i=1,2,3,\cdots) \tag{15}$$

Eqs. (14-15) represents the functional relationship between the $C_m(t)$ and the phase space variable. C_i is explicit function of *t*, the relation between them can be expressed in the Eq. (16):

$$C_m(t) = C_m(\alpha(t),\dot{\alpha}(t),\ddot{\alpha}(t),\cdots;t) \tag{16}$$

For more general cases, a similar analysis can be performed with expressions for $C_m(t)$, then ΔC_λ is related to aircraft motion $(\alpha,\dot{\alpha},\beta,\cdots,Ma,h,u,v,\cdots,\delta_e,\dot{\delta}_e)$. In this case ΔC_λ can also be rewritten as:

$$\Delta C_\lambda(\alpha,\dot{\alpha},\cdots,\dot{\delta}_e) = \frac{\partial C_\lambda}{\partial \alpha}\Delta\alpha + \frac{\partial C_\lambda}{\partial \dot{\alpha}}\Delta\dot{\alpha} + \cdots + \frac{\partial C_\lambda}{\partial \dot{\delta}_e}\Delta\dot{\delta}_e + H.O.T \tag{17}$$

Finally, the dynamic derivative $\frac{\partial C_\lambda}{\partial \alpha}$, $\frac{\partial C_\lambda}{\partial \dot{\alpha}}$, $\cdots$ $\frac{\partial C_\lambda}{\partial \dot{\delta}_e}$ can be obtained by calculating the time domain data ΔC_λ . There are many ways to do this, such as phase method, frequency domain transform method and regression method etc.

3. Numerical simulation

Based on the study of the influence of the length of the strut on dynamic stability, this section studies the support interference of the strut diameter based on the HBS standard model. The influence of the diameter of the strut on the static aerodynamic force and the dynamic derivative is given by the static/dynamic flow field calculation of the diameter of different strut diameters.

3.1. Calculation model

For study the influence of the tail support on the flow field of the model, three kinds of struts were designed. The support section is a circular section installed at the bottom of the model. The axis coincides with the symmetry axis of the model, and the support extends beyond the calculation domain. The ratio ds/d of the diameter of the three struts to the diameter of the bottom of the HBS is 20%, 50%, and 80%, respectively. Figure 1 shows the tail support of the HBS.

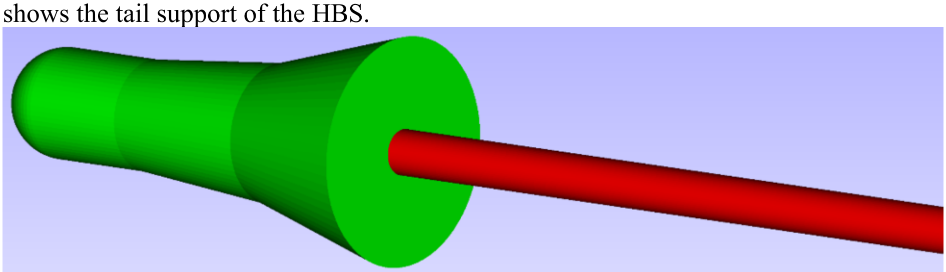
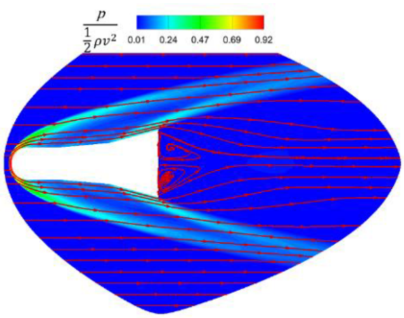


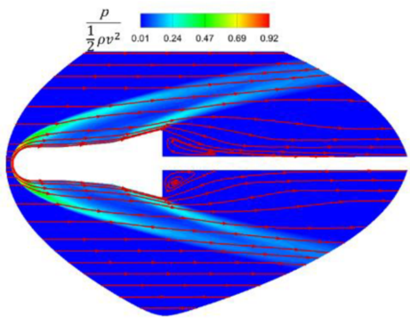
Figure 1. HBS outline tail support diagram

3.2. Effect of strut diameter

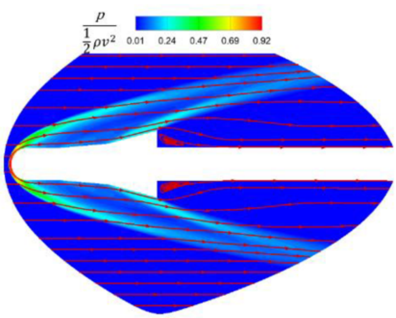
The calculation state of HBS support disturbance is taken from the wind tunnel experimental conditions: Mach number $Ma_\infty = 6.85$, $Re_d = 0.72\times10^6$ with reference length as the reference length, centroid position $X_{cg}/L = 0.72$. Figure 2 gives the symmetry plane flow line and pressure of different supports when HBS-shaped 0° angle of attack Cloud map. The leading edge bow shock of different strut diameters is consistent with the compression shock wave of the tail skirt. The difference in the bottom flow field is the largest, so the interference to the bottom resistance is also the most obvious. Figure 3 gives the static aerodynamic coefficient with the angle of attack. The pitching moment coefficient and the lift coefficient curve of different struts are basically coincident, and the difference in drag coefficient is the largest. The resistance coefficient of ${}^{d_s}/_{d} = 20\%$ and the no-bar state are basically coincident. With the increase of ${}^{d_s}/_{d}$, the difference in drag coefficient is also obvious.



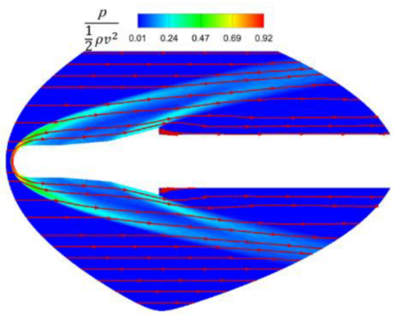
(a) Without support



(b) d_s/d=20%

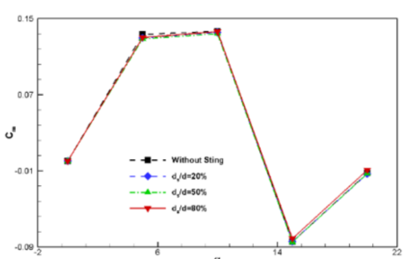


(c) d_s/d=50%

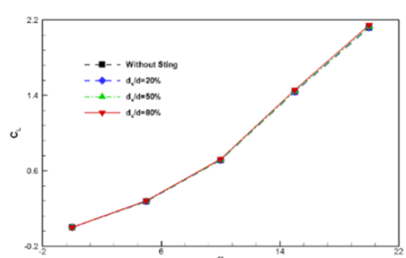


(d) d_s/d=80%

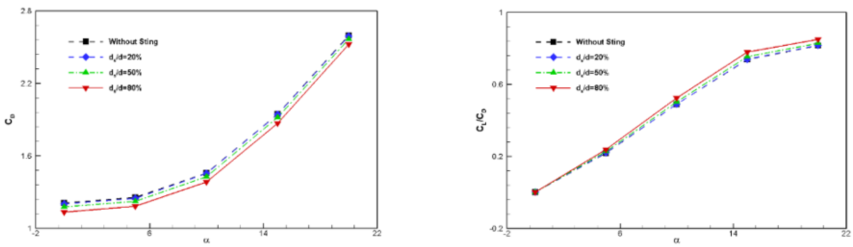
Figure 2. HBS symmetry surface flow line and pressure cloud map



(a) Pitching moment coefficient



(b) Lift coefficient



(c) Resistance coefficient (d) Lift-drag ratio

Figure 3. Static aerodynamic coefficient with angle of attack

3.3. Style and spacing

The combined derivative $C_{mq} + C_{m\dot{\alpha}}$ of HBS's different strut diameters is listed in Table 1. Unlike the drag coefficient, the strut diameter has little effect on the dynamic derivative, and the difference between the different states does not exceed 5%.

Table 1. Combined derivative of HBS different strut diameter $C_{mq} + C_{m\dot{\alpha}}$.

Angle of attack	Without support	d_s/d=20%	d_s/d=50%	d_s/d=80%
0°	-19.98	-19.98	-19.19	-19.26
5°	-18.72	-18.75	-18.64	-18.51
10°	-17.69	-17.68	-17.80	-17.67
15°	-23.58	-23.43	-23.46	-23.35
20°	-61.36	-61.50	-61.44	-61.31

4. Conclusion

Based on the research on the influence of the length of the strut on the dynamic stability, the support of the diameter of the strut is carried out for the HBS standard model. Through the calculation of the static/dynamic flow field with different diameters of the strut, the diameter of the strut is given to the static aerodynamic force and the study of the influence of the dynamic derivative. This paper designed three kinds of struts. The surface is a circular section installed at the bottom of the model, the axis coincides with the axis of symmetry of the model, and the support extends beyond the calculation domain. The ratio of the diameter of the rod to the diameter of the bottom of the HBS ds/d is 20%, 50%, and 80%, respectively. The main results are as follows:

(1) The shock wave and the tail skirt compression shock wave are consistent with each other, and the difference in the bottom flow field is the largest, so the interference to the bottom resistance is also the most obvious.

(2) The pitching moment coefficient and the lift coefficient curve of different struts are basically coincident, and the difference in the drag coefficient is the largest.

(3) The resistance coefficient of ${d_s}/{d} = 20\%$ and the state without the poles substantially coincide. As ${d_s}/{d}$ increases, the difference in drag coefficient becomes apparent.

(4) The dynamic aerodynamic characteristics of the different strut diameters of the HBS model show that the strut diameter has little effect on the calculation results of the dynamic derivative.

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A Fuzzy Control Strategy Based on PI^2 for Semi-Active Suspension

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Abstract. Many studies have used fuzzy control strategies to control semi-active suspensions. The conventional fuzzy control strategy depends on the designer's experience, and it is difficult to find the optimal control parameters. This paper uses the reinforcement learning algorithm PI^2 (Policy Improvement with Path Integrals) to optimize the membership function parameters. Through simulation, this method is more effective than conventional fuzzy control strategy in reducing the body vertical acceleration and dynamic deflection of suspension.

Keywords. Semi-active suspension, fuzzy control, Policy Improvement with Path Integrals

1. Introduction

Suspension systems have the function of absorbing ground-transmitted vibrations and improving the smoothness of the vehicle's ride as well as its handling stability. The traditional passive suspension has the disadvantage of being unable to adjust to different road conditions. Although active suspension has a good control effect, it has the disadvantages of complex structure and excessive energy consumption. Semi-active suspension can adjust the damping coefficient of the damper according to the degree of vehicle vibration, has good control performance and low energy consumption and low structural complexity. These advantages have made semi-active suspensions the most researched and widely used suspension system [1-2]. Fuzzy control possesses the advantages of strong control robustness as well as does not require an accurate model of the controlled object. Many scholars have investigated the use of fuzzy control for the control of semi-active suspension, and the literature [3] proved that fuzzy control can improve the performance of the suspension system.

The “trial-and-error” method is the main method of designing fuzzy controllers, which relies on the experience of the designer. Since there are many parameters that need to be determined for designing a fuzzy controller, it is difficult to accurately find the appropriate parameters of the fuzzy controller by “trial and error”. With the introduction of intelligent algorithms such as neural networks and genetic algorithms, many scholars have studied the optimization of fuzzy controllers using intelligent algorithms.

The affiliation function of a fuzzy controller is generally determined by dozens of parameters. Heuristic algorithms such as Particle Swarm Optimization (PSO) and Differential Evolutionary Algorithms (DE) have the disadvantage of easily falling into

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local optimums when optimizing such multi-parameter models. Unlike DE and PSO, which are algorithms that only utilize the current optimal samples for updating, reinforcement learning is based on all existing samples to get the descent direction, which is a better use of information. In this paper, a reinforcement learning algorithm is considered to be used for the optimization of the fuzzy controller, and a fuzzy control strategy based on Policy Improvement with Path Integrals (PI^2) is proposed to control the semi-active suspension.

2. Simulation Model

2.1. Quarter Semi-Active Suspension Model

The semi-active suspension quarter-vehicle model is shown in Fig. 1, where m_w corresponds to the unsprung mass; m_s corresponds to the spring-loaded mass; K_s corresponds to the suspension stiffness; K_w corresponds to the tire stiffness; F_d corresponds to the magnetorheological damper output force; x_s corresponds to the droop displacement of the spring-loaded mass; x_w corresponds to the droop displacement of the unsprung mass; and q is the road surface input.

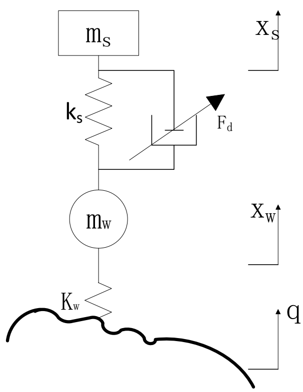

Figure 1. Quarter vehicle model with semi-active suspension

Semi-active suspension dynamics equations:

$$\begin{cases} m_s\ddot{x}_s + F_d + K_s(x_s - x_w) = 0 \\ m_w\ddot{x}_w - F_d + K_s(x_w - x_s) + K_w(x_w - \text{q}) = 0 \end{cases} \tag{1}$$

2.2. Road Surface Roughness Excitation Models

The road condition can be measured by unevenness. The road roughness function q（I） describes the relationship between the height q of the road surface relative to the reference plane and the length I from the starting point position. The power spectrum of q（I）is $G_q(I)$. Its expression is:

$$G_q(n) = G_q(n_0)\left(\frac{n}{n_0}\right)^{-\omega} \tag{2}$$

In the above equation, $G_q(n)$- road power spectral density value; n - spatial frequency; n_0- reference spatial frequency; ω - frequency index. Generally speaking, n_0 is taken as 0.1 and ω as 2.

The international standard divides road surfaces into eight levels, with Chinese roads mainly concentrated in three levels: A, B, and C. The standards are shown in Table 1.

Table 1. Classification criteria for road roughness

Road level	$G_q(n_0)\times 10^{-6}m^2/m^{-1}$ $n_0 = 0.1m^{-1}$		
	lower limit	geometric mean	upper limit
A	8	16	32
B	32	64	128
C	128	256	512

The time-domain model of road excitation using filtered white noise method is:

$$\dot{q}(t) = -2\pi f_0 q(t) + 2\pi\sqrt{G_q(n_0)v}\,\omega\,(t) \tag{3}$$

In the formula, v is the vehicle's driving speed; $\omega(t)$ is Gaussian white noise with mean value of 0; $q(t)$ is vertical displacement; f_0 is Cut off the spatial frequency below $f_0 = 0.01m^{-1}$.

2.3. Smoothness Evaluation Indicators

The smoothness of a car refers to its ability to reduce the impact of vibration on passenger comfort. Due to the fact that the human body's perception of smoothness depends on the frequency and intensity of vehicle vibrations, body vertical acceleration is selected as the evaluation index for vehicle smoothness. In addition to body vertical acceleration, tire dynamic load and dynamic deflection of suspension are also important indicators.

3. Fuzzy Controller Optimized Based on PI^2

3.1. Design of Fuzzy Controller

The fuzzy controller mainly consists of an input fuzzification interface, knowledge base, fuzzy inference engine, and defuzzification interface. Analyze the suspension dynamics and select the vertical velocity v and body vertical acceleration a as input variables, and the damper control force F as output variable. The membership function is selected as Gaussian membership function, the inference method of the fuzzy controller is Mamdani method, and the deblurring method is Centroid method.

The set of fuzzy language:

a={NB,NS,Z,PS,PB} v={NB,NS,Z,PS,PB} F={ NB,NS,Z,PS,PB }

The fuzzy set domain:

a={-2,-1,0,1,2} v={-2,-1,0,1,2} F={ -2,-1,0,1,2 }

The quantification factor and proportional factor:

$k_v = \frac{2}{v_{max}} \quad k_a = \frac{2}{a_{max}} \quad k_F = \frac{F_{max}}{2}$

According to the analysis of the suspension dynamics, when the absolute value of v is too large or has an increasing trend, the output force should reduce its absolute value or offset its increasing trend. Therefore, the design of fuzzy control rules is shown in Table 2:

Table 2. Fuzzy Control Rules

F		Body vertical acceleration a				
		NB	NS	Z	PS	PB
body vertical speed v	NB	PB	PB	PB	PS	Z
	NS	PB	PS	PS	Z	NS
	Z	PS	Z	Z	Z	NS
	PS	PS	Z	NS	NS	NB
	PB	Z	NS	NB	NB	NB

3.2. Policy Improvement with Path Integrals

Policy Improvement with Path Integrals (PI^2) is a reinforcement learning algorithm that combines stochastic optimal control and has numerical robustness in high-dimensional learning problems [4]. The optimal control of a random system is to find suitable control variables to minimize a certain system performance indicator. By obtaining the optimization objective value function, the stochastic optimal control problem can be approximated as a path integral approximation problem.

Unlike other algorithms, PI^2 uses probability-weighted averaging to update parameters. Given the initial value ω, then add random perturbation ε to generate multiple variational paths τ_i, so as to obtain multiple paths with different costs. The value of ω is updated according to the obtained results by weighting and averaging them. The optimal control quantity u is:

$$u = \int P(\tau_i) u_L(\tau_i) d\tau_i \tag{4}$$

The local control variable in the formula $u_L(\tau_i)$ is:

$$u_L(\tau_i) = \omega + \varepsilon_i \tag{5}$$

The probability $P(\tau_i)$ is:

$$P(\tau_i) = \frac{e^{-\frac{1}{\lambda}J(\tau_i)}}{\int e^{-\frac{1}{\lambda}J(\tau_i)} d\tau_i} \tag{6}$$

In the formula, $J(\tau_i)$ represents the τ_i cost of the path. The coefficient λ>0 makes the path with larger cost $J(\tau_i)$ lower probability $P(\tau_i)$. When the optimal control quantity is finally obtained, it can ensure that the optimal control quantity converges to the place with a lower cost.

3.3. Fuzzy Controller Optimized Based on PI^2

According to the smoothness evaluation index, this paper adopts the cost function:

$$\mathrm{J} = \sqrt{\left(K_a \sum_{i=0}^{N} a_i^2 + K_d \sum_{i=0}^{N}(i_d \times d_i)^2 + K_f \sum_{i=0}^{N}\left(i_f \times f_i\right)^2\right)} \tag{7}$$

In the formula, a_i is the value of the ith sampling point of the body vertical acceleration; d_i is the numerical value of the ith sampling point of the dynamic deflection of suspension; f_i is the numerical value of the ith sampling point of the tire dynamic load; K_a、K_d and K_f represent the weight of the three indicators, $K_a + K_d + K_f = 1$. N is the number of sampling points; i_d and i_f are used to process the three indexes in the same magnitude.

The fuzzy controller adopts a Gaussian membership function, and its mathematical expression is:

$$f(x\ ;\ \sigma\ ;\ c) = e^{-\frac{(x-c)^2}{2\sigma^2}} \tag{8}$$

In the formula, σ is the width of the Gaussian curve and c is the center coordinate value of the Gaussian curve. According to Eq.(8), the fuzzy controller has a total of 15 Gaussian curves with two inputs and one output, which means it has 30 parameters. Set the $\omega = [x_1\ x_2\ x_3 \cdots\cdots x_{30}]$ corresponding thirty parameters that need to be optimized. Take the parameter values when the Gaussian membership function is uniformly distributed as the initial values ω_0. According to Eq.(4), Eq.(5), Eq.(6) and Eq.(7), the optimization process of PI^2 for membership function parameters is shown in Figure 2.

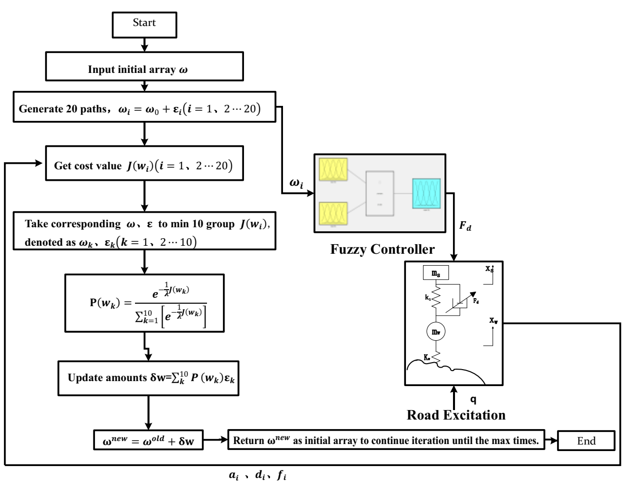

Figure 2. PI^2 Optimization Process Diagram

4. Simulation and Analysis

This paper uses simulation software for the simulation experiment. The suspension simulation is established according to Eq.(1) and parameters are shown in Table 3. The parameter c_p is the damping coefficient of passive suspension. The road surface roughness excitation model is establishied according to Eq.(2) and Eq.(3).

Table 3. simulation parameters of suspension

Parameter	value	unit
m_s	275	Kg
m_w	39	Kg
k_s	17730	N/m
k_w	187000	N/m
c_p	1150	$N \cdot s \cdot m^{-1}$

The membership function parameters of the fuzzy controller are optimized by using the reinforcement learning algorithm PI^2 under the condition of 90Km/h on Class A road. Figure 3 shows the comparison between the membership function trained by the PI^2 algorithm and the initial membership function.

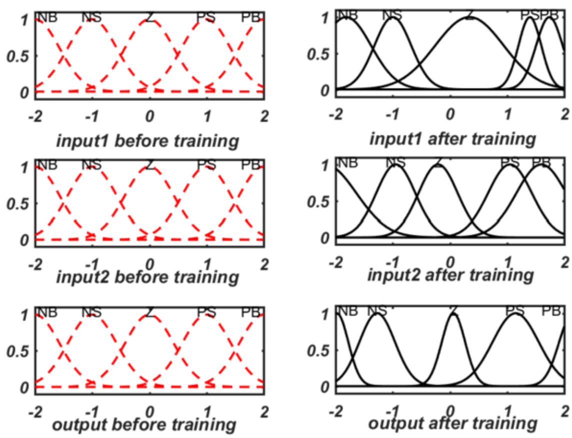

Figure 3. Comparison of membership function before and after training

Simulate under the condition of a speed of 90Km/h on Class A road. By comparing the three control strategies, the variation curves of their body vertical acceleration are shown in Figure 4. From Figure 4, it can be seen that compared to passive suspension, the conventional fuzzy control strategy can effectively suppress the body vertical acceleration. The fuzzy control strategy based on PI^2 can better suppress the vertical vibration of the vehicle body than the conventional fuzzy control strategy, which means it has better smoothness.

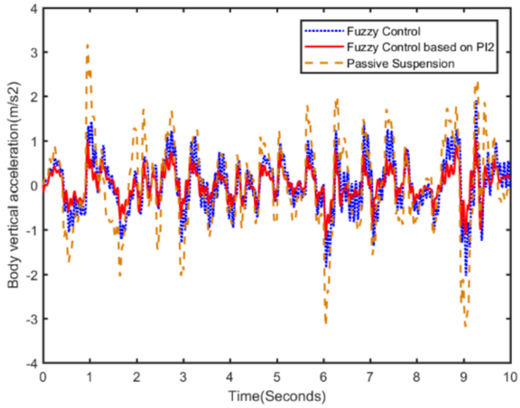

Figure 4. Body vertical acceleration at 90Km/h on Class A road

Select a speed of 90Km/h and simulate three levels of road surfaces A, B, and C. Table 4 shows the root mean square values of the body vertical acceleration, the dynamic deflection of suspension, and the tire dynamic load corresponding to the three methods. From Table 4, it can be seen that all three indicators increase with the deterioration of road conditions. Compared with passive suspension, conventional fuzzy control strategy and fuzzy control strategy based on PI^2 can improve the body vertical acceleration, with the improvement degree of fuzzy control strategy based on PI^2 being greater. The dynamic deflection of suspension has a small and acceptable deviation compared to passive suspension. On the indicator of the tire dynamic load, the fuzzy control strategy based on PI^2 performs slightly better, indicating a slight improvement in vehicle operation stability.

Table 4. Comparison of Performance Indexes of Suspension on Various Grades of Road at 90Km/h

Control Strategy	Body vertical acceleration /m·s-2	Dynamic deflection/m	Tire dynamic load/N
		Class A road	
Passive Suspension	*0.962*	*0.0135*	*312.1*
Fuzzy Control	*0.571*	*0.0141*	*328.8*
Fuzzy Control based on PI^2	*0.373*	*0.0152*	*299.1*
		Class B road	
Passive Suspension	*2.009*	*0.0263*	*624.2*
Fuzzy Control	*1.094*	*0.0287*	*656.1*
Fuzzy Control based on PI^2	*0.730*	*0.0291*	*596.9*
		Class C road	
Passive Suspension	*4.058*	*0.0537*	*1248.2*
Fuzzy Control	*2.426*	*0.0576*	*1411.4*
Fuzzy Control based on PI^2	*1.995*	*0.0589*	*1234.8*

5. Conclusion

In summary, the following conclusions can be drawn:

(1) Compared with passive suspension, semi-active suspension with fuzzy control strategy can improve vehicle smoothness; The fuzzy control strategy based on PI^2 has better improvement effect than conventional fuzzy control strategy, and can slightly improve the stability of vehicle operation.

(2) The fuzzy control strategy based on PI^2 can ensure that the dynamic deflection of suspension is within an acceptable range and will not deteriorate excessively.

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