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Level 10

50 Clarence Street

SYDNEY NSW 2000

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Proceedings of Business and Economic Studies

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BIO-BYWORD SCIENTIFIC PUBLISHING PTY LTD

Level 10

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Sydney NSW 2000

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Intrinsic Dynamics and Logical Framework of Innovative Quality Productivity Enabling High Quality Development of Festival Tourism

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Abstract: Under the Chinese-style modernisation, the innovative quality productivity as a driving engine is an important focus point for the promotion of high-quality tourism development. In the evolutionary process of productivity development, the reality of productivity development promotes the emergence of festivals, and influences the change of travel patterns until contemporary festivals become a form of tourism, which is the historical context of the innovative quality productivity-enabled festivals tourism. In terms of intrinsic motivation, festivals have become an effective carrier for the construction of new relationships between people, nature and society driven by the Innovative quality of productivity. On the logical framework, the innovative quality productivity empowers the high-quality development of festival tourism, mainly relying on the optimal combination of the three major elements of the innovative quality producers, means of production and production objects, and with science and technology, culture and policy as the three major strategic support, through the scientific and technological “empowerment” and festival “enablement” combination, to promote the development of festival tourism, and to promote the development of festival tourism. Through the combination of science and technology “empowerment” and festivals “enabling”, it promotes the innovation and integration of the industrial chain, and facilitates the development of the new and old productive forces in accordance with local conditions and synergistic progress.

Keywords: Innovative quality productivity; Festival Tourism; High quality development

Online publication: February 3, 2026

1. Introduction

In September 2023, General Secretary Xi Jinping mentioned the new quality productive forces twice during his inspection tour in Heilongjiang, with key terms mainly involving “strategic emerging industries” and “future industries”^[1]. In January 2024, General Secretary Xi Jinping further pointed out that developing new quality productive forces is an inherent requirement and a crucial focal point for promoting high-quality

development^[2]. In March 2024, Secretary Xi Jinping emphasized during his participation in the deliberation of the Jiangsu delegation that it is essential to firmly grasp the primary task of high-quality development and foster new quality productive forces in line with local conditions^[3]. The concept of “new quality productive forces” represents a form of productivity that corresponds to and matches high-quality development under the new development paradigm. Guided by technological innovation, it is characterized by high technological content, high added value, high efficiency, high quality, and strong sustainability, embodying new trends and stages in the development of productivity. It serves as a key force driving economic and social transformation and upgrading, as well as achieving high-quality development. The promotion of industrial transformation by new quality productive forces is an inevitable requirement for high-quality industrial development^[4].

Meanwhile, the integration of culture and tourism represents a crucial pathway for achieving high-quality development in China’s tourism industry, as well as an inherent need for the industry to advance its transformation and upgrading. Currently, driving the high-quality development of cultural and tourism industries with new quality productive forces has become a crucial topic in the tourism sector. Festivals and events not only constitute an important part of China’s excellent traditional culture but also serve as significant carriers for people to express their aspirations for a better life. Interacting symbiotically with tourism, festival and event tourism has emerged as a new form of tourism.

Against the backdrop of new quality productive forces, how to empower the high-quality development of festival and event tourism has become an urgent issue to explore. Based on the theoretical connotations and core elements of new quality productive forces, as well as the developmental characteristics of festival and event tourism, this paper reveals the internal impetus and logical framework for new quality productive forces to empower the innovative and high-quality development of festival and event tourism by examining the capabilities, such as policies and technologies, conferred by new quality productive forces in the process of promoting the establishment of new relationships among people, nature, and society.

2. The dynamic relationship between productive forces and tourism: The historical context of new quality productive forces empowering festivals and events

Marx posited that productive forces represent human labor capacity and serve as the fundamental driving force behind social and historical development. They manifest as the objective material forces through which humans utilize and transform nature during the labor process to meet their own survival and development needs, namely, material production activities. Its productivity system primarily consists of three fundamental elements: workers, means of labor, and objects of labor. During the modernization process of any society, transformations and innovations in these three foundational elements are inevitable. Consequently, the state or development level of productivity varies across different eras and stages of development. The enhancement of productivity is accompanied by economic prosperity, growth in per capita income, and an increase in leisure time, directly fostering an improvement in residents’ consumption capacity and willingness. This includes changes in tourism motivation, travel modes, and demand for tourism services.

As people’s living standards rise, their needs for spiritual and cultural life, leisure and entertainment, and experiences in different locales intensify, with tourism becoming a significant indicator of improved quality of life. The development of social productivity and the continuous evolution of production relations provide a solid economic foundation and consumer demand for the expansion of the tourism market. Human productivity can

be divided into four stages: periods dominated by natural productivity, labor productivity, capital productivity, and technology-driven social productivity, respectively ^[5]. Different periods of productivity determine distinct production relations, which in turn reciprocally affect productivity. The continuous transformation in the relationship between the two also leads to the ongoing evolution of the development modalities of the tourism industry (**Table 1**).

Table 1. Evolution of social productivity development and tourism development modalities segmented by technological revolutions

Stage of social development	Productive forces characterization	Stage of tourism development	Primary travel motivations	Scale and form of tourism
End of primitive society- Formation of slave society	Rise of agriculture, animal husbandry, and handicrafts	Individual consumption	Commercial trade purposes	Spontaneous economic activities by merchants
Slave /feudal systems	Widespread use of tools for agriculture, animal husbandry, handicrafts; irrigation projects; initial commercial development	Individual consumption / official organization	Commercial trade / pilgrimage / leisure motives	Trade activities by merchants; leisure-focused travel by nobility; religious pilgrimages
Industry 1.0	Steam age	Modern package tours	Sightseeing	Group tours primarily for the bourgeoisie
Industry 2.0	Electricity & automation age	Modern mass tourism	Diplomacy / leisure / vacation	Massification & internationalization
Industry 3.0	Information age	Post-industrial tourism	Experience / services / comprehensive	Personalization & customization

Improvements in production tools and increases in production efficiency have expanded the scope of social division of labor, leading to a gradual increase in labor surplus and making travel possible. The advent of industry has spurred the rise of package and mass tourism in modern times, aimed at sightseeing, vacations, and other purposes. The dynamic evolution of tourism development reveals a transition in human activities from primitive forms of travel based on survival and economic exchange to modern tourism phenomena encompassing diverse value pursuits and experiences. This transformation is closely linked to the level of productivity development, with productivity and production relations interacting to jointly shape the physiological and psychological foundations of human travel needs.

Festivals and events, which originated in traditional societies, essentially reflect the relatively backward state of productivity at the time and represent ancient people's aspirations for a better life. In modern times with developed productivity, festivals and events have become important tourism resources and vehicles for people to showcase their pursuit of a better life. Focusing on tourists' pursuit of in-depth experiences, personalized expressions, and spiritual fulfillment, festival and event tourism emphasizes the planning and provision of activities with significant differences, distinct themes, and profound cultural connotations to cater to tourists' strong desires for unique experiences, participatory innovation, and social interaction.

In its initial stages, festival and event tourism focused on traditional folk festivals such as the Water-Splashing Festival, with the core aim of showcasing and preserving local indigenous cultures and attracting tourists to personally experience and gain a deeper understanding of the unique characteristics of the destination. As advancements in productivity drive the continuous optimization and upgrading of the industrial structure, the forms of event tourism products have taken on a rich and diverse innovative trend. Emerging events such as film

festivals, music festivals, anime expos, esports competitions, and marathons have sprung up, not only reflecting the fruitful outcomes of innovative development in the cultural industry but also precisely attracting various specific consumer groups.

This has effectively broadened the coverage of the event tourism market and, at the same time, deepened the layers of tourism experiences vertically. Furthermore, with the introduction of the concept of “cultural and entertainment tourism,” event tourism has gained new opportunities. By leveraging and promoting local cultural heritage or tourism resource advantages, a variety of diverse activities such as festivals, cultural and arts festivals, and sports events are meticulously planned. This achieves a deep integration of culture and entertainment, creates engaging scenarios, and constructs new tourism services and models, thereby enhancing the overall experience for tourists.

The development from events to event tourism essentially represents the progression of productivity and production relations. Event tourism is a crucial component of the tourism system, vividly demonstrating the specific practical forms of cultural and entertainment tourism. Within the framework of modern tourism demands for in-depth experiences, personal expression, and spiritual fulfillment, event tourism exhibits a powerful consumption-driving effect and broad development prospects. It can be said that the emergence of events, market innovation, and policy guidance have all provided the context for the new quality productive forces to empower event tourism.

3. The internal driving force of new quality productive forces empowering event tourism

3.1. Relationship reconstruction: The core key to empowering event tourism with new quality productive forces

New quality productive forces differ from traditional productive forces in that they emphasize the leap in “newness” and “quality” during the development process of productive forces. They no longer rely primarily on traditional factors of production such as labor, capital, and land. Their core characteristics lie in innovation-driven development as the key driving force and high-quality development as the value orientation, aiming to continuously enhance the overall efficiency of productive forces. In other words, innovation-driven development becomes the key to “newness,” while high-quality development serves as the anchor point for “quality,” with the goal of continuously improving “productive forces”^[6].

Based on this, the “new” elements of new quality productive forces are reflected in technological advancements that innovate the constituent elements of productive forces, enabling new types of workers, objects of labor, and means of labor to mutually depend on each other and undergo optimized combinations and leaps, thereby driving a significant increase in total factor productivity. The “quality” of new quality productive forces is grounded in high-quality development, emphasizing the new development philosophy of “innovation, coordination, green development, openness, and sharing.” It not only pursues sustainable development but also facilitates efficient resource allocation and industrial chain optimization. The organic integration and development of “newness” and “quality” aim to reconstruct and optimize the relationships between people, between people and nature, and between people and society through the dual drives of innovation and high-quality improvement, thereby promoting comprehensive upgrades and sustainable development of the socioeconomic system.

In the specific field of event tourism, the interactions among people, nature, and society exhibit rich diversity and deep interweaving characteristics. Driven by current productivity, event tourism is no longer merely a simple

sightseeing and leisure activity. It has evolved into a complex and dynamic system. This system not only meets the diverse needs of modern tourists for social interaction, cultural experiences, and closeness to nature but also actively promotes community economic development, ecological environmental protection, and the fulfillment of social responsibilities. Specifically, as a medium for reconstructing social relationships, event tourism facilitates the diversified expansion of interpersonal networks through emotional and interest resonance as well as cross-cultural exchanges, establishing new social models based on shared interests and values. This model deepens understanding and connections among people from different backgrounds, fostering social inclusivity and cultural diversity.

Concurrently, event tourism activities can incorporate eco-friendly designs, such as eco-music festivals, which not only enhance tourists' awareness and sense of responsibility towards ecological conservation but also enable practical participation in nature conservation. This demonstrates a new interactive paradigm of harmonious coexistence between humans and nature, promoting the development of sustainable tourism. Furthermore, event tourism acts as a catalyst, fostering collaborative efforts among communities, governments, businesses, and tourists.

Community residents are no longer bystanders but active participants in the planning and execution of events and festivals. Through these celebrations, they showcase local culture and strengthen community cohesion. The government formulates encouraging policies to guide events and festivals towards green and intelligent development, while ensuring that local residents benefit, achieving dual economic and social benefits. Enterprises, through the integration of technological innovation and cultural creativity, develop novel tourism products, drive industrial upgrading, and fulfill their social responsibilities. This multi-party participation model has constructed a social ecosystem based on shared goals, promoting the efficient and equitable allocation of social resources.

Thus, the core essence of new quality productive forces and the inherent characteristics of event tourism exhibit a high degree of alignment in promoting harmonious interactions among people, between humans and nature, and within society. This provides important theoretical guidance for the effective empowerment of new quality productive forces in the field of event tourism.

3.2. Internal mechanism: New quality productive forces empower event tourism to promote profound transformation and integration of relationships

3.2.1. Human-to-human: Social connections and relationship reshaping

Technological advancements drive innovation in information exchange and collaboration models, giving rise to new forms of social division of labor and interactive networks. Over more than four decades of reform and opening-up, China has achieved the “First Centenary Goal” of building a moderately prosperous society in all respects. New-quality productive forces emphasize technological innovation, enabling productivity to serve people's better lives and fostering the formation of new social and production relations among individuals. Contemporary socializing methods have diversified, with young people demonstrating a strong inclination towards shared interests and a sense of belonging in their social needs, both online and offline. This is manifested in the “new tribes” characteristic of event tourism^[7]. Compared to traditional tribes based on blood ties or geographical location, the most essential feature of new tribes is that they come together based on shared hobbies.

Furthermore, new tribes are characterized by emotional connections, non-directionality, and selective socializing^[8]. From this perspective, human relationships are being reshaped within individual and group contexts. The empowerment of event tourism by new-quality productive forces not only reflects the deep integration and

innovation of technology and event culture but also vividly illustrates the changes in interpersonal relationships and group structures in a tech-driven society. Technological empowerment enables people from different social strata and interest groups to transcend barriers and participate together in the same events, which not only helps to alleviate social conflicts but also provides motivation for new-quality workers to innovate based on the personalized experience needs of event tourists.

3.2.2. Human and nature: Ecological wisdom and sustainable practices

Technological advancements drive improvements in resource utilization efficiency, reductions in environmental pollution, and enhancements in ecological governance capabilities, fostering the construction of a harmonious coexistence between humans and nature. From Marx's perspective, productivity primarily pertains to the relationship between humans and nature, and in any era, the application of productivity involves understanding and managing this relationship. During the process of economic development, a series of ecological issues inevitably arise. These issues, as lingering challenges from historical evolution, continuously constrain the healthy development of the socio-economy.

Based on this, the construction of an ecological civilization becomes a crucial link in resolving deep-seated contradictions between humans and nature and promoting sustainable development. New-quality productivity represents advanced productivity and can be seen as the material foundation and innovative impetus for resolving conflicts between humans and nature in this process. Its development contributes to achieving the goals of ecological civilization construction, promoting the symbiosis between humans and nature, and advancing the realization of ecological priority and green development. General Secretary Xi Jinping pointed out, "Protecting the ecology and developing ecotourism complement each other, and this path should be firmly pursued."

As the first World Expo hosted by China, the 1999 Kunming International Horticultural Exposition not only unveiled the charm of horticultural art to global visitors but also profoundly demonstrated the government's recognition of the value of exploring local characteristic tourism resources and strengthening the ecological environment as the foundation of horticulture. Another example is live-action tourism performances such as Impression Liu Sanjie, which skillfully employ modern light and shadow technology to vividly present Guilin's ecological landscapes to viewers, offering not only a platform for deeply immersive experiences of natural beauty but also, driven by economic benefits, further inspiring local governments to prioritize regional ecological environmental protection.

Various events, whether international exhibitions or local masterpieces, strongly confirm that event tourism is not only a visual window for intuitively displaying the importance of ecology but also an effective vehicle for subtly disseminating ecological awareness. With the infusion of green productivity characterized by high technology, high efficiency, and high quality, event tourism places greater emphasis on green strategies, utilizing innovative technological means to endow events with ecological aesthetic expression and ecological education functions.

By leveraging elements such as local culture and traditional knowledge, it promotes ecological wisdom that respects and conforms to nature, while simultaneously demonstrating respect and care for the ecological environment, highlighting its contemporary responsibility in ecological civilization construction. This, in turn, subtly strengthens the construction of the relationship between humans and nature.

3.2.3. Man and society: Cultural inheritance and community co-construction

Scientific and technological progress leads the innovation of social governance models, which is not merely confined to iterative updates at the technological level, but also lies in how it profoundly influences and reshapes the interactive relationship between humans and society. There exists a close intrinsic connection and dynamic interaction between the level of productivity development and the socioeconomic foundation and structure: advancements in productivity shape the evolutionary trajectory of social structures and economic relations, while human social behaviors and subjective creativity, in turn, drive leaps in productivity and overall societal progress.

In this process, new-quality productivity not only promotes the optimized reorganization of production factors and technological innovation to enhance economic efficiency but also, from the dimensions of humanistic care and social justice, emphasizes that the fruits of technological innovation should serve the people, opening up new pathways for the transformation and optimization of social structures. The widespread application of digital and intelligent technologies not only enhances the effectiveness of public services but also, imperceptibly, builds a bridge connecting individuals with society, and tradition with modernity, fostering the formation of a more equitable, open, and collaborative social ecosystem.

Tourism has traditionally been regarded as an act of individual exploration and self-actualization. Today, catalyzed by new quality productive forces, it is gradually becoming a powerful means of fostering cultural, social, and even national identity. Event tourism, in particular, with its profound cultural and identity attributes, has become a stage for multi-dimensional and multi-themed interactions, where not only governments, businesses, and communities actively participate, but tourists also become active contributors to the process of cultural inheritance and innovation.

The Harbin Ice and Snow Festival serves as a vivid example. It not only showcases the unique charm of the “Ice City” and the warm hospitality of its residents but, more importantly, provides an opportunity for the Oroqen ethnic group to step into the public spotlight and present its rich cultural traditions to the world, achieving a dual enhancement of cultural pride and social integration. This is a direct manifestation of how event tourism promotes inclusive social growth.

The process of “empowering” the intellectualization of event tourism through new quality productive forces is not merely a simple superposition of technological applications. Rather, it offers boundless possibilities for constructing new relationships between humans and society through data-driven approaches and intelligent services. This includes the deep involvement and self-renewal of communities: community members enhance their attention to and participation in public affairs during the preparation and participation in events, which not only strengthens internal community cohesion but also promotes positive interactions and optimal adjustments between policies and social structures through practice.

As the fundamental unit of society, communities serve as a bridge connecting individuals to the broader social network, driving profound changes in human-society relationships and constructing a new vision of a more harmonious, vibrant, and sustainably developing society. Furthermore, the proactive “enabling” role of event tourism can enhance tourists’ experiences, turning every trip into a profound journey of cultural exploration and self-discovery, while also creating conditions for improving the quality of the workforce. Driven by the intelligent transformation of event tourism, workers are required to continuously learn new technologies and knowledge.

This process not only promotes the transformation and upgrading of human resources but also gives rise to a greater number of new-quality workers equipped with digital skills, injecting new vitality into socio-economic development. It can be said that the rapid development of new-quality productive forces, through the unique

window of event tourism, not only accelerates the intelligent transformation of the tourism industry but also profoundly influences the interaction patterns between humans and society, fostering the formation of more open, inclusive, and cooperative social relationships and providing a vivid practice for building a community with a shared future for mankind (**Figure 1**).

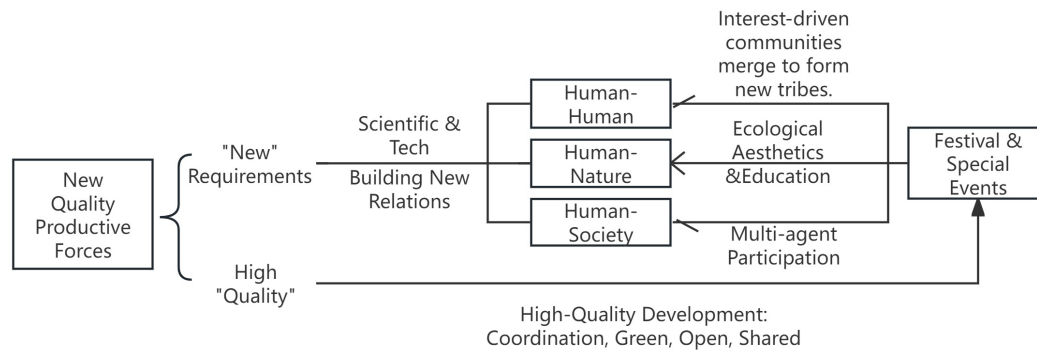


Figure 1. The intrinsic connection between new-quality productive forces and event tourism.

The core of new quality productive forces lies in reconstructing new modes of connection among people, nature, and society driven by technological innovation. Event tourism, as a crucial arena in this process, has significantly promoted the innovation of the relationships among the three. The integration of technology has enriched the social dimension of event tourism, giving rise to “new tribes” communities that transcend traditional boundaries. Based on shared interests and emotional resonance, these communities have strengthened the diversity and flexibility of social networks, laying the foundation for enhancing social inclusiveness and cultural diversity.

At the level of environmental protection, new quality productive forces lead event tourism to adopt green strategies. Through efficient and environmentally friendly practices, they not only promote the sustainability of tourism but also deepen the public’s awareness of the importance of ecological conservation, embodying the modern development concept of harmonious coexistence between humans and nature. Furthermore, while enhancing the intelligence of event tourism, new quality productive forces provide new pathways for social governance structures and cultural heritage, increasing community participation and public service efficiency, facilitating the effective alignment of policy practices with social needs, and contributing to the optimization of social structures and the strengthening of cultural identity.

4. Logical framework for empowering high-quality development of event tourism with new quality productive forces

The application of innovative technologies serves as the core driving force for empowering event tourism with new quality productive forces. Strategic emerging industries or future industries are committed to original technological innovations that “create something out of nothing,” whereas the focus of technological innovation in the cultural and tourism industry lies in the in-depth application and transformation of existing scientific and technological achievements, with a greater emphasis on the integration of cultural and tourism products and the innovation of business formats.

Rather than focusing on original innovation, it aims to achieve disruptive improvements that “elevate the existing to excellence” through the integration and fusion of technologies, thereby promoting the transformation,

upgrading, and high-quality development of the cultural and tourism industry. Therefore, it necessitates the “empowerment” of new quality productive forces and the proactive “enabling” of event tourism, allowing new technologies, services, and models to be integrated into events, fostering the development of new relationships, and achieving high-quality development in event tourism (**Figure 2**).

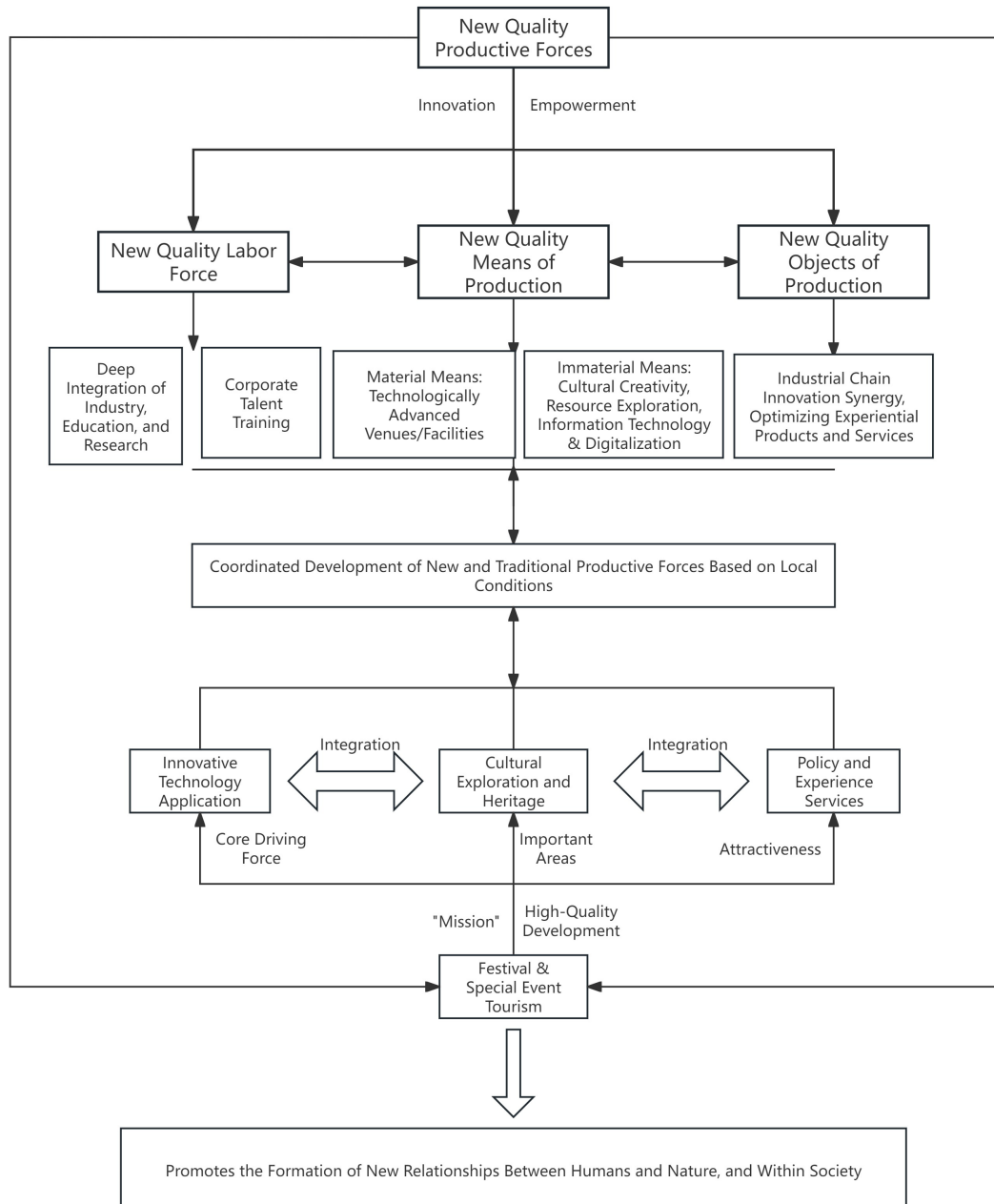


Figure 2. Logical framework for empowering high-quality development of event tourism with new quality productive forces.

4.1. Cultivating a new quality workforce: Promoting deep integration of industry, education, and research, enhancing digital literacy, and transforming development philosophies

With the application of scientific and technological innovation as the core driving force, this includes building a

workforce of new quality laborers and applying innovative technologies to event planning and operations. This implies cultivating a cadre of professionals with digital skills, innovative thinking, and interdisciplinary knowledge to drive the intelligent transformation of the event tourism industry chain. Event activities constitute a systematic project that encompasses the entire process from preparation to conclusion. The integration of new elements into each stage relies on new-quality workers equipped with corresponding skills. For instance, in new marketing, relevant personnel are required to possess keen digital insights and be familiar with and effectively utilize various platforms for precise marketing.

In terms of new services, the venue layout and facility setup involve the deployment of communication equipment, the application of high-tech display methods, and complex traffic organization and planning, necessitating the participation of workers with expertise in communication technology, intelligent hardware operation, and traffic engineering. In new management, the handling of large-scale crowd control, security monitoring, and emergency response requires the indispensable application of technologies such as artificial intelligence, big data analysis, and the Internet of Things, demanding that on-site management personnel possess the ability to efficiently schedule crowds and provide risk warnings using technological means. Each stage calls for the active participation of new-quality workers, with a comprehensive and multi-level demand for such talent.

From this, it can be inferred that the characteristics of new-quality workers in event activities are their adaptability to digital equipment platforms, proficiency in utilizing modern information technology, and possession of information decision-making capabilities, making them high-caliber composite talents who integrate cutting-edge technological knowledge with practical application wisdom. Therefore, promoting the deep integration of industry, academia, and research, as well as enhancing the digital literacy of corporate employees, represent effective approaches to cultivating new-quality workers and aligning with industrial development.

These efforts are also a practical necessity for ensuring the high-quality organization of events and festivals, improving social service efficiency, safeguarding public security, and facilitating the transformation and application of technological innovation achievements. Specifically, it is advisable to encourage universities and research institutions to strengthen their collaboration with the events and festivals industry, establishing an educational system and talent pool that meet the development requirements of new-quality productive forces.

Enterprises should be guided to increase their investment in training and conduct specialized training programs covering digital thinking, the application of emerging technologies, and data-driven decision-making capabilities through a combination of online and offline methods, thereby enhancing the overall digital literacy of the enterprise. Additionally, enterprises should adapt their future development philosophies in a timely manner, leveraging the current rise of the experience economy and interest-based consumption to reasonably utilize innovative technologies and drive the differentiated supply of events and festivals to match individual needs.

4.2. Integration of old and new elements and technological innovation: Revitalizing regional resources and expanding the connotations of events and festival tourism

The development of new-quality productive forces represents an innovative continuation of traditional development models. From the perspective of traditional productivity, the means of production for event tourism encompass a series of material foundations and non-material conditions used for organizing events, such as event venues and facilities, transportation tools, communication equipment, promotional media, stage construction materials, sound and lighting equipment, as well as non-material conditions like cultural connotations, information technology, and management systems. To achieve an innovative continuation and development of event tourism,

the key lies in “quality.” This “quality” does not merely refer to optimization and progress at the material or non-material level but rather signifies a shift from the traditional emphasis on scale expansion and quantitative accumulation to a development model that prioritizes rich connotations, distinct characteristics, and strong sustainability.

In the past, event content was often monotonous, with severe homogenization competition and an excessive pursuit of short-term traffic effects. Leveraging consumer-oriented cultural forms, there was a tendency to imitate popular event content, neglecting factors such as regional cultural compatibility, which ran counter to concepts such as low-carbon, ecological, harmonious, culturally sustainable, and high-quality development. To reverse this situation, cultural innovation and heritage should serve as the driving forces. During the development process, one should not abandon something beneficial for fear of minor drawbacks. It is essential to both uphold and disseminate local characteristic cultures while also being bold in innovation, infusing them with a new era spirit through innovative thinking and technological empowerment. By organically connecting old and new productive forces and driving them with technology, we can activate regional characteristics, enrich the event tourism experience, and provide resource and content support for the high-quality development of event tourism.

Strive to achieve high-quality event tourism that features the simultaneous development of ecology, economy, and society. We should fully leverage the technologies developed through the advancement of new quality productive forces and the new-quality laborers cultivated thereby, explore local cultures according to local conditions, or innovate cultural connotations to inject momentum into the high-quality development of events. We should preserve the essence of traditional culture while infusing it with the spirit of the new era: thoroughly explore how to integrate innovative elements into traditional events, enabling both the old and the new to develop in tandem.

This involves incorporating modern aesthetics, technological elements, and social responsibility into event design, so that it can not only meet tourists’ needs for traditional cultural experiences but also showcase the contemporary style that keeps pace with the times. We should advocate for an ecological, equitable, and free participation philosophy: break away from the traditional one-way communication model and encourage tourists to deeply participate in the design, organization, and dissemination processes of events. Through co-creation, social interaction, engagement, and technology, we should empower tourists with greater voice, agency, and immersive experiences, especially enhancing the quality of event tourism by meeting the needs of the younger generation.

4.3. Strengthen policy support and guidance to enhance participation and experience: Build a high-quality development system for event tourism

The high-quality development of event tourism constitutes a complex system, encompassing multiple dimensions such as innovation-driven growth, green development, talent cultivation, industrial integration, and collaborative development. This makes policy support and guidance the essential “climatic conditions” for its healthy progress. For local events, the government should not only encourage community residents to actively participate in event activities but also lead by example and play an exemplary role. Active regulation by government departments has enhanced the online image of event activities, boosted offline service reputation, and improved the tourist experience. The proactive involvement and effective management of the government provide strong guarantees for the orderly conduct and brand image building of event activities.

Meanwhile, it is essential to strengthen policy implementation to create a favorable development environment for events and stimulate the innovative vitality and enthusiasm of market entities. In general, when constructing

a system for high-quality development of events, priority should be given to policy services and experiences. High-quality policy services serve as an effective guarantee for tourist satisfaction and a key driving force for enterprises to adapt to the development of new quality productive forces. By utilizing policy tools to promote deep engagement of tourists, a positive interaction can be fostered, establishing a dual-driven mechanism of policy and market that facilitates innovation in event tourism, optimizes services, and enhances tourist satisfaction. This approach also inspires enterprises to engage in innovative thinking and explore new business models and technological applications.

5. Conclusion

The development of new-quality productive forces has paved a path of high-quality development for festival and event tourism. Under the innovation-driven strategy, it is hoped that festival and event tourism can deeply integrate innovation, digital technology, and cultural innovation resources to achieve experience reconstruction, combining personalization with intelligence. Let technology serve as a medium to spread awareness of ecological conservation, making festival and event tourism a vivid representative of the harmonious coexistence of nature and culture. By fully leveraging the opportunities brought about by the leap in new-quality productive forces and taking technological application, culture, and policy as the three strategic pillars, we can promote the high-quality development of festival and event tourism, making it an important vehicle for building new harmonious relationships among people, nature, and society.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Xi Jinping Presided over the Symposium on Promoting the Comprehensive Revitalization of Northeast China in the New Era, Emphasizing Firmly Grasping the Important Mission of Northeast China and Striving to Write a New Chapter in Its Comprehensive Revitalization, 2023, People's Daily, September 10, 2023.
- [2] "Xi Jinping Emphasizes Accelerating the Development of New Quality Productive Forces and Solidly Promoting High-Quality Development at the 11th Collective Study Session of the Political Bureau of the CPC Central Committee," 2024, China Talent, 2.
- [3] "Xi Jinping Emphasizes Developing New Quality Productive Forces Based on Local Conditions During His Participation in the Deliberations of the Jiangsu Delegation," Chinese Government. https://www.gov.cn/yaowen/liebiao/202403/content_6936752. 2024-3-5.
- [4] Liang P, 2024, Interview During the Two Sessions: Writing a Grand Article on Developing New Quality Productive Forces, <https://news.sina.com.cn/zx/gj/2024-0307/docinamnaau9310057.shtml>
- [5] Guan Z, Fu M, Yang J, 2024, New Quality Productive Forces: Research Progress and Future Prospects. *Journal of Beijing University of Technology (Social Science Edition)*, 1–14.
- [6] Deng L, 2024, The Theoretical Implications and Contemporary Significance of Xi Jinping's Important Expositions on New Quality Productive Forces. *Academic Exploration*, 1–8.
- [7] Wu S, Dai G, 2019, Connection and Interaction Characteristics of the Recycling Neo-tribes in the Midi Music

Festival. *Tourism Tribune*, 34(6): 74–84.

- [8] Chen L, Li C, 2021, “Neo-tribes” in the Online Society: A Study on Post-subcultural Circles. *Media Observation*, 2021(6): 5–12.

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Efficiency Evaluation and Barrier Analysis of Blockchain Technology Application in Cross-Border Trade Finance: A Case Study of Supply Chain Finance in the Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract: Under the special institutional environment of “One country, Two systems, and Three jurisdictions” in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA), cross-border trade finance faces prominent information asymmetry and institutional frictions. Existing studies lack quantitative evaluation of blockchain technology’s application efficiency in this context and systematic analysis of barrier mechanisms. This paper constructs an analytical framework of “technological characteristics-financing process-efficiency output”, using the DEA-BCC model, Malmquist index, grounded theory, and ISM-ANP model for empirical analysis. The results showed that blockchain significantly empowers cross-border trade finance, with total factor productivity (TFP) increasing by 14% in 2023–2024, mainly driven by technological efficiency improvement. Core enterprises (comprehensive technical efficiency 0.82) outperform SMEs (0.65), showing a “Matthew Effect”. Moreover, barriers form a three-level structure of “underlying root-middle-level transmission-surface manifestations”, with technical (weight 0.32) and institutional barriers (0.28) as core constraints, especially insufficient cross-border regulatory coordination (0.12) and inconsistent cross-chain standards (0.10). Prioritizing these underlying barriers is key to breaking “digital silos”, and the proposed hierarchical governance strategy provides support for GBA financial infrastructure interconnection.

Keywords: Blockchain technology; Cross-border trade finance; DEA-Malmquist; ISM-ANP model; Guangdong-Hong Kong-Macao Greater Bay Area

Online publication: February 10, 2026

1. Introduction

Against the strategic background of the digital economy reshaping global trade and China's "dual circulation" development pattern, cross-border trade finance, as a hub connecting international and domestic markets, directly affects industrial and supply chain resilience. The GBA, with its unique "one country, two systems, three customs territories, three currencies" institutional heterogeneity, has created an active cross-border trade ecosystem but also triggered frictions in capital, logistics, and information flow integration. Long constrained by cross-border information asymmetry and high verification costs, the traditional trade finance model faces a severe "Macmillan Gap", where financial intermediaries adopt credit rationing due to difficulty in penetrating supply chain information fog, leaving numerous foreign trade SMEs in a predicament of difficult and expensive financing. The WTO notes the global trade finance gap remains at the trillion-dollar level, reflecting the efficiency boundary of traditional financial infrastructure in addressing cross-border trust issues.

Blockchain technology, relying on distributed ledgers, asymmetric encryption, and smart contracts, constructs a "trustless trust" mechanism, regarded as the cornerstone of the "value internet". Theoretically, it can transform non-standardized trade information into trusted digital assets, addressing information asymmetry and multi-level credit transmission issues. However, existing research lags behind industry practices. Most focus on technical architecture or single-case descriptions, lacking systematic empirical research combining technological characteristics with the GBA's special institutional environment. Specifically, there is a lack of quantitative analysis on financing efficiency improvement and systematic exploration of barrier mechanisms restricting technology implementation^[1].

To fill these gaps, this paper constructs an integrated analytical framework of "technological characteristics-financing process-efficiency output". Taking GBA supply chain finance as the research carrier, it uses the DEA-BCC model and Malmquist index to measure static and dynamic efficiency, and combines grounded theory with the ISM-ANP model to analyze barrier factors' hierarchical structure and core connections. This study aims to reconstruct the theoretical logic of blockchain empowering cross-border trade finance and provide empirical support for the deep integration of fintech in the GBA under institutional heterogeneity.

2. Theoretical basis and literature review

2.1. Core concepts

Blockchain technology, from a technical perspective, is a distributed database based on cryptographic principles, ensuring data timeliness, immutability, and consistency through timestamping, hash algorithms, and consensus mechanisms. In cross-border trade finance, consortium or private blockchains are commonly used to balance decentralization, access control, and performance. Economically, blockchain reduces trust costs, establishing an algorithm-based "code is law" system that transforms non-standardized trade information into tradable digital assets^[2].

Cross-border trade finance refers to funding financing and credit support services for importers and exporters, covering instruments such as letters of credit, collection, and supply chain finance models. Compared with domestic trade finance, it faces more complex challenges in integrating capital, logistics, and information flows, with key pain points including high information verification costs and lengthy, inefficient processes^[3].

GBA supply chain finance, shaped by three legal and currency systems, must address both traditional information asymmetry and cross-jurisdictional regulatory compliance and data flow restrictions. Innovative models include cross-border capital pool optimization and "regulatory sandbox" initiatives, such as Hong Kong's eTradeConnect and the mainland's GBA Trade Finance Blockchain Platform, which aim to break institutional barriers through technology^[4].

2.2. Theoretical foundations

Information asymmetry theory explains financial market frictions and credit rationing. Blockchain transforms information structure by enabling full-network broadcasting, multi-party verification, and timestamping, reducing adverse selection and moral hazard through algorithmic consensus, shifting from “ex-post supervision” to “ex-ante prevention” and “in-process control”^[5].

Transaction cost theory identifies search, bargaining, and execution costs as key inefficiencies in cross-border trade finance. Blockchain reduces these costs through decentralized information sharing, smart contract automation, and standardized interfaces, eliminating manual intervention and opportunistic behaviors^[6].

Synergy theory emphasizes non-linear interactions between system subsystems. Blockchain provides a collaborative infrastructure for GBA cross-border trade finance, integrating stakeholders into a trust ecosystem, enabling real-time synchronization and parallel processing, and strengthening core enterprise credit penetration to enhance overall ecosystem financing accessibility^[7].

Financial intermediation theory argues that blockchain’s application in trade finance is not simple disintermediation but functional reshaping. While blockchain undertakes trust verification and settlement functions, financial institutions retain core roles in risk pricing, liquidity provision, and regulatory compliance, with technology empowering them to focus on high-value-added services^[8].

2.3. Literature review and gaps

Existing research on blockchain in cross-border trade finance covers application modes, efficiency evaluation, and barrier factors. Application mode studies summarize core enterprise-led, financial institution-led, and third-party platform-led models, but lack comparative analysis of their adaptability in specific institutional environments like the GBA. Efficiency evaluation studies, mainly using DEA models, focus on single institutions or links, lacking a supply chain-wide perspective and integration of non-financial indicators, with insufficient attention to SMEs. Barrier factor research identifies technical, institutional, and market obstacles but lacks quantitative analysis of hierarchical relationships and action paths.

Three key research gaps exist as follows:

- (1) Lack of consideration of the GBA’s unique institutional endowment;
- (2) Fragmented efficiency evaluation systems;
- (3) Superficial analysis of barrier mechanisms.

This paper addresses these gaps through an integrated analytical framework and empirical tests.

3. Practical status of blockchain cross-border trade finance in the GBA

The application of blockchain in GBA cross-border trade finance has evolved into a mature commercial ecosystem with three distinct paradigms.

3.1. Core enterprise-led vertical credit integration model

Represented by Huawei and TCL, this model leverages core enterprises’ industrial chain control and credit to build closed financing networks. By integrating IoT devices to upload full-life-cycle cargo data, core enterprises’ accounts payable are digitized into liquid, divisible digital payment obligations. SMEs can obtain financing using these credit-backed vouchers, reducing the average financing cycle from 20 days to less than 5 days and lowering costs by over 20%. However, it forms “credit silos” centered on core enterprises, limiting horizontal asset flow across industrial chains.

3.2. Financial institution-led horizontal alliance model

Led by the Hong Kong Monetary Authority’s eTradeConnect and its interconnection with the People’s Bank of China’s Trade Finance Blockchain Platform, this model aims to break inter-bank information barriers. It enables cross-border verification of trade data while respecting jurisdiction-specific data sovereignty, reducing document review error rates from 15% to less than 0.5% and shortening processing time from days to hours. Challenges include complex inter-bank interest coordination and inconsistent data privacy standards.

3.3. Third-party platform ecological model

Technology giants like Tencent and OneConnect build open “blockchain + AI” platforms, integrating multi-dimensional data (customs, taxation, logistics, ERP) for dynamic enterprise profiling and real-time risk control. JD Technology’s practice shows a “de-coreization” trend, allowing SMEs to accumulate “data credit” and reduce reliance on core enterprises. These platforms have increased GBA SMEs’ cross-border trade finance coverage from 32% to 48%, enhancing financial inclusiveness and promoting cross-chain standard unification.

4. Efficiency evaluation

4.1. Evaluation index system

Input indicators include financing cost (ten thousand yuan per ten million yuan), process time (days), technology investment (ten thousand yuan), and labor cost (ten thousand yuan). Output indicators include financing scale (ten million yuan), financing success rate (%), risk control effect (reciprocal of non-performing rate), and business expansion capacity (ten million yuan).

4.2. Sample selection and data sources

100 GBA enterprises (20 core enterprises, 80 SMEs) from electronic information, textile and clothing, mechanical equipment, and chemical industries are selected. Data sources include enterprise surveys, platform operation data (GBA Chain, Yuexinrong), financial institution data (China Merchants Bank, HSBC), and public statistics. The data period is January 2023 to December 2024, with missing data supplemented by interpolation (**Table 1**).

Table 1. Descriptive statistics of input and output indicators for blockchain cross-border trade finance efficiency evaluation (2023–2024)

Indicator type	Variable name	Unit	Mean	Standard deviation (S.D.)	Minimum (Min)	Maximum (Max)
Input indicators	Financing cost	Ten thousand yuan per ten million yuan	12.45	3.20	8.50	22.00
	Process time	Days	7.25	4.12	2.00	18.00
	Technology investment	Ten thousand yuan	58.60	24.35	15.00	120.00
	Labor cost	Ten thousand yuan	18.30	5.60	8.00	35.00
Output indicators	Financing scale	Ten million yuan	4.50	3.85	0.50	25.00
	Financing success rate	%	48.50	18.20	15.00	95.00
	Risk control effect	% (Non-performing rate)	0.85	0.35	0.10	2.50
	Business expansion capacity	Ten million yuan	2.10	1.50	0.00	8.00

4.3. Evaluation models

The input-oriented DEA-BCC model (variable returns to scale) measures static comprehensive technical efficiency (TE), decomposed into pure technical efficiency (PTE) and scale efficiency (SE, $TE = PTE \times SE$). The Malmquist index quantifies dynamic total factor productivity (TFP) changes, decomposed into technological efficiency change (EC) and technological progress (TC).

4.4. Static efficiency results

The overall average comprehensive technical efficiency is 0.68, with only 20% of enterprises reaching the efficiency frontier. Core enterprises (0.82) outperform SMEs (0.65) due to stronger technology investment and resource integration capabilities. Core enterprises' efficiency bottleneck lies in scale inefficiency, while SMEs face insufficient technical application capacity (**Table 2**).

Table 2. Static efficiency evaluation results of blockchain technology application

Enterprise type	Core enterprises	Small and medium-sized micro-enterprises	Total
Sample size	20	80	100
Average comprehensive technical efficiency	0.82	0.65	0.68
Average pure technical efficiency	0.91	0.78	0.80
Average scale efficiency	0.90	0.83	0.85
Number of efficient enterprises (TE=1)	8	12	20
Efficiency rate (%)	40.0	15.0	20.0

4.5. Dynamic efficiency results

TFP increased by 14% from 2023 to 2024, driven by both technological progress (1.04) and technological efficiency improvement (1.10). Core enterprises (18% growth) outperform SMEs (12%), but SMEs show significant growth potential with continued technical capacity improvement (**Table 3**).

Table 3. Dynamic efficiency evaluation results of blockchain technology application (2023–2024)

Enterprise type	Core enterprises	Small and medium-sized micro-enterprises	Total
Total factor productivity (TFP)	1.18	1.12	1.14
Technological progress index	1.05	1.03	1.04
Technological efficiency change index	1.12	1.09	1.10
Pure technical efficiency change index	1.08	1.06	1.07
Scale efficiency change index	1.04	1.03	1.03

5. Barrier factor analysis

5.1. Identification based on grounded theory

Through open, axial, and selective coding of 20 interviews (150,000 words), 4 main categories, 12 sub-categories, and 35 initial concepts are identified as outlined:

- (1) Technical barriers: Inconsistent cross-chain standards, high security risks, insufficient adaptability, data

sharing difficulties;

(2) Institutional barriers: Imperfect cross-border regulatory coordination, lagging laws, unclear policies;

(3) Market barriers: Fragmented credit consensus, low enterprise awareness, imperfect third-party services;

(4) Subject barriers: Insufficient core enterprise participation motivation, weak SME technical capacity, limited financial institution innovation willingness.

5.2. Hierarchical structure based on ISM model

The ISM model classifies 12 sub-category barriers into three levels (**Table 4**). The barriers are as listed:

(1) Underlying roots (S1-S6): Core drivers affecting the entire barrier system, including regulatory coordination, technical standards, laws, policies, security risks, and credit consensus;

(2) Middle-level transmission (S7-S10): Connect underlying and surface barriers, including data sharing difficulties, insufficient adaptability, core enterprise motivation, and financial institution innovation restrictions;

(3) Surface manifestations (S11-S13): Direct application difficulties, including low awareness, weak SME capacity, and imperfect third-party services.

Table 4. Heatmap of ISM reachability matrix of barrier factors

No.	Barrier factors	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	Level
S1	Lack of cross-border regulatory coordination	1	0	0	0	0	0	1	1	1	1	1	1	1	Underlying
S2	Inconsistent cross-chain standards	0	1	0	0	0	0	1	1	0	0	1	1	1	Underlying
S3	Lagging laws and regulations	0	0	1	0	0	0	0	0	1	1	1	0	1	Underlying
S4	Unclear regulatory policies	0	0	0	1	0	0	0	0	0	1	1	0	0	Underlying
S5	High technical security risks	0	0	0	0	1	0	0	0	1	0	1	0	0	Underlying
S6	Fragmented credit consensus	0	0	0	0	0	1	0	0	1	1	1	0	0	Underlying
S7	Difficulty in data sharing	0	0	0	0	0	0	1	0	0	0	1	1	1	Middle-level
S8	Insufficient technical adaptability	0	0	0	0	0	0	0	1	0	0	0	1	0	Middle-level
S9	Insufficient motivation of core enterprises	0	0	0	0	0	0	0	0	1	0	0	0	1	Middle-level
S10	Restricted financial institution innovation	0	0	0	0	0	0	0	0	0	1	1	0	1	Middle-level
S11	Low enterprise awareness	0	0	0	0	0	0	0	0	0	0	1	0	0	Surface
S12	Weak technical capacity of SMEs	0	0	0	0	0	0	0	0	0	0	0	1	0	Surface
S13	Imperfect third-party services	0	0	0	0	0	0	0	0	0	0	0	0	1	Surface

5.3. Weight determination based on ANP model

The ANP model shows technical barriers (0.32) and institutional barriers (0.28) are core constraints. Top five barrier factors by weight: lack of cross-border regulatory coordination (0.12), inconsistent cross-chain standards (0.10), fragmented credit consensus (0.09), lagging laws (0.08), high technical security risks (0.07) (total weight 46%).

5.4. Core connections

Core barriers form a “vicious circle”, where insufficient regulatory coordination restricts financial institution innovation, highlighting low enterprise awareness. Inconsistent cross-chain standards cause data sharing and adaptability issues, limiting SME application. Fragmented credit consensus and lagging laws reduce core enterprise participation, hindering platform ecological construction.

6. Countermeasure suggestions

6.1. Technical level

At the technical level, efforts should be focused on three aspects: standard unification, security assurance, and adaptability improvement. A “Blockchain Technology Standards Committee” should be established to formulate unified standards for interfaces, data formats, and smart contracts, supplemented by certification and policy support. Meanwhile, increase investment in the research and development of encryption technologies, identity authentication, and privacy protection technologies, and establish emergency response mechanisms and third-party security assessment systems. In addition, it is necessary to develop lightweight and low-cost application modules, provide targeted technical training and subsidies for SMEs, and enhance technical adaptability.

6.2. Institutional level

Optimization at the institutional level should focus on cross-border regulatory coordination, improvement of the legal system, and optimization of policy support. A regular communication mechanism should be established between regulatory authorities in the Chinese mainland, Hong Kong, and Macao, a regulatory information sharing platform should be built, and a “regulatory sandbox” model should be explored in pilot areas. At the same time, revise relevant laws and regulations such as the Negotiable Instruments Law and the Civil Code to clarify the legal status of electronic documents and smart contracts, and formulate targeted management measures for blockchain cross-border trade finance in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). Additionally, introduce policies such as financing interest subsidies and technical investment grants, encourage financial institutions to innovate through measures such as preferential risk reserve policies, and establish a dynamic evaluation mechanism for policy effects.

6.3. Market level

At the market level, efforts should be made to build a unified credit consensus, enhance enterprise awareness, and improve the third-party service system. It is necessary to integrate multi-dimensional credit data such as customs, taxation, and logistics, establish a distributed credit ledger, and promote cross-border credit rating cooperation to form a unified credit consensus. For instance, popularize the advantages of blockchain technology through industry forums and case demonstrations, and drive the participation enthusiasm of the entire industrial chain through leading enterprises. Meanwhile, cultivate professional third-party service institutions to provide services

such as technology development, security assessment, and legal consulting, and establish a diversified dispute resolution mechanism to improve the market service ecosystem.

6.4. Subject level

At the subject level, it is necessary to strengthen the coordination capacity of all participants, and enhance the participation motivation of core enterprises, the technical capacity of SMEs, and the innovation vitality of financial institutions. Tax incentives and credit incentives can be used to enhance the participation enthusiasm of core enterprises and establish an industrial chain benefit-sharing mechanism. For SMEs, simplify the financing process, provide personalized solutions, and encourage core enterprises to provide credit support through long-term cooperation agreements. Financial institutions need to set up specialized innovation departments, and the government can jointly establish a risk compensation fund with enterprises and institutions to reduce innovation risks and stimulate innovation willingness.

7. Research conclusions and prospects

7.1. Conclusions

The research conclusions show that blockchain technology can significantly improve the efficiency of cross-border trade finance in the GBA. The average overall comprehensive technical efficiency is 0.68, among which core enterprises (0.82) outperform SMEs (0.65). The TFP increased by 14% from 2023 to 2024, mainly driven by the dual wheels of technological progress and efficiency improvement. Concurrently, the obstacles to blockchain application present a four-dimensional structure of “technology-institution-market-subject” and a three-level hierarchical characteristic of “underlying roots-middle-level transmission-surface manifestations”. Insufficient cross-border regulatory coordination, inconsistent cross-chain standards, and fragmented credit consensus are the core restrictive factors, with a total weight of 31%. Based on this, improving application efficiency requires building a “four-in-one” governance system of “technological innovation-institutional guarantee-market cultivation-subject coordination”, and breaking through development bottlenecks through measures such as standard unification, regulatory coordination, and credit integration.

7.2. Limitations and prospects

Limitations include a limited sample scope, incomplete efficiency evaluation indicators, and insufficient consideration of external environmental impacts. Future research should expand samples for cross-regional comparisons, improve indicator systems with long-term benefit metrics, analyze external environment impacts (e.g., RCEP, Belt and Road), and explore integrated blockchain-AI-big data application efficiency.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Swan M, 2015, Blockchain: Blueprint for a New Economy, Sebastopol, O'Reilly Media.
- [2] Jin H, 2024, Research on Fintech Empowering Foreign Exchange Reform & Supervision and Serving Real Economy.

China Journal of Commerce, 33(17): 127–130.

- [3] Tapscott D, Tapscott A, 2016, Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World, Penguin, New York.
- [4] Ganne E, 2018, Can Blockchain Revolutionize International Trade? World Trade Organization (WTO), Geneva.
- [5] Babich V, Hilary G, 2020, Distributed Ledgers and Operations: What Operations Management Researchers Should Know About Blockchain Technology. *Manufacturing & Service Operations Management*, 22(2): 223–240.
- [6] Kshetri N, 2018, Blockchain's Roles in Meeting Key Supply Chain Management Objectives. *International Journal of Information Management*, 2018(39): 80–89.
- [7] Saberi S, Kouhizadeh M, Sarkis J, et al., 2019, Blockchain Technology and its Relationships to Sustainable Supply Chain Management. *International Journal of Production Research*, 57(7): 2117–2135.
- [8] Kumar S, Sahoo S, Lim W, et al., 2024, Why do Businesses Adopt Blockchain for Supply Chain Management? A Systematic Literature Review. *IEEE Transactions on Engineering Management*, 71(6): 16124–16139.

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Application and Practice of Big Data Technology in Financial Management

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Abstract: In the era of accelerating digital economy penetration, big data technology is reshaping traditional corporate financial management models through its core advantages of massive data processing, in-depth data analysis, and precise trend forecasting. This paper focuses on the application value and practical approaches of big data technology in financial management. Through systematic analysis of four core modules, budget management, cost control, risk management, and investment/financing decisions, the study examines application scenarios and implementation effects of big data technology. Addressing current challenges such as insufficient technical compatibility, data security risks, and talent shortages in enterprise applications, targeted optimization strategies are proposed. Practical case studies from enterprises of varying scales demonstrate the practical significance of big data technology in enhancing financial management precision and strengthening corporate value creation capabilities. The research indicates that big data technology drives the transformation of financial management from accounting-oriented to strategy-oriented, providing crucial support for efficient operations in complex market environments. Establishing a comprehensive technical application system, strengthening data governance, and cultivating talent reserves are key to enabling enterprises to fully leverage big data in financial management.

Keywords: Big data technology; Financial management; Risk control; Budget management; Value creation

Online publication: February 10, 2026

1. Introduction

With the rapid advancement of digital technologies including cloud computing, artificial intelligence, and the Internet of Things (IoT), the volume of data generated during business operations has grown exponentially, establishing data as a core production factor for enterprises. As a pivotal component of corporate management, traditional financial management models relying on manual accounting and experience-based decision-making have increasingly revealed shortcomings such as inefficiency, data lag, and inadequate risk assessment, making them ill-suited to today's complex and dynamic market environment. Big data technology, characterized by massive data collection, rapid processing, and multi-dimensional analysis, can break through information barriers

in traditional financial management. It enables deep integration of financial and operational data, providing more comprehensive, precise, and real-time decision-making support. In recent years, enterprises worldwide have actively deployed big data applications in financial management, transitioning from upgrading financial systems to building data analytics platforms. This trend is propelling financial management into a new era of intelligent and refined operations. Against this backdrop, in-depth research on the application and practice of big data technology in financial management holds significant practical urgency.

2. Core connotation and integration logic of big data technology and financial management

2.1. Core characteristics of big data technology

Big data technology encompasses a suite of methodologies for collecting, storing, processing, and analyzing massive, heterogeneous, and rapidly growing datasets to extract actionable insights. Its core characteristics are summarized as the following “5Vs”:

- (1) Volume: Encompassing petabytes to petabytes of data;
- (2) Velocity: Enabling real-time data capture and processing for instant decision-making;
- (3) Variety: Supporting structured data like financial statements, semi-structured data such as contracts, and unstructured data including audio and video;
- (4) Veracity: Ensuring data quality through cleaning and validation;
- (5) Value: Identifying hidden economic patterns and business trends to create enterprise value.

2.2. The need for digital transformation in financial management

Traditional financial management, centered on accounting, focuses on basic tasks like post-event bookkeeping, reporting, and tax filing, with three major pain points as follows:

- (1) Its data dimensionality is limited to financial metrics while neglecting external information such as business and market data;
- (2) Decision-making lags due to reliance on historical data analysis, making it difficult to respond swiftly to market changes;
- (3) Risk anticipation is insufficient, lacking systematic identification and early warning mechanisms for potential risks.

As enterprises expand and market competition intensifies, financial management urgently needs to transition toward budget precision, cost control, risk prevention, and scientific decision-making. Big data technology can effectively address the shortcomings of traditional models, providing technical support for this transformation ^[1].

2.3. The integration logic of big data and financial management

The integration of big data technology with financial management fundamentally represents a data-driven restructuring of financial management models. This integration operates through three key dimensions as follows:

- (1) Data convergence that eliminates silos between finance and business units by consolidating sales, production, supply chain, and customer data with financial metrics to establish a unified data ecosystem;
- (2) Process optimization that automates and enhances traditional financial workflows through big data analytics, enabling intelligent execution of budgeting, cost accounting, and risk assessment;
- (3) Value enhancement that extends beyond conventional financial reporting to value management, providing

data-driven decision support for corporate investments, financing, and strategic planning to maximize organizational value.

3. Core application scenarios of big data technology in financial management

3.1. Budget management: Precise compilation and dynamic monitoring

Traditional budgeting relies on historical data and departmental submissions, which often suffer from subjectivity, low accuracy, and delayed adjustments. Big data technology, through multi-dimensional data collection and analysis, enables comprehensive optimization of the entire budget management process.

During the budget preparation phase, enterprises can integrate historical financial data, market demand data, industry trends, and policy changes, leveraging big data modeling techniques to accurately forecast key metrics like sales revenue and cost expenditures. For instance, retail businesses analyze consumer behavior patterns, holiday spending trends, and regional purchasing power to develop tailored sales budgets by region and product category. Manufacturing companies, meanwhile, combine raw material price fluctuations, production capacity, and order volumes to create precise production and procurement budgets ^[2].

During budget execution, big data technology enables dynamic monitoring and real-time adjustments. By establishing a budget management system that synchronizes budget metrics with operational data, the system automatically triggers alerts when expenditures exceed predefined thresholds. It also dynamically adjusts budgets in response to market changes (e.g., rising raw material costs or declining demand), overcoming the limitations of rigid, static budgeting. For instance, internet companies leverage real-time data on user engagement and conversion rates to dynamically allocate marketing and R&D budgets.

3.2. Cost control: Full chain traceability and fine accounting

Cost control stands as a cornerstone of financial management, where big data technology enables precision management across the entire cost chain, from generation to accounting. During cost aggregation, IoT technology collects real-time data on raw material consumption, energy usage, and labor costs in production processes, ensuring accurate calculation of product and departmental expenses. In cost analysis, big data models dissect cost structures and drivers to identify unnecessary expenditures. For instance, manufacturing firms analyze equipment operation data to optimize maintenance cycles, reducing both equipment failure rates and maintenance costs. Similarly, logistics companies leverage transportation route data, fuel consumption metrics, and labor cost analysis to refine delivery strategies and lower transportation expenses ^[3].

Furthermore, big data technology enables cost forecasting and optimization. By analyzing historical cost data and market variables (such as raw material prices, labor costs, and regulatory policies), it predicts future cost trends and provides optimization recommendations. For instance, companies can identify cost-effective suppliers through supplier data analysis, while optimizing production processes to reduce unit costs by refining manufacturing workflows.

3.3. Risk control: Comprehensive identification and advance warning

In financial management, risks primarily include credit risk, market risk, liquidity risk, and compliance risk. Big data technology enables early identification, precise assessment, and timely resolution of risks through the development of risk warning models. For credit risk control, enterprises integrate historical transaction data, credit records, industry credit ratings, and social media data to build multi-dimensional credit evaluation models for

accurate customer rating assessments. Regarding accounts receivable, real-time monitoring of payment status and operational conditions allows predictive analysis of overdue risks and prompt collection measures. For instance, financial institutions use big data to evaluate borrowers' repayment capacity and willingness, reducing non-performing loan ratios. Enterprises analyze supplier credit data to mitigate supply chain disruption risks.

In market risk management, real-time collection of price, exchange rate, interest rate, and policy data helps assess market fluctuations' impact on operations. Foreign trade companies monitor exchange rate volatility to formulate hedging strategies, while energy firms adjust procurement plans and inventory levels based on international oil price trends. For compliance risk control, big data technology automatically identifies abnormal transactions and violations in financial records. Compliance monitoring systems, aligned with accounting standards, tax regulations, and industry requirements, continuously track financial statements, reimbursement vouchers, and fund flows to detect fraudulent claims, tax evasion, and fund misappropriation, thereby reducing corporate compliance risks^[4].

3.4. Investment and financing decision-making: Scientific evaluation and precise judgment

Investment and financing decisions directly determine the survival and development of enterprises. Traditional decision-making relies on the experience of decision-makers and limited financial data, which carries high risks. Big data technology provides objective and precise support for investment decisions through comprehensive data analysis. In investment decisions, companies can analyze target projects' industry prospects, market competitiveness, financial status, and potential risks using big data. For instance, investment institutions collect target enterprises' operational data, industry rankings, user reviews, and intellectual property data to build investment evaluation models, assessing project value and return rates.

When making fixed asset investments, companies analyze market demand data, capacity utilization rates, and technological iteration data to evaluate project feasibility and profit cycles. For financing decisions, big data technology helps enterprises select optimal financing channels and solutions. By analyzing cost data, financing terms, and policy support data of different financing methods, combined with their own financial conditions and cash flow data, companies can develop personalized financing strategies. For example, small and medium-sized enterprises can access financial institutions through big data platforms and obtain credit loans using multi-dimensional operational data to solve financing difficulties. Large enterprises can analyze capital market data to choose optimal combinations of equity financing and bond financing.

3.5. Financial analysis and forecasting: Multi-dimensional insight and forward-looking judgment

Traditional financial analysis often remains confined to ratio-based evaluation of financial statements, offering a narrow perspective. Big data technology has revolutionized financial analysis by expanding its dimensions and depth, enabling a shift from historical review to future forecasting. Enterprises can now integrate financial data, operational metrics, industry benchmarks, and macroeconomic indicators for multidimensional analysis as listed:

- (1) Profitability analysis: Identifying core profitable operations and growth opportunities through metrics like product gross margins, customer contribution rates, and regional profitability;
- (2) Operational efficiency analysis: Optimizing workflows by examining inventory turnover, accounts receivable turnover, and asset utilization rates;
- (3) Growth potential analysis: Predicting future trends through market share, growth rates, and R&D investment effectiveness.

On top of that, big data technologies leverage machine learning and neural network algorithms to build predictive models, providing precise forecasts for key indicators such as revenue, profits, and cash flow. This data-driven approach offers strategic planning insights. For instance, tech companies analyze R&D investments, patent portfolios, and market demand trends to forecast new product market prospects and profitability potential.

4. Practical cases of big data technology in financial management

4.1. Large-scale manufacturing: Haier group's financial digital transformation

As a globally renowned manufacturing enterprise, Haier Group has developed a “Financial Shared Platform” leveraging big data technology to achieve end-to-end intelligent financial management. This platform integrates financial, production, supply chain, and customer data from Haier's global operations, establishing a unified data hub. For budget management, big data models enable precise budget formulation and dynamic adjustments across subsidiaries and business units worldwide. In cost control, real-time production equipment data collected through IoT optimizes manufacturing processes and reduces unit costs. For risk management, a global capital risk early-warning system monitors exchange rate and interest rate fluctuations in real time to mitigate cross-border operational risks. Empowered by big data, Haier Group has achieved a 60% increase in financial accounting efficiency and a 95% budget accuracy rate, effectively supporting its global expansion strategy ^[5].

4.2. Internet industry: Alibaba's intelligent financial system

Leveraging big data and cloud computing technologies, Alibaba has developed its intelligent financial platform “Alibaba Financial Brain,” achieving automated and intelligent financial management. The platform features three core functions as follows:

- (1) Smart accounting: Using OCR technology to automatically recognize reimbursement vouchers and invoices, enabling automated bookkeeping and tax filing;
- (2) Precise forecasting: Integrating transaction data from e-commerce platforms, user data, and logistics data to predict revenue and cash flow, supporting corporate investment and financing decisions;
- (3) Risk prevention: Real-time monitoring of merchants' transaction data to identify fraudulent transactions and irregular settlements, ensuring fund security.

The implementation of Alibaba Financial Brain liberates financial personnel from tedious routine tasks, allowing them to focus more on strategic planning and value management.

4.3. Financial industry: Big data risk control practice of China construction bank

China Construction Bank has implemented big data technology to build a multi-dimensional risk control model for credit risk management. By integrating clients' bank transaction records, credit card spending data, mortgage and auto loan repayment histories, along with external data sources including social security records, housing provident fund records, business registration records, and judicial data, the bank conducts comprehensive credit evaluations. Additionally, it has established a real-time risk monitoring system to track credit applications and fund transfers, identifying suspicious transactions. This risk control model has consistently kept the bank's non-performing loan ratio below the industry average, significantly enhancing the quality of its credit assets.

5. Problems in the application of big data technology in financial management

5.1. Technical level: Insufficient system adaptation and lagging data governance

Some enterprises face outdated technical architectures, with their existing financial systems being incompatible with big data technologies and lacking sufficient data storage and processing capabilities, which hinders the implementation of big data applications. In addition, enterprises face complex data sources characterized by inconsistent standards, incompatible formats, and uneven data quality, coupled with a lack of a robust data governance framework. Furthermore, the development of big data analytical models requires specialized technical expertise, yet most enterprises lack in-house development capabilities and rely on external service providers. This dependency results in models that struggle to adapt to actual business needs, leading to poor compatibility.

5.2. Talent level: Shortage of compound talents

The application of big data in financial management requires professionals who are proficient in both financial expertise and big data technologies, including data analysis tools. Currently, most financial personnel in China specialize in traditional accounting practices but lack skills in big data processing, machine learning, and data modeling. Meanwhile, big data specialists often lack familiarity with financial management operations, resulting in a talent supply-demand imbalance. This shortage prevents companies from independently conducting big data analysis, thereby limiting the deep integration of big data technologies.

5.3. Security level: Increased data leakage risk and compliance pressure

Financial management data contains core business secrets and sensitive information, and the entire data lifecycle, from collection and storage to transmission and analysis, faces security risks in the big data era. Cyberattacks and system vulnerabilities may cause data breaches, while data sharing often leads to unclear ownership and usage rights, increasing the risk of misuse. Moreover, with the implementation of laws like the Data Security Law and Personal Information Protection Law, enterprises must strictly comply with data processing regulations, further intensifying compliance pressures ^[6].

5.4. Management level: Cognitive bias and insufficient organizational synergy

Some corporate executives misinterpret big data technology, equating its implementation with mere financial system upgrades while overlooking critical dimensions like data integration, process optimization, and organizational transformation. The persistent data silos between finance and operations departments further exacerbate this issue, as business units lack data-sharing awareness, resulting in ineffective integration of financial and operational data. Compounding these challenges, the absence of robust incentive mechanisms for big data adoption has dampened employee engagement, ultimately undermining the effectiveness of such implementations.

6. Optimization strategy of financial management empowered by big data technology

6.1. Build an adaptive technical system and strengthen data governance

Enterprises should select big data platforms that align with their scale and operational requirements, making full use of technologies such as cloud computing and distributed storage to enhance data processing capabilities. Small and medium-sized enterprises can rely on third-party cloud service platforms to reduce technical investment costs, whereas large enterprises may establish proprietary data middle platforms to enable centralized data management and resource sharing. In parallel, data governance mechanisms should be strengthened by establishing unified data

standards and specifications, clearly defining processes and responsibilities for data collection, storage, processing, and utilization.

Data quality audit systems, incorporating techniques such as data cleaning and validation, should be implemented to eliminate invalid or erroneous data and ensure data reliability. Furthermore, data ownership and usage rights must be clearly defined, and standardized data-sharing procedures should be established. To optimize analytical performance, enterprises are encouraged to collaborate with universities, research institutions, and professional service providers to develop customized big data analytical models tailored to specific business characteristics. Dynamic optimization mechanisms should also be introduced to enable timely updates of model parameters in response to market fluctuations and operational changes, thereby enhancing model accuracy and adaptability.

6.2. Strengthening talent training and building a compound team

Enterprises should strengthen talent development for big data-driven financial management through a combination of internal training, external recruitment, and incentive mechanisms. Regular training programs should be organized for financial personnel to enhance their proficiency in data analysis tools such as Python and SQL, big data modeling, and basic machine learning techniques, while industry experts can be invited to share practical case studies to improve application capabilities. In parallel, preferential recruitment policies should be implemented to attract interdisciplinary professionals with expertise in both big data technologies and financial management, and cooperation with universities should be promoted through industry-academia joint training programs to cultivate specialized talent. Additionally, dedicated incentive mechanisms, including special awards for big data applications, should be established to recognize outstanding achievements in data analysis, model development, and value creation, thereby motivating employees to actively learn and apply big data technologies.

6.3. Strengthen data security to ensure compliant operations

Data security should be comprehensively strengthened through the integration of technical safeguards, management systems, and regulatory compliance measures. Advanced security technologies, including firewalls, data encryption, and intrusion detection systems, should be deployed to protect data storage and transmission, while robust data backup and recovery mechanisms must be established and regularly tested to prevent data loss. At the same time, system vulnerabilities should be promptly patched to address emerging cybersecurity threats. In terms of management, data security responsibilities should be clearly defined, and a dedicated data security management team should be established to oversee routine monitoring and risk prevention, supported by a well-defined contingency plan to enable rapid response to data breach incidents and minimize potential losses. Furthermore, enterprises must strictly comply with relevant laws and regulations, such as the Data Security Law and the Personal Information Protection Law, ensuring lawful data collection, processing, and utilization. A compliance review mechanism should also be implemented, with regular self-assessments conducted to reduce legal and regulatory risks.

6.4. Change management concept and strengthen organizations' coordination

Managerial awareness of big data applications should be strengthened by encouraging organizational leadership to participate in specialized training programs, enabling a comprehensive understanding of the transformative role of big data in financial management and promoting its integration into corporate strategic planning and resource allocation. At the organizational level, departmental data silos should be dismantled through the establishment of cross-departmental collaboration mechanisms with clearly defined data-sharing responsibilities, supported by the

development of an enterprise-wide data sharing platform that enables seamless integration of financial, operational, and market data for comprehensive big data analytics. Moreover, the transformation of financial management should be actively advanced by guiding finance departments to shift from traditional accounting-oriented functions toward strategic support roles, encouraging financial professionals to engage deeply with business operations, understand core processes, and apply data analysis to support managerial decision-making, thereby achieving effective integration of finance and business operations.

7. Conclusion

Big data technology is fundamentally transforming the models and essence of corporate financial management. Its applications in core scenarios such as budget management, cost control, risk management, and investment/financing decisions have effectively addressed traditional financial management's shortcomings including insufficient precision, delayed decision-making, and weak risk anticipation, driving the transformation of financial management toward refinement, intelligence, and strategic orientation. Case studies demonstrate that whether for large enterprises or small and medium-sized businesses, the rational application of big data technology can significantly enhance financial management efficiency and strengthen market competitiveness. However, enterprises currently face multiple challenges in implementation, including inadequate technological adaptation, talent shortages, data security risks, and insufficient organizational coordination. To overcome these challenges, strategies such as building compatible technical systems, cultivating interdisciplinary talents, fortifying security defenses, and enhancing organizational collaboration must be implemented.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Wang X, 2025, Application of Big Data Technology in Enterprise Tax Management. *China Strategic Emerging Industries*, 2025(32): 182–184.
- [2] Zhou F, Liang B, Guo P, 2025, Application Research of Big Data Technology in Financial Management of University Infrastructure. *China Management Informatization*, 28(21): 70–73.
- [3] Wu J, 2025, Application of Big Data Technology in Enterprise Financial Management. *Digital Communication World*, 2025(9): 130–132.
- [4] Zhao C, 2025, Application of Big Data Technology in Enterprise Financial Management. *Mass Investment Guide*, 2025(17): 157–159.
- [5] Sun H, 2025, Application and Benefit Analysis of Big Data Technology in Enterprise Financial Management. *China Collective Economy*, 2025(5): 153–156.
- [6] Zhao L, Ding X, 2025, Application of Big Data Technology in Enterprise Financial Management. *China Exhibition*, 2025(11): 155–157.

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The FinTech Revolution: A Systematic Literature Review of Its Impact on the Global Financial Landscape

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Abstract: Financial Technology (FinTech) refers to financial innovations which are technology-enabled including artificial intelligence (AI), big data analytics, blockchain and so on. As a disruptive revolution, the advancement of FinTech has changed the traditional methods of lending, payment and investment, and has emerged as a significant factor in the development of business and financing over the past decade. Furthermore, the adoption of FinTech such as digital bank not only promotes the prosperity of business at the macro level, but also changes daily behaviors of each tiny individual at the micro level. This paper aims to explore the innovations of financial technology in traditional financing channels from both macro and micro perspectives, to provide reasonable references for financial decision-makers. In conclusion, with the development of modern technology such as blockchain, big data, and APIs, FinTech is transforming the world on both a macro and micro level.

Keywords: FinTech; Systematic literature review; Global financial landscape; Financial innovation; Open banking; Artificial intelligence; Big data analytics; Machine learning

Online publication: February 10, 2026

1. Introduction

1.1. Research background

Financial Technology (FinTech) refers to financial innovations which are technology-enabled including artificial intelligence (AI), big data analytics, blockchain and so on. As a disruptive revolution, the advancement of FinTech has changed the traditional methods of lending, payment, and investment, and has emerged as a significant factor in the development of business and financing over the past decade. “Global FinTech 2023: Reimagining the Future of Finance” report shows the FinTech sector now occupies a 2% share of global financial services revenue and is estimated to reach \$1.5 trillion in annual revenue by 2030^[1]. Furthermore, the adoption of FinTech such as digital

bank not only promotes the prosperity of business at the macro level, but also changes daily behaviors of each tiny individual at the micro level. Under this background, research on FinTech has seen a remarkable increase in recent years. Therefore, this paper aims to explore the innovations of financial technology in traditional financing channels from both macro and micro perspectives, to provide reasonable references for financial decision-makers.

2. Methodology

To research FinTech theories, adoption models and modern financial methods, this study undertakes a systematic literature review. Multiple data sources are reviewed from official reports like “Global FinTech Industry Report” and core papers on authoritative databases such as Springer Nature to ensure an insightful analysis. Besides, the review process incorporates a few key points as follows:

- (1) It involves a development analysis of current FinTech industry;
- (2) The topic of how FinTech changes the financial world is reviewed by introducing four main financial scenarios including Lending, Payment, Investment and Saving and Personal Finance;
- (3) FinTech firms and traditional banks would be compared, a corresponding final conclusion would be drawn.

3. Findings

3.1. Current development status of the FinTech industry

The relationship between finance and technology can be summarized as: Finance supports technology, and technology in turn benefits finance. FinTech is currently playing a significant role in promoting financial services such as credit, investment, risk transfer and so on. “FinTech Report 2025” indicates the features of current FinTech industry through innovation, accessibility, and efficiency ^[2]. From the perspective of innovation analysis, it can be divided into two points: technological innovation and scenario innovation. A dependable AI-driven-FinTech adoption framework that integrates behavioural insights with cyber-physical security mechanisms has been applied in risk management and user engagement and blockchain-based systems addressing key pain points of traditional financial services.

FinTech is creating new usage scenarios, which breaks the traditional financial model. Zhuang *et al.* used a DID analysis and regression model and demonstrated that open banking has disruptively improved bank performance and examines the impact mechanisms underlying this effect in China ^[3]. Gero Friedrich Bone-Winkel *et al.* used a comprehensive dataset from the Estonian P2P lending platform Bondora, consisting of over 350,000 loans and 112 features with a loan volume of 915 million euros, which demonstrates that modern technologies such as machine learning have brought about transformative changes to traditional lending ^[4]. Regarding accessibility, the market share of the FinTech industry is increasing steadily. For instance, the report shows that the annual growth rate of the FinTech industry is about 5.38%, with over 103,000 companies ^[2]. By 2030, the market will reach a value of USD 686.85 billion. In terms of efficiency, financial technology has significantly enhanced industry efficiency. For instance, Mehmet Çağlar *et al.* measured the efficiency of FinTech operating in eight different sub-sectors for the period of 9 years ^[5]. The results show that FinTechs’ profitability efficiency performances are higher than their marketability efficiency performances.

The development of financial technology also faces some challenges at present, such as regulatory compliance challenge, cybersecurity challenge and Tech experts’ challenge. For example, an open banking institution, Evolve

Bank was hit by a ransomware attack in 2024 due to technical flaws ^[6]. While such challenges came one after another, these challenges cannot be sufficient to stop the development of FinTech in general. FinTech is promoting the development of traditional financial methods such as lending, payment and investment.

3.2. FinTech changes the financial world

3.2.1. Lending

Lending is the action of allowing a person or organization the use of a sum of money under an agreement to pay it back later with interest. As one of the most historical financing methods, lending businesses have great significance in boosting economic growth and empowering individuals and companies to achieve their goals. However, lending through traditional channels faces a few challenges such as risk assessment and management and regulatory compliance.

The main reasons for these challenges are as follows. Traditional loans rely on intermediaries. Due to the lack of transparency in information, relevant regulators cannot play their role in time and the risk of this transaction form increases. Besides, complex procedures increase the transaction overhead costs. In this context, decentralized finance (DeFi) such as peer-to-peer (P2P) lending seeks to address these issues by leveraging current FinTech such as blockchain, machine learning to create an open, transparent, and inclusive financial ecosystem. Due to AI-driven underwriting processes, and the ability to access diversified portfolios at scale, institutional investors are increasingly participating in modern financial services such as P2P lending. Taking the United States as an example, the size of its P2P lending market reaches 41.6 billion US dollars in 2025 and is expected to be about 319.3 billion US dollars by 2034, growing at a CAGR of 25.44% from 2025 to 2034 ^[7]. Regarding the potential credit risks that may arise from loans, the credit scoring system based on big data analysis has performed well. This system determines the creditworthiness of a person or a small, owner-operated business by generating a three-digit score that ranks a borrower's riskiness, which has significantly reduced the risks associated with loan financing transactions. Amin Karami *et al.* reviewed 50 papers published between 2019 and 2025 demonstrating big data reduces biases, refines risk profiles, and provides actionable insights ^[8].

3.2.2. Payment

The development of FinTech has changed the reliance of traditional payment methods on physical money exchange. Over the past decade, depending on blockchain and digital currency technology, payment systems such as PoS, P2P online payment, digital wallets have been seen as simple and faster ways through many online financial services, becoming an important factor in growth of the cashless economy and electronic payment methods.

Among these innovation solutions of payment, Alipay is considered as a global leader. In terms of technological innovation, this platform takes the lead in applying QR code payment, face recognition payment, blockchain and digital RMB technologies. For global services, Alipay supports payments in 220+ countries and regions with 50+ currency partnerships globally. In 2025, Alipay processed \$20.1 trillion in transactions, 1.4 billion monthly active users accessed Alipay in global mobile payments ^[9]. Apart from point-to-point payment platforms like Alipay, mobile payment platforms such as Apple Pay are also experiencing rapid development. This platform is a contactless payment system and digital wallet created by Apple company, which enables users to securely store credit cards, debit cards, and various other payment instruments on their Apple devices. The core of the technology of it is Near Field Communication (NFC). When users hold devices like iPhone near the terminal,

the NFC chip can allow to approve the transaction without a physical card, which has greatly changed people's payment methods.

3.2.3. Personal finance

Personal finance is the management of personal or family financial activities including earning income, making a budget, saving, making wise investments, dealing with debts, purchasing insurance and preparing for future financial needs. The development of fintech not only promotes the growth of the financial industry, but also objectively provides convenience for the improvement of personal finance. For example, traditional insurance has the characteristics of complexity and uncertainty, the insurance policies are often complex and difficult for customers to understand. Besides, the claims process can be lengthy and bureaucratic, leading to customer frustration.

FinTech helps simplify processes of insurance services by using AI, big data, blockchain and the Internet of Things (IoT), which improves the ecosystem of the insurance industry. Due to the rapid development of insurance fintech, some scholars have defined a new term called Insurance technology (Insurtech). Insurtech offers individualized, tailored and personalized solutions to life's risks using data analytics, sensors, wearables and cell phone data ^[10]. Among insurance technology companies, the most famous one is Lemonade. This company is known for its AI-powered platform that can simplify insurance purchasing and claims processing. As a digital insurer, it uses machine learning to assess potential risks. Its rapid growth and innovative model have made it a unicorn with a valuation exceeding \$2 billion ^[11]. Moreover, FinTech platforms provide flexible options like digital wallets or digital banks. These innovative technologies have made people's lives more convenient and enhanced the efficiency of personal financing and savings.

4. Conclusion

In conclusion, with the development of modern technology such as blockchain, big data, and APIs, FinTech is transforming the world on both a macro and micro level. From a macroscopic perspective, the related FinTech industry shows clear characteristics of innovation, accessibility and efficiency, a variety of innovative financial service models such as P2P platforms and crowdfunding, have significantly reduced the indirect costs of transactions, promoted the development of the global economy. From a microscopic perspective, FinTech has promoted the decentralization and de-intermediation of finance, reduced the fund risk, significantly improved users' experience. Overall, fintech has become a key driver of the growth of finance industry. In the future, technology will drive the development of the financial system, making it more open, efficient and inclusive. The findings of this study are used to provide a general reference for financial decision-makers.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Goyal D, Varma R, Rada F, et al., 2023, *Global FinTech 2023: Reimagining the Future of Finance*, BCG Global, 3rd ed.

- [2] Bursuk I, 2025, FinTech Report 2025, StartUs Insights.
- [3] Liu Z, Li X, Li Z, 2024, Inclusive FinTech, Open Banking, and Bank Performance: Evidence from China,. *Financial Innovation*, 10(149): 1–24.
- [4] Bone-Winkel G, Reichenbach F, 2024, Improving Credit Risk Assessment in P2P Lending with Explainable Machine Learning Survival Analysis. *Digital Finance*, 501–542.
- [5] Çağlar M, Nişel S, 2024, Efficiency Measurement of Fintech Companies: A Two-Stage DEA Approach. *Electronic Commerce Research*, 24(2): 1335–1366.
- [6] Likarenko Y, 2024, The Top 10 FinTech Challenges (And How to Solve Them), Uptech, October 1, 2024.
- [7] Precedence, 2025, Peer to Peer (P2P) Lending Market Size, Report 2022–2030, Precedence, November 4, 2025.
- [8] Karami A, Igbokwe C, 2025, The Impact of Big Data Characteristics on Credit Risk Assessment. *International Journal of Data Science and Analytics*, 20(1): 4239–4259.
- [9] Elad B, 2025, Alipay Statistics 2025: User Adoption, Transaction Volumes, and Technological Innovations. *CoinLaw*, June 16, 2025.
- [10] Cosma S, Rimo G, 2024, Redefining Insurance through Technology: Achievements and Perspectives in Insurtech. *Research in International Business and Finance*, 70(1): 1–17.
- [11] Dommeti M, 2025, Top 20 Insurance Tech Companies, Theconnects, June 12, 2025.

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The Concept, Classification and Characteristics of Sleeping Resources in Guangdong Hong Kong Macao Great Bay Area

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Abstract: Under the background of the construction of Guangdong Hong Kong Macao Great Bay area, there are a large number of underutilized “sleeping resources” in the region, which restricts the overall efficiency improvement and the coordinated development of urban and rural areas. Based on the reality of Dawan District, this paper defines the narrow and broad connotation of sleeping resources, and divides its system into four categories: culture, nature and ecology, economy and industry, and society and space from three dimensions: value attribute, sleeping state and regional characteristics. It then analyzes its three characteristics of value diversification and concealment, spatial cluster and cross-border, regional strategy and urgency. Combined with the development trend of digital economy, it puts forward the innovation strategy of resource activation, in order to provide theoretical reference and practical guidance for the resource integration, value release and high-quality coordinated development of Guangdong Hong Kong Macao Greater Bay area.

Keywords: Sleeping resources; Guangdong Hong Kong Macao Greater Bay area; Million project; Resource activation

Online publication: February 10, 2026

1. Introduction

Under the strategic background of comprehensively promoting the construction of Guangdong Hong Kong Macao Great Bay area, the region has become an important engine of China’s economic development with its unique geographical advantages, rich resource endowment and strong economic foundation. However, in the process of high-speed urbanization and industrial transformation and upgrading, there are still a large number of “sleeping resources” in idle or inefficient use in the region, covering idle production capacity of traditional industries, inactive historical and cultural assets and various elements that have not been fully activated by the digital economy. The “sleeping” state of these resources not only causes a waste of resources, but also restricts the improvement of regional overall competitiveness and the depth of urban-rural integration development. With

the in-depth implementation of the “million project” in Guangdong Province and the vigorous rise of the digital economy wave, how to systematically identify, scientifically classify and effectively activate these sleeping resources has become a key issue to promote the sustainable development and common prosperity of Guangdong Hong Kong Macao Great Bay area. The purpose of this study is to combine the development conditions of Dawan District, clarify the concept and connotation of sleeping resources, build its classification system, analyze its core characteristics, and explore the activation path under the empowerment of digital economy, in order to provide theoretical support and practical framework for the optimal allocation of regional resources, potential release and strategic synergy.

2. Basic connotation of sleeping resources

2.1. Sleeping resources in a narrow sense

Sleeping resources in a narrow sense mainly refer to those specific tangible elements with clear physical form and long-term idle or inefficient utilization. Its core features are “entity existence” and “functional stagnation”. In the context of Dawan District, such resources are typical, such as old industrial plants and warehouses vacant due to industrial transfer or upgrading. For instance, idle dwellings in traditional villages hollowed out by the outflow of population, and corner plots or abandoned facilities temporarily shelved in the process of urban renewal. These resources have complete physical carriers, but their original functions have faded or failed to meet the new development needs, and have not been timely transformed into cultural and creative space, community service places or new industrial carriers. Their potential value is limited to the physical reuse and functional transformation of existing space.

2.2. Sleeping resources in a broad sense

The broad sense of sleeping resources breaks through the category of tangible entities, and points to the collection of all elements with potential value but not fully activated, covering tangible and intangible resources and their associated values. It not only includes idle assets in a narrow sense, but also extends to intangible cultural skills (such as intangible cultural heritage in the face of inheritance crisis), social capital (such as the network of hometown of overseas Chinese that is not effectively linked), technical knowledge (such as untransformed process know-how in traditional industries) and brand value (such as aging regional industrial brands). In addition, the broad concept emphasizes the collaborative value between resources. For example, if the beautiful ecological landscape and unique local culture exist in isolation, their composite value will be in a “sleep” state. Therefore, sleeping resources in a broad sense refer to the sum of various elements that cannot be identified, integrated and maximized in their multi-dimensional values (economy, culture, ecology and Society) due to cognitive, technological, mechanism or market constraints. Their activation focuses more on value discovery, element restructuring and system innovation.

3. Classification of sleeping resources in Guangdong Hong Kong Macao Great Bay Area

3.1. Classification basis of sleeping resources

The scientific classification of sleeping resources in Guangdong Hong Kong Macao Bay area is mainly based on the following three core dimensions:

- (1) Value attribute dimension: According to the core value orientation of resources, it is divided into “cultural

- category” focusing on historical memory and cultural inheritance, “natural and ecological category” emphasizing ecological service function, “economic and industrial category” focusing on production factors and market value, and “social and spatial category” focusing on social relations and spatial justice;
- (2) Sleeping state dimension, which can be divided into “completely idle type” (such as abandoned plants), “inefficient utilization type” (such as a protected area with single function) and “value masking type” (such as unrecognized cultural value) according to the degree of resource availability, so as to distinguish activation difficulty and intervention focus;
 - (3) The dimension of regional characteristics, which closely combines the institutional complexity of the “One country, Two systems, Three Customs Zones” in Dawan District, the profound cultural heritage of the hometown of overseas Chinese, the world-renowned manufacturing foundation and the significant internal development gradient (such as the difference between the core area of the Pearl River Delta and the eastern and northwestern regions of Guangdong), to ensure that the classification system fits the regional reality and reflects the unique pattern of resource distribution and the particularity of activation challenges.

3.2. Main categories of sleeping resources

3.2.1. Cultural sleeping resources

Such resources carry the deep historical context and unique local identity of Dawan District, but they are facing severe challenges under the impact of modernization. It mainly includes traditional villages and ancient dwellings, such as Fengjianshui Township and Kaiping Diaolou group in Shunde. These villages “formed earlier, have rich traditional resources, and have certain historical, cultural, scientific, artistic, social and economic values”, but are generally faced with material decline and population hollowing out ^[1]. Intangible cultural heritage, such as Guangzhou embroidery and Cantonese opera, as a “living and carried by human life activities” cultural style, has prominent problems of aging and disconnection from modern life ^[2]. Industrial heritage, that is, “industrial cultural relics with historical, technical, social, architectural or scientific value”, such as the ruins of Foshan old ceramic workshop and Jiangmen paper mill, whose historical value and technical memory have not been fully explored ^[3]. The historical context space, such as the arcade block in Guangzhou, has great potential for cultural narrative, but is currently lack of vitality.

3.2.2. Natural and ecological sleeping resources

Such resources have important ecological regulation and service functions, but the path to realize the value of ecological products is not smooth. It mainly includes coastal wetland and tidal flat resources, such as mangrove in Shenzhen and Qi’ao Island wetland in Zhuhai, which are facing “huge pressure and threat” in the rapid urbanization ^[4,5]. At present, the development of ecotourism and education functions is insufficient. Idle land resources, including abandoned agricultural land and hollow village homestead in the urban-rural fringe, have resulted in “waste of land resources, thus affecting resource utilization” and have not been effectively transformed into green infrastructure ^[6]. Potential tourism resources, that is, things that “currently do not have the conditions for development or the degree of development is not enough, but are likely to be developed into tourism resources in the future”, such as the geological landscape of Yanzhou island in Huizhou and the ancient post road in southern Guangdong, have been “kept in purdah for a long time because of insufficient supporting facilities” ^[7].

3.2.3. Economic and industrial sleeping resources

Such resources used to be the engine of economic growth in Dawan District, but now their potential is limited due to the lag of transformation. It mainly includes county characteristic industrial clusters, such as Chaozhou ceramics and Zhongshan mahogany furniture, as the “core carrier of high-quality development of county economy”, currently have “problems such as unbalanced market, insufficient factor guarantee and short industrial chain”, and the brand added value is low^[8]. Idle assets and inefficient production capacity, such as old commercial bodies and old factories of collective enterprises in various cities and towns, with intact physical space but outdated business functions and low utilization rate. Agricultural resources and rural products, such as Zengcheng litchi, Sihui sugar orange and other geographical indication products, generally have the problems of insufficient deep processing, short industrial chain and poor integration of agriculture, culture and tourism, and the economic value has not been fully released.

3.2.4. Social and spatial sleeping resources

Such resources maintain social network and collective memory, but their functions degenerate due to social changes. It mainly includes hollow villages and communities. Under the background of accelerated urbanization, “the force of most rural settlements began to be unbalanced”^[9]. Some communities in western Guangdong and other places have a very low utilization rate of public service facilities due to the outflow of young adults. Inefficient public spaces, such as urban corners and spaces along the old railway, lack design and community participation, and fail to be transformed into dynamic places for public activities. The social capital of the hometown of overseas Chinese, such as the overseas Chinese approval files and the former residences of the family members of overseas Chinese in Jiangmen and other places, connects millions of overseas Chinese and is a valuable carrier of cultural identity. However, at present, the local activation and overseas linkage mechanism is not perfect, and its strong social network value has not been effectively activated.

4. Characteristics of sleeping resources in Guangdong, Hong Kong and Macao Greater Bay Area

4.1. Diversity and concealment of value composition

The sleeping resources in Dawan district are generally characterized by multiple values. A single resource often contains multiple value dimensions such as culture, ecology, economy and society. For example, the Sangji fish pond system in the Pearl River Delta is not only an important agricultural cultural heritage (cultural value), but also has a unique ecological cycle function (ecological value). It can also develop characteristic tourism and agricultural products (economic value), and maintain a specific community production mode (social value). However, due to the lack of systematic evaluation, recording and dissemination mechanism, this multiple value is in a highly “hidden” state. Many industrial heritages and traditional villages have not yet established complete value archives, resulting in their real value not being fully recognized by the government, the market and the public, which constitutes the primary obstacle to activation.

4.2. Clustering and cross-border nature of spatial distribution

Sleeping resources are not isolated and scattered in space, but show a significant cluster distribution trend, and often break through the administrative boundary to form resource corridors. Cultural resources are closely connected along the Xijiang Pearl River waterway, forming a traditional village group in Guangfo and Zhaoqing,

and a building belt in Zhongjiang Zhuhai overseas Chinese hometown. Ecological resources are distributed in circles around the Pearl River Estuary, such as the deep pearl mangrove wetland group and the island chain around the bay. Industrial inefficient assets exist in Dongguan Huizhou, Foshan Zhongshan and other traditional manufacturing agglomeration areas. What is particularly prominent is its “cross-border nature”, where it is reflected in the fact that the resource corridor crosses multiple urban administrative boundaries. On the other hand, the social capital of the hometown of overseas Chinese has formed a unique “local overseas” two-way cross-border network. For example, the overseas Chinese approval files in Wuyi area are closely linked to hundreds of overseas Chinese groups. This spatial characteristic requires that the activation strategy must have regional synergy and international vision.

4.3. Strategy and urgency of regional development

It is of far-reaching strategic significance and realistic urgency to revitalize the sleeping resources for the Greater Bay area of Guangdong, Hong Kong and Macao. From a strategic perspective, this is a key measure to improve the overall allocation efficiency of regional resources, explore new economic growth points, promote the coordinated development of urban and rural areas, and implement the “hundred million project” and high-quality development requirements, directly serving the major national strategy for the construction of Guangdong Hong Kong Macao great Bay area. From the perspective of urgency, in the process of rapid urbanization and industrial upgrading, if the sleeping resources are not effectively intervened in time, their physical carrier may accelerate the decline (such as building collapse), intangible culture may disappear permanently (such as non-lost transmission), and social capital may continue to flow. At the same time, the enabling window period brought about by the digital economy is fleeting. It is an urgent requirement to identify, evaluate and activate these resources in time with the help of digital technology to avoid the permanent annihilation of their value and miss the best opportunity for transformation.

5. Innovation path of digital economy enabling sleeping resources activation

5.1. Digital technology integration and value digging path

Digital technology is the key to penetrate the “invisibility” of resources and realize the explicit and accurate evaluation of their multiple values. It can use 3D laser scanning, UAV tilt photography and other technologies to digitally archive cultural heritage and historical buildings, build high-precision “digital twin” models, and permanently preserve and visualize their spatial and structural information. Through big data analysis, the market demand, tourist interest and potential related industries of sleeping resources (such as specific intangible cultural heritage and local products) are mined to achieve precise positioning. The blockchain technology is used to establish a tamper-proof value certificate and traceability system for unique cultural resources and ecological products (such as carbon sink), support its subsequent capitalization and capitalization operation, and implement the concept of “working capital” mentioned by Wu ^[10].

5.2. Platform operation and multiple collaborative paths

Drawing on the integrated thinking of the “area + project” mechanism, an online–offline resource activation and operation platform should be established ^[11]. The online platform can integrate key functions such as a database of underutilized resources in the Dawan District, a policy support toolbox, supply-demand matchmaking, crowdfunding, and maker services, thereby serving as a comprehensive portal for resource display, investment

promotion, and collaborative development. Offline, guided by government leadership and supported by market-oriented operations and broad social participation, targeted “micro-renovation and refined upgrading” initiatives can be implemented in specific areas, such as historic towns or former industrial zones, while introducing new business models aligned with the digital era, including digital cultural and creative industries, smart agriculture, and immersive experience services. At the same time, coordination among multiple stakeholders should be strengthened. The government provides planning guidance and policy safeguards, professional operating teams undertake market-based operations, and local residents and communities participate deeply through mechanisms such as resource equity participation and profit-sharing. Together, these measures can foster a sustainable community of shared interests.

5.3. Innovation mechanism and long-term development path

A comprehensive institutional framework should be established to ensure the long-term sustainability of resource activation projects as outlined:

- (1) Innovation in property rights and benefit distribution mechanisms is required, including the exploration of digital property rights registration, convenient transfer procedures, and income guarantee systems for underutilized resources, particularly rural idle homesteads and collectively operated construction land, within the framework of the “separation of three rights”;
- (2) A closed-loop mechanism integrating “resource activation, industrial cultivation, and income feedback” should be developed, whereby a portion of the revenues generated by activation projects is reinvested in continuous resource maintenance, the enhancement of community public services, and youth entrepreneurship funds, thereby stimulating endogenous development momentum;
- (3) Monitoring, evaluation, and dynamic adjustment mechanisms should be strengthened by leveraging digital platforms to track the comprehensive social, economic, cultural, and ecological benefits of projects. This approach can ensure that the activation process remains aligned with the goals of sustainable development and common prosperity, while enabling timely strategy optimization based on feedback.

Funding

The 2025 Annual Integrated Teaching-Research-Innovation Team Project of Guangdong University of Science and Technology Innovative Pathways for Activating Dormant Resources in the Greater Bay Area under the Guidance of the “Project of Promoting High-quality Development in 100 Counties, 1,000 Towns and 10,000 Villages”: the Cultural Decoding × Digital Twin Dual-Helix Intelligent Integration Team (Project number: GKJXXZ2025009)

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Hu Y, Chen S, Cao W, et al., 2014, Concept and Cultural Connotation of Traditional Villages. *Urban Development Studies*, 21(1): 10–13.

- [2] Gao B, 2008, Intangible Cultural Heritage as Public Culture. *Literary Review*, 2008(2): 77–83.
- [3] Shan J, 2006, Focusing on New Cultural Heritage: Protection of Industrial Heritage. *China Cultural Heritage*, 2006(4): 10–47.
- [4] Luo L, 2009, Research on the Construction of Urban Wetland Parks, thesis, Dalian University of Technology.
- [5] Zeng F, Zhang W, Liu S, et al., 2011, Evaluation of Coastal Potential Tourism Resources Based on AHP: A Case Study of Dongbi Island Tourism Resort in Fuqing City. *Journal of Hainan Normal University (Natural Science)*, 24(3): 325–329.
- [6] Gao D, 2024, Investigation and Research on the Problem and Solutions of Rural Idle Land in Wafangdian City, thesis, Ocean University of China.
- [7] Tang R, 2023, The Value Implication and Realization Path of Cultural Construction Enabling Rural Revitalization. *National Governance*, 2023(14): 30–35.
- [8] Zhao Y, 2025, Mechanism Innovation and High-Quality Development Path of County Characteristic Industrial Clusters Empowering Rural Revitalization. *Contemporary Rural Finance and Economics*, 2025(9): 27–31.
- [9] Wang C, Yao S, Chen C, 2005, An Empirical Study on the Hollowing Out of Rural Settlements in China. *Scientia Geographica Sinica*, 2005(3): 3257–3262.
- [10] Wu Q, 2025, From “Dormant Resources” to “Fluid Capital”, *Hefei Evening News*, August 28, 2025.
- [11] Li H, 2025, Investing 3 Billion to “Awaken” Rural Dormant Resources, *Yangcheng Evening News*, September 6, 2025.

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Research on the Development and Application of Intelligent Financial Profitability Analysis Robot Based on RPA

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Abstract: In the context of accelerating digital economy penetration, financial digital transformation has become a critical pathway for enterprises to enhance core competitiveness. Robotic process automation (RPA) technology, with its efficiency, precision, and cross-system collaboration capabilities, provides innovative solutions for financial process innovation. This paper develops an intelligent financial profitability analysis robot based on Laiye Technology's UiBot platform, focusing on core processes such as data collection, metric calculation, and report generation. It achieves full-process automation from multi-source data integration to visualized analysis reports. By integrating dual-dimensional metrics of accounting profits and cash flows, the system constructs dynamic analytical models adaptable to various industries, effectively addressing issues like inefficiency, high error rates, and delayed decision-making in traditional financial analysis. Practical results demonstrate that the robot achieves over 98% data collection accuracy, reduces business processing time to 30% of manual operations, significantly lowers corporate financial operational costs, and provides real-time, precise decision-making support for management. This solution holds significant practical value and promotion potential.

Keywords: RPA technology; Intelligent finance; Profitability analysis; Robot development; Financial digitization

Online publication: February 10, 2026

1. Introduction

1.1. Research background

As market competition intensifies, businesses are demanding greater timeliness and precision in financial analysis. Traditional financial profitability analysis relies on manual processes for data collection, organization, calculation, and report generation. This approach not only incurs substantial labor costs but also risks human error, resulting in delayed analysis outcomes that fail to meet dynamic decision-making needs. Statistics show that traditional finance departments spend approximately 60% of their working hours on repetitive data processing, with less than

30% of their efforts dedicated to value analysis and decision support.

Against this backdrop, robotic process automation (RPA) technology emerged as a game-changer. As an automated tool that mimics human operations, RPA can work 24/7 under predefined rules, efficiently handling cross-system data exchanges and repetitive tasks. It has already demonstrated significant advantages in fields like financial reimbursement and tax filing. Forrester predicts that the global RPA market will reach \$22.5 billion by 2025, with the financial sector contributing over 35% of the market share, making it the most mature vertical application area for RPA.

1.2. Research significance

Theoretically, this research bridges RPA technology with in-depth financial analysis, proposing an integrated framework that enriches the applied intelligent finance domain. Practically, the developed robot automates the full profitability analysis cycle. It liberates financial personnel from repetitive tasks, enables real-time risk monitoring, and provides a cost-effective, reusable digital transformation model for enterprises, especially SMEs.

1.3. Research content and technical approach

1.3.1. Research content

This paper focuses on the development and application of an intelligent financial profitability analysis robot, with four following key components:

- (1) Establishing a multi-source automated data collection system to efficiently extract data from corporate financial systems and platforms like Tonghuashun Finance;
- (2) Developing a dynamic profitability analysis model that integrates multi-dimensional metrics and optimizes industry-specific algorithms;
- (3) Creating visual report generation and anomaly alert modules to enhance the practicality of analytical results and decision support capabilities;
- (4) Verifying the robot's performance and application effectiveness through real-world scenario testing.

1.3.2. Technical approach

This study follows a technical roadmap of “requirement analysis-system design-development implementation-testing optimization” using steps as follows:

- (1) Identify the core requirements and business processes for corporate financial profitability analysis;
- (2) Design the functional architecture and technical solutions for the robot based on the UiBot platform;
- (3) Implement the module functionalities using Python programming and Excel advanced functions;
- (4) Optimize the robot's performance and stability through simulation testing and real-world application scenarios.

2. Literature review

In the digital economy context, RPA technology has become a crucial tool for driving financial digital transformation. Pang pointed out that RPA financial robots, through simulating manual operations, cross-system collaboration, and round-the-clock operation, have been widely applied in the financial sector. They are evolving from single efficiency tools into “intelligent partners” with smart analysis and decision-support capabilities, providing a theoretical foundation for building intelligent financial analysis systems^[1]. In research on financial

digital transformation in higher education, Chen believes that RPA financial robots can effectively address issues such as complex financial processes, high repetition rates, and elevated labor costs in universities, demonstrating significant advantages in fund management, tax management, and budget management. The study also emphasizes the need for system maintenance upgrades and the cultivation of interdisciplinary talent to ensure stable RPA application ^[2].

From the perspective of financial accounting, Shuang developed an RPA-based intelligent financial accounting model for universities. Research indicates that RPA technology can significantly improve accounting efficiency and data accuracy while reducing human error rates. However, its effectiveness still depends on optimizing business processes and improving management system coordination, offering practical references for expanding RPA into financial analysis ^[3]. In the healthcare industry, Zhang and Yin analyzed the application effectiveness of intelligent financial robots in scenarios such as invoice processing, voucher generation, risk alerts, and financial report analysis using public hospitals as examples. The study concludes that intelligent financial robots enhance financial management efficiency, strengthen compliance control and risk prevention capabilities, and play a significant role in upgrading financial management models ^[4]. In corporate financial practices, Liu highlighted that the application of financial robots in corporate financial activities can effectively enhance work efficiency and quality, serving as a crucial pathway to promote intelligent financial development and helping to free up financial personnel for analytical and managerial functions ^[5]. Wang, using state-owned enterprises as examples, analyzed the application effects of RPA intelligent financial robots under the background of digital and intelligent financial transformation. The study revealed that RPA projects not only reduced labor costs and error rates but also improved financial management efficiency and decision support capabilities ^[6].

In summary, existing research has validated the application value of RPA financial robots across multiple industries, yet systematic studies focusing on in-depth financial analysis scenarios such as profitability analysis remain relatively insufficient. Therefore, conducting research on the development and application of RPA-based intelligent financial profitability analysis robots holds significant practical implications.

3. Relevant theories and technical foundations

3.1. Principles of RPA technology

RPA is a technology that automates repetitive and standardized tasks by simulating human operations on computers through predefined rules. Its core advantage lies in non-invasive integration, enabling cross-platform and cross-system data interaction and process automation without modifying existing information systems. RPA technology primarily consists of three components: process designers, robotic actuators, and control centers. It supports various operations such as screen scraping, data entry, and rule evaluation, capable of processing structured data and fixed-format documents. The entire operation process is fully traceable, meeting the compliance requirements of financial work.

3.2. Indicator system for financial profitability analysis

Profitability analysis constitutes the cornerstone of corporate financial evaluation, assessing a company's profit-generating capacity through financial metrics. This study establishes a comprehensive framework integrating both accounting profit and cash flow dimensions. Accounting profit indicators, such as Return on Equity (ROE), Net Profit Margin, and Return on Assets (ROA), measure profitability scale and efficiency, while cash flow metrics

like Earnings Per Share (EPS) and Earnings Quality Ratio (EQR) demonstrate the authenticity and sustainability of profits. Cross-analyzing these multi-dimensional indicators enables a more holistic and objective assessment of a company's profitability.

3.3. The integration logic between RPA and financial analysis

The integration of RPA with financial profitability analysis demonstrates inherent compatibility. Financial profitability analysis involves processes such as data collection, metric calculation, and report generation, all of which feature well-defined rules and high repeatability, perfectly suited for RPA applications. Automating these processes through RPA effectively addresses traditional challenges like time-consuming data collection, high computational error rates, and delayed report generation. Moreover, RPA's cross-system collaboration capability breaks down information silos, enabling centralized integration of multi-source financial data to provide more comprehensive data support for profitability analysis.

4. Design and development of intelligent financial profitability analysis robot

4.1. Overall architecture design of the robot

Based on the concept of functional modularization, the robot adopts a three-tier architecture design consisting of: data acquisition layer, model computation layer, and result output layer as outlined:

- (1) Data collection layer: This layer extracts data from multiple sources including corporate financial systems, Tonghuashun Finance, and tax platforms, covering core financial statements such as balance sheets, income statements, and cash flow statements, along with relevant business data;
- (2) Modeling layer: Integrates dynamic profitability analysis models to enable automated calculation, cross-analysis, and industry benchmarking of multi-dimensional metrics;
- (3) Output layer: Generate visual analysis reports with dynamic charts, metric interpretations, and anomaly alerts. Supports report export and online viewing.

4.2. Development of core functional modules

4.2.1. Multi-source data automation collection module

The data collection script developed on the UiBot platform automates multi-source data acquisition through simulated login, screen scraping, and API calls. Customized solutions are designed for different data sources. For internal platforms like corporate financial systems, UI automation simulates manual operations to precisely capture target data whereas for external platforms such as Tonghuashun Finance, web crawlers retrieve publicly available financial data. For offline files in PDF or Excel formats, OCR technology combined with Excel advanced functions enables data extraction and standardization. A data validation mechanism ensures accuracy through field matching and logical checks, achieving a collection accuracy rate exceeding 98%.

4.2.2. Dynamic profitability analysis module

The system integrates accounting profit and cash flow metrics to build a dynamic analytical framework. For instance:

- (1) Python scripts automate metric calculations, with ROE decomposed using the DuPont analysis method and net profit margin benchmarked against industry averages;
- (2) An industry-specific weighting mechanism optimizes metric logic based on sector characteristics,

enhancing analytical adaptability;

- (3) Data cleaning techniques eliminate outliers and missing values, ensuring calculation error rates remain below 2%.

The model supports rapid adaptation across industries including manufacturing and retail, allowing users to customize metric weights and analytical dimensions as needed.

4.2.3. Visualization report and abnormal alert module

Using Excel visualization tools and Python data visualization libraries, we generated analytical reports featuring dynamic charts and textual interpretations. The reports include summary tables, trend charts, and industry benchmarking radar charts to visually present the company's profitability status. Additionally, we developed an anomaly alert module with preset thresholds such as profit margin fluctuations $\geq 10\%$ and ROE significantly below industry averages. When abnormal indicators are detected, the system automatically triggers notifications via email or system messages, enabling management to complete strategic adjustments within 48 hours.

4.2.4. Process automation control module

The system features a closed-loop control process with “trigger-execution-feedback” functionality, supporting both scheduled and manual triggering modes. Scheduled triggering allows users to set up daily, weekly, or monthly automatic analysis tasks, while manual triggering enables real-time activation of the system as needed. The control module continuously monitors process execution status, automatically initiating breakpoint resumption and error retry mechanisms to ensure stability during network outages or data loss. Additionally, it automatically logs operation details including data sources, processing times, and computational results, meeting compliance audit requirements (**Figure 1**).

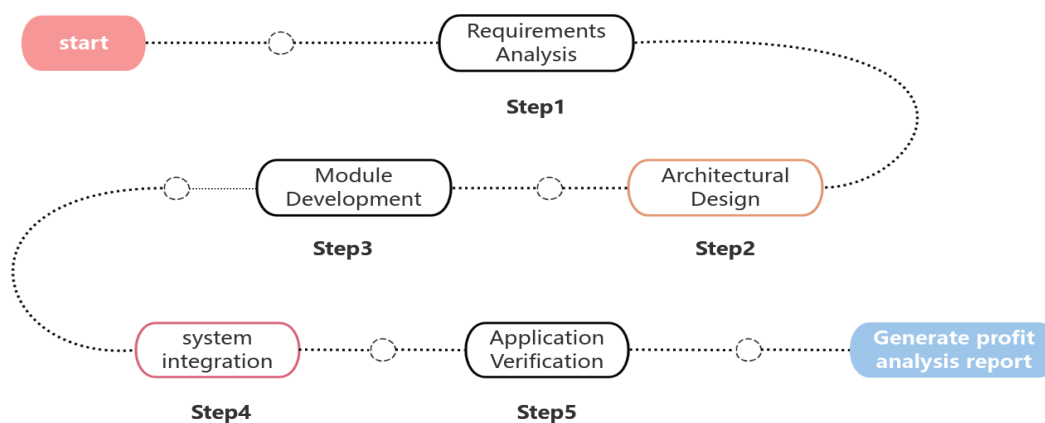


Figure 1. Flowchart of robotic technology for profitability analysis in intelligent finance.

4.3. Development tools and technology selection

The tools and selection are as follows:

- (1) Core development platform: Laiye Technology's UiBot, designed for workflow design and automated script development. It supports both visual programming and code editing modes, catering to developers with varying technical backgrounds;

- (2) Programming tools: Python is used for metric calculation, data cleaning, and anomaly detection, with Pandas for data processing and Matplotlib for visual chart generation;
- (3) Data processing tools: Excel advanced functions (e.g., VLOOKUP, INDEX-MATCH) for data formatting and auxiliary calculations;
- (4) Auxiliary tools: OCR technology for processing scanned documents, images, and other unstructured data to enhance data collection comprehensiveness.

5. Robot application testing and effectiveness evaluation

5.1. Test environment and scenario design

The testing environment is built on Windows 10 operating system, equipped with an Intel Core i5 processor and 8GB RAM, and compatible with enterprise-standard financial software (e.g., Kingdee, Yonyou) and office applications. Two representative companies from the manufacturing and retail sectors were selected to simulate the full financial profitability analysis process. Key metrics evaluated included data collection accuracy, indicator calculation error rates, business processing efficiency, and report generation quality.

5.2. Analysis of test results

The robot successfully automated multi-source data collection, covering all core financial data of two enterprises with an accuracy rate of 98.5%. Minor errors occurred only in a few non-standard format data, which could be corrected after manual review. The error rate of key indicators is controlled within 1.8%, meeting the precision requirements for financial analysis. Core metrics like ROE and net profit margin are calculated with absolute accuracy, achieving consistency with manual calculations. A single enterprise's full-process analysis now takes just 15 minutes, a 93.75% reduction from traditional manual operations (averaging 4 hours), significantly boosting analytical efficiency. The generated visual report is logically clear and data-rich, with dynamic charts intuitively showing trend changes. The anomaly alert module accurately identifies three potential risk points for the two enterprises, providing effective support for decision-making.

5.3. Evaluation of application effect

5.3.1. Efficiency improvement

Robots liberate financial staff from tedious tasks like data collection, calculations, and report generation, reducing the financial analysis cycle from days to hours and significantly boosting efficiency. Test data shows these systems can cut HR costs in finance departments by over 40%, allowing professionals to focus on more strategic financial planning and risk assessment.

5.3.2. Precision assurance

Through automated execution and multi-layer data verification, the system effectively reduces human operational errors, with the indicator calculation error rate controlled below 2% and data collection accuracy exceeding 98%. This significantly enhances the reliability of financial analysis results, providing management with precise data support for decision-making.

5.3.3. Strengthening decision support

The real-time monitoring and anomaly alert features empower enterprises to promptly identify profit trend shifts

and latent risks, reducing decision response time from days to 48 hours. This enables businesses to swiftly adjust strategies and enhance market adaptability.

5.3.4. High reusability

The robot has developed a standardized solution template, including a code repository, test cases, and operational documentation. This template can be quickly adapted to meet the industry-specific characteristics and personalized needs of different enterprises, thereby lowering the threshold and costs for SMEs to achieve financial digital transformation.

6. Conclusion and outlook

6.1. Research findings

This study develops an intelligent financial profitability analysis robot based on RPA technology. Through functional modules including automated multi-source data collection, dynamic indicator model computation, visualized report generation, and anomaly alerts, the system achieves full-process automation of financial profitability analysis.

The test results demonstrate four key advantages as follows:

- (1) Significantly improves analytical efficiency, reducing business processing time to under 30% of manual operations;
- (2) Ensures analytical accuracy with over 98% data collection precision and $\leq 2\%$ indicator calculation error rate;
- (3) Enhances decision support by improving corporate response speed through real-time alert mechanisms;
- (4) Offers strong reusability and industry adaptability, providing standardized solutions for diverse enterprises.

The application of this robot effectively transforms financial analysis from “post-event statistics” to “pre-event warnings and in-process controls”, offering a practical pathway for corporate financial digital transformation.

6.2. Existing limitations

While robots have demonstrated promising application outcomes, they still face three key limitations:

- (1) Their processing capacity for unstructured data remains constrained, with recognition accuracy needing improvement for handwritten invoices and irregular-format reports;
- (2) Their adaptive capabilities are inadequate, requiring manual rule reconfiguration whenever corporate financial processes or data formats change;
- (3) Industry-specific adaptation depth is insufficient, failing to adequately support customized metrics and analytical logic in specialized sectors.

6.3. Future outlook

Future enhancements can be achieved through the following approaches:

- (1) Integrating generative AI with OCR technology to boost unstructured data processing capabilities and expand data collection scope;
- (2) Implementing machine learning algorithms to enhance robots’ autonomous learning and adaptive capabilities, enabling automated optimization of process rules;
- (3) Deepening industry-specific customization by refining metric systems and analytical models tailored to

sectoral characteristics, thereby improving industry adaptability;

- (4) Expanding application scenarios by extending robotic functions to budget management, cost control, and related domains, establishing a comprehensive intelligent financial analysis framework.

With the continuous advancement of digital technologies, RPA applications in finance will deepen further, driving transformative changes in corporate financial management.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Pang X, 2025, RPA Financial Robot: The Evolution Path from an Efficiency Tool to an Intelligent Partner. *Business Culture*, 2025(21): 89–91.
- [2] Chen T, 2025, Application of RPA Financial Robot in the Digital Transformation of University Finance. *Taxation*, 19(10): 79–81.
- [3] Shuang A, 2025, Practical Exploration of Intelligent Financial Accounting Model in Universities Based on Robotic Process Automation. *China Agricultural Accounting*, 35(14): 72–74.
- [4] Zhang L, Yin X, 2025, Application of Intelligent Financial Robots in the Digital and Intelligent Transformation of Hospital Finance. *Friends of Accounting*, 2025(8): 130–135.
- [5] Liu A, 2023, Application of Financial Robots in Corporate Financial Activities, *Accounting Information*, May 15, 2023.
- [6] Wang S, 2025, Application Research of Intelligent Financial Robots in Financial Digitalization. *Financial News*, 2025(15): 184–186.

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Ecological Niche Construction Strategies for Cross-Border Integration of Traditional Industries Under the Perspective of Platform Economy

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Abstract: This paper examines the critical pathways for traditional industries to achieve cross-border integration in the context of the digital economy, grounded in the profound reshaping of traditional industrial ecosystems by platform economies. The study first analyzes the survival crises and transformation opportunities faced by traditional industries under platform economies, then introduces niche theory to establish a three-dimensional analytical framework of “platform-industry-user.” Through empirical case analysis, the paper identifies core issues in cross-border integration, including niche gaps, resource misallocation, and competitive barriers. It proposes platform-enabled niche-building strategies, encompassing technological coupling, organizational restructuring, and value co-creation, aiming to provide theoretical support and practical guidance for traditional industries in seeking new spaces for survival and development amid the platform economy wave.

Keywords: Platform economy; Traditional industry; Cross-industry integration

Online publication: February 10, 2026

1. Introduction

In the era of digital economy, the explosive growth of global digital economy deeply penetrates the real economy, triggering deep industrial transformation. Traditional industries are facing the survival dilemma of being squeezed by emerging platform enterprises due to their single structure and weak growth. Cross-border integration has become an important strategic choice for them to break through industry boundaries, acquire new users and markets. Although existing research has achieved certain results in platform economy business models, digital transformation of traditional industries, and application of niche theory, there is still a lack of specific application of niche theory in cross-border integration of traditional industries under platform economy. This article focuses on the logical starting point, core mechanism, and implementation path of ecological niche construction ^[1]. Using literature research, case analysis, and comparative analysis methods, a model for ecological niche

construction based on platform economy characteristics is proposed, emphasizing the role of data elements while acknowledging that some empirical analyses may have limitations due to difficulties in obtaining data.

2. Theoretical basis of ecological niche for cross-border integration of traditional industries under the platform economy

2.1. Ecological metaphor of platform economy

The ecological niche theory foundation of cross-border integration of traditional industries under the platform economy provides solid theoretical support for in-depth exploration of the cross-border integration mechanism of traditional industries in the wave of platform economy ^[2]. The platform economy has a unique ecological metaphor, and its core lies in the construction of platforms as super ecosystems. In the era of digital economy, platforms, with their powerful digital connectivity capabilities, tightly connect a massive number of entities on both sides of supply and demand, breaking the traditional single and closed production and operation mode of enterprises. Unlike a single enterprise that only focuses on internal resource integration and business expansion, the ecosystem formed by the platform is more complex and diverse, covering many different types of participants, including suppliers, consumers, developers, service providers, etc. These participants achieve information sharing, resource complementarity, and collaborative innovation through the platform, jointly promoting the continuous evolution and development of the ecosystem. For example, e-commerce platforms not only connect various merchants and consumers, but also attract logistics companies, financial institutions, advertisers and many other related entities to settle in, forming a huge and complex commercial ecosystem. In this ecosystem, various entities are interdependent and influence each other, jointly creating and sharing value, thus achieving the maximization of the overall benefits of the ecosystem.

2.2. Ecological niche characteristics of cross-border integration of traditional industries

The multilateral market mechanism in the platform economy is the key to maintaining the dynamic balance of the super ecosystem. A multilateral market refers to a market structure that connects two or more interdependent customer groups through a platform and facilitates transactions or interactions between them. In the platform economy, multilateral market mechanisms play a crucial role, enabling platforms to achieve stable ecosystem operation through cross-subsidy strategies ^[3]. Cross-subsidy refers to a business model in which a platform provides low-priced or free services to a certain customer group in order to attract that group to join the platform, and then compensates for costs and profits by charging fees to other customer groups. For example, search engine platforms provide free search services to ordinary users, attracting a large number of users to use their platforms, which in turn attracts advertisers to place ads on the platform. The platform earns profits by charging advertising fees to advertisers. This cross subsidy mechanism not only helps the platform rapidly expand its user base and enhance market influence, but also promotes interaction and communication between different customer groups, enhancing the vitality and stability of the ecosystem. At the same time, multilateral market mechanisms can flexibly adjust pricing strategies and service models based on the characteristics and value contributions of different customer groups, thereby achieving optimized allocation and efficient utilization of ecosystem resources.

2.3. Analysis of the motivation for ecological niche construction

The cross-border integration of traditional industries presents unique ecological niche characteristics under the platform economy, which is both a result of adapting to the environment and a key to sustainable development.

The expansion of ecological niche width is an important manifestation. Under the traditional economic model, traditional industries are limited to their own industries, with narrow business and limited space. In the era of platform economy, cross-border integration has enabled it to break through industry boundaries and enter new fields. Integrating manufacturing with emerging technologies, achieving intelligent upgrading, transforming towards service-oriented manufacturing, providing value-added services, and expanding the breadth of the ecosystem. Ecological niche overlap and competition are inevitable. The cross-border integration of traditional industries and Internet platform enterprises is deepening, and the competition is fierce. Internet platform enterprises have advantages in technology, data and users ^[4]. Traditional industries need to give play to physical advantages such as brand, channel and supply chain to form differentiated competition. Filling the ecological niche gap brings new opportunities. Hence, the development of platform economy leaves gaps in services and markets, and traditional industries can use their physical advantages and industry experience to fill them. In the field of fresh e-commerce, traditional agricultural and sideline product wholesalers cooperate with e-commerce platforms to provide fresh products with the advantages of supply chain and cold chain logistics, achieving mutual benefit and win-win results. The driving forces behind ecological niche construction include passive adaptation under environmental pressure and seeking differentiated competitive advantages. Under pressure from market saturation and regulatory changes, traditional industries need to integrate and adjust their business models across borders; When homogeneous competition is fierce, it is also necessary to seek unique value, enhance core competitiveness, and achieve sustainable development.

3. Ecological niche status and problems of cross-border integration of traditional industries

3.1. Typical case analysis of cross-border integration of traditional industries

In the practice of cross-border integration of traditional industries, enterprises have diverse integration modes and effects due to different strategies and resources. Some have successfully transitioned to ecological niches, while others have suffered setbacks in transformation. In successful cases, Haier Kaos is a benchmark for the transformation of traditional manufacturing into an ecological platform. Haier relies on the manufacturing industry background, takes the industrial Internet platform as the carrier, breaks the closed production mode, and brings users into the whole process. By accurately capturing demand through mass customization, efficient integration between production and consumption can be achieved. It also takes Caos as the core, attracts many subjects to join, builds the industrial Internet ecology of the whole industrial chain, realizes resource sharing and complementary advantages, successfully transforms into an ecological platform operator, and significantly improves the niche.

The root interconnection platform it built not only provides intelligent services for its own equipment, but also opens one-stop solutions to small and medium-sized enterprises in the industrial chain to help its digital transformation. Sany Heavy Industry also takes this opportunity to enhance its stickiness with upstream and downstream enterprises and build an industrial Internet ecosystem. However, traditional retail giants such as Suning and Gome have experienced the digital pains of losing their ecological niche when facing the impact of e-commerce. In the early stages of the rise of e-commerce, although they laid out online, their strategic positioning was unclear, the integration of online and offline was poor, resources were scattered, efficiency was low, and there was no innovative value creation model. The user stickiness was insufficient, and ultimately the market share was eroded and the ecological niche was squeezed.

3.2. Main problems in current ecological niche construction

There are many problems in the ecological niche construction of traditional industries, which restrict their sustainable development in the era of platform economy. The primary issue is the vague positioning of ecological niche and the lack of core competitiveness^[5]. Many traditional enterprises blindly follow the trend of cross-border integration, without combining their own advantages with market demand to find a unique positioning. Seeing the success of the Internet platform, he was eager to build his own platform. However, due to the lack of clear strategic planning and differentiation advantages, the platform was seriously homogenized, which made it difficult to attract users and partners, and could not stand on the market. The weak ability to integrate resources and low level of platformization are also major bottlenecks. Traditional enterprise organizational structures are rigid, with information barriers between departments, making it difficult to integrate dispersed data and computing resources. In addition, it lags behind in technology research and development, talent introduction, and lacks the technical and talent support to build an efficient and stable platform. During the transformation, it faced technological bottlenecks and resource constraints, and therefore cannot achieve large-scale operation and value maximization. The lagging value creation model and insufficient user stickiness are equally prominent. Traditional enterprises often focus on product sales and lack a data-driven value-added service model, which makes it difficult to meet personalized user needs and leads to user churn, posing a threat to the stability of their ecosystem.

3.3. Root causes of problems

The problems in constructing the ecological niche of traditional industries are the result of a combination of strategic cognitive biases and organizational genetic defects. In terms of strategic cognitive bias, some enterprises have insufficient understanding of the laws of platform economy and have misconceptions of “technology only” or “traffic only”. The former ignores key elements such as user needs, while the latter blindly expands the number of users but neglects quality and stickiness, leading to difficulties in sustainable operation of the platform. In terms of organizational genetic defects, traditional hierarchical management is not suitable for the flat and decentralized requirements of the platform economy. The decision-making process is cumbersome, information transmission is inefficient, there are interest games and information barriers between departments, and resources are difficult to effectively integrate and coordinate. The platform economy requires enterprises to have the ability to make quick decisions, and the conflict between the two hinders the transformation of traditional industries to platformization.

4. Ecological niche construction strategy for cross-border integration of traditional industries

4.1. Ecological niche anchoring strategy based on technology coupling

In the platform economy, technology is the key to cross-border integration of traditional industries and anchoring ecological niches. Building a differentiated technological moat is an important measure, and emerging technologies such as the Internet of Things and big data can support the reconstruction of traditional industrial production processes. In the manufacturing industry, installing sensors can monitor the real-time operation status of equipment. By utilizing big data analysis to mine massive amounts of data, users' needs and market trends can be deeply understood, providing a basis for decision-making, establishing technological dominance, and building an insurmountable technological moat. Building open API interfaces to achieve interconnectivity is also crucial. Traditional industry platforms cannot be isolated in order to develop and grow, but should be integrated into a larger ecosystem. For instance, building open API interfaces can lower the cooperation threshold with

third-party developers and partners, and attract external forces to participate in platform construction. Moreover, open interfaces on e-commerce platforms to attract merchants, logistics, finance, and other stakeholders, enrich application scenarios, meet diverse user needs, enhance platform vitality and competitiveness, expand influence and user base, and consolidate the ecological niche.

4.2. Ecological niche adaptation strategy based on organizational restructuring

The cross-border integration of traditional industries requires not only technological innovation, but also the restructuring of organizational structure and management models to adapt to the platform economy environment. Promoting organizational flexibility and agility transformation is the core. The traditional hierarchical system has problems such as departmental barriers and cumbersome decision-making, making it difficult to quickly respond to market and user demands. Therefore, it is necessary to break down departmental walls and establish a project-based team, which is formed across departments with the project as the center. Members can work together to leverage their strengths and flexibly adjust the workflow and make quick decisions during execution, improving efficiency and response speed. For example, software development projects can respond to changes in customer needs in a timely manner. Cultivating platform leadership is also crucial. In the era of platform economy, traditional industries need to cultivate compound management talents and reshape corporate culture. Managers should have an open-minded mindset, guide their teams to participate in ecological construction, possess cross departmental coordination and resource integration capabilities, and create a cultural atmosphere that encourages innovation and tolerates failure. Employees should actively participate in innovative practices to build a high-quality team and provide guarantees for effective adaptation to the ecological niche.

4.3. Ecological niche enhancement strategy based on value co-creation

Value co-creation is the core feature of platform economy, which can enhance the ecological niche of traditional industries and gain greater development space. Transitioning from selling products to selling services is an important approach. Traditional industries are mostly limited to product sales, while under the platform economy, user demands are diverse and personalized, leading to an increase in service demand. Traditional industries should extend their industrial chains and provide full lifecycle solutions and value-added services. In addition to selling cars, automobile manufacturing companies also provide services such as finance, insurance, maintenance, and second-hand car trading, providing users with a one-stop experience. This can increase user stickiness, improve satisfaction and loyalty, explore new profit growth points, and enhance one's own value in the ecosystem. Stimulating the vitality of ecological partners and building symbiotic relationships are key strategies. The platform ecosystem is composed of numerous ecological partners, and its vitality affects the health of the system. Traditional industries need to establish reasonable incentive mechanisms to guide upstream and downstream partners to maintain ecological order. E-commerce platforms establish fair distribution rules, provide technical support training, and incentivize merchants to improve product quality and services. At the same time, we will deepen cooperation with ecological partners to jointly develop new products and services, achieve resource sharing and complementary advantages. Through these, traditional industries and partners form a close community of shared interests, promote ecosystem development, and achieve sustained improvement of ecological niche.

5. Conclusion

This article focuses on the construction of the ecological niche of traditional industries under the platform

economy, and draws the core viewpoint that traditional industries need to work together from the three dimensions of technology, organization, and value. Technology coupling anchors the ecological niche, organizational restructuring adapts to ecological changes, and value co-creation enhances the ecological niche. The government should strengthen digital infrastructure, improve data security and privacy protection regulations, and create a favorable external environment. However, this study has limitations such as limited sample selection and insufficient dynamic evolution simulation. Future research can combine complex systems theory to deepen quantitative analysis of the dynamic evolution of ecological niches, providing more forward-looking and guiding theoretical support and practical guidance for the cross-border integration of traditional industries.

Disclosure statement

The author declares no conflict of interest.

References

- [1] An Y, 2014, Platform Economy. *Macroeconomic Management*, 2014(7): 86.
- [2] Wen H, Wang C, 2024, Multidimensional Review of the Development of Platform Economy in China. *Economic and Management Review*, 40(5): 32–41.
- [3] Wu Y, Liu L, 2024, Preliminary Study on the Economic Development of Public Resource Trading Platforms. *China Tendering*, 2024(7): 152–154.
- [4] Wu Q, Wu Q, 2020, Research on the Mechanism of “Internet Plus” Driving Cross-Border Integration of Traditional Industries. *Xuehai*, 2020(4): 163–169.
- [5] Liu J, 2018, Cross-Border Revitalization of Traditional Handicrafts from the Perspective of Cultural and Creative Industries. *Journal of Zhejiang Vocational College of Arts*, 16(4): 112–117.

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Innovation of Financial Supervision Model for Public Institutions in the Context of Informatization

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Abstract: Driven by the wave of digitalization, information technology has been deeply integrated into various fields of social and economic development, and the financial work environment of public institutions has undergone profound changes accordingly. The traditional financial supervision model is difficult to adapt to the regulatory needs of the new era. Taking the informatization background as the starting point, this paper analyzes the prominent problems existing in the current financial supervision model of public institutions, explores the innovative paths of the financial supervision model combined with the application advantages of information technology, aiming to provide theoretical reference and practical guidance for improving the efficiency of financial supervision of public institutions, strengthening the standardization of fund use, and ensuring the safety of public resources.

Keywords: Informatization; Public institutions; Financial supervision model

Online publication: February 10, 2026

1. Introduction

With the continuous advancement of the modernization of the national governance system and governance capacity, public institutions, as the core carriers of public service provision, the standardization and safety of their financial work have become increasingly important. Financial supervision, as a key means to regulate financial behaviors and prevent fund risks, occupies a core position in the management of public institutions. At present, information technology represented by big data, cloud computing, and artificial intelligence is developing rapidly, providing new opportunities for the reform of the financial supervision model of public institutions. However, problems such as lagging supervision, low efficiency, and insufficient collaboration in the traditional financial supervision model have become more prominent in the context of informatization, restricting the effective play of supervision functions^[1]. Therefore, based on the development trend of informatization, innovating the financial supervision model of public institutions, solving the dilemmas of traditional supervision, and improving the accuracy and effectiveness of supervision have become important issues to be solved urgently in the field of

financial management of public institutions. This paper will conduct in-depth discussions around this core issue.

2. Existing problems of the financial supervision model for public institutions

2.1. Lagging supervision concepts and cognitive biases

At present, the cognition of financial supervision in most public institutions still remains at the traditional level, and the supervision concepts have not kept up with the pace of informatization development, showing obvious lag and cognitive biases. Some institutions simply equate financial supervision with accounting review, believing that supervision work only needs to complete basic tasks such as voucher verification and account checking, ignoring the control value of supervision over the entire process and chain of fund use, and failing to fully recognize the extended functions of financial supervision in risk early warning and decision support under the background of informatization^[2]. At the same time, the management of some institutions does not attach sufficient importance to financial supervision, focusing too much on business development, believing that financial supervision will restrict the efficiency of business advancement, and having resistance to supervision work, resulting in the lack of necessary system support and resource guarantee for financial supervision work. In addition, supervisors themselves also have the problem of rigid concepts, being accustomed to relying on the traditional way of manual inspection, having low willingness to apply information-based supervision tools, and being difficult to adapt to the new requirements of supervision work under the background of informatization, which further exacerbates the disconnection between supervision concepts and practical development.

2.2. Imperfect supervision mechanisms and insufficient collaboration

There are many loopholes in the financial supervision mechanisms of public institutions, and the lack of collaborative linkage between internal departments and external regulatory subjects seriously affects supervision efficiency. In terms of internal supervision mechanisms, most institutions have not established a full-process and full-element supervision system. Supervision work is mostly concentrated on post-event inspection, lacking effective mechanisms for pre-judgment of fund use and in-process control, leading to supervision lagging behind business development and making it difficult to prevent risks in advance. At the same time, the division of internal supervision responsibilities is unclear, and there are overlapping or blank areas of supervision between financial departments and business departments. When problems arise, it is easy to shirk responsibility from each other, and it is impossible to form a supervision joint force. In terms of external collaborative supervision, there is a lack of effective information sharing mechanisms and collaborative linkage mechanisms between external regulatory subjects such as finance, audit, and discipline inspection and supervision. Each subject has inconsistent regulatory standards and non-interoperable regulatory data, leading to problems such as duplicate inspections and regulatory blind spots in regulatory work^[3]. In addition, the information transmission between public institutions and external regulatory subjects is not timely and smooth, and the problems fed back by external supervision are difficult to be rectified quickly, which further weakens the authority and effectiveness of supervision work.

2.3. Traditional supervision methods and insufficient technology application

Traditional financial supervision methods are mainly based on manual inspection, which is inefficient and inaccurate, and the application of information technology is seriously lagging behind, making it difficult to meet the needs of financial supervision work in the new era. In daily supervision work, supervisors need to spend a lot of time and energy sorting out and verifying paper vouchers, statements and other data, which is not only

inefficient but also prone to supervision loopholes due to human errors, making it impossible to timely detect hidden financial risks. At the same time, most public institutions have not built a complete information-based supervision platform. The existing financial systems mainly focus on accounting functions, lacking core modules such as supervision analysis and risk early warning, and cannot realize real-time monitoring and intelligent analysis of fund flow and financial data^[4]. Even if some institutions have introduced simple information-based tools, they have problems such as single function and poor data compatibility, which cannot realize the effective connection between financial data and business data, and it is difficult to accurately identify and control financial risks in the process of business development. In addition, supervisors have insufficient ability to apply information technology, lacking the mastery of technologies such as big data analysis and artificial intelligence, and cannot give full play to the advantages of information technology in supervision work, which further limits the upgrading and optimization of supervision methods.

3. Innovative paths of financial supervision model for public institutions in the context of informatization

3.1. Update supervision concepts and reshape supervision cognition

Based on the development trend of informatization, updating supervision concepts and reshaping supervision cognition is the premise of innovating the financial supervision model of public institutions. For instance:

- (1) Strengthen the management's attention to financial supervision. Through special training, policy promotion and other methods, guide the management to fully recognize the important significance of financial supervision under the background of informatization for standardizing financial management, preventing fund risks, and improving public service efficiency, abandon the wrong cognition of "valuing business over supervision", incorporate financial supervision work into the overall development plan of the institution, and provide system support and resource guarantee for the innovation of the supervision model;
- (2) Promote supervisors to establish a full-process supervision concept, break the limitations of traditional post-event supervision, strengthen the cognitive understanding of the full-chain supervision of fund use before, during and after the event, fully recognize the advantages of information technology in risk early warning and real-time monitoring, take the initiative to change the traditional thinking of relying on manual inspection, and enhance the willingness to apply information-based supervision tools^[5];
- (3) Establish a collaborative supervision concept, guide all departments to fully recognize that financial supervision is not the sole responsibility of the financial department, but a systematic work that requires the collaborative cooperation of all departments, strengthen the initiative and consciousness of all departments to participate in supervision, and lay an ideological foundation for building a collaborative and linked supervision system.

To further deepen the update of supervision concepts, public institutions can build an information-based supervision publicity platform, regularly push information-based supervision related knowledge and typical cases through internal office systems, official accounts and other channels, and create a good atmosphere of "everyone attaches importance to supervision and everyone participates in supervision"^[6]. At the same time, incorporate the effect of supervision concept update into the department performance appraisal system, commend and reward departments and individuals that actively practice the information-based supervision concept and cooperate with

supervision work, and interview and remind those with lagging concepts and resistance to supervision work. Through positive incentives and negative constraints, promote the supervision concept to be deeply rooted in the hearts of the people and provide ideological guarantee for the innovation of the supervision model.

3.2. Improve supervision mechanisms and strengthen collaborative linkage

Supported by information technology, improve supervision mechanisms, strengthen internal collaboration and external linkage, and build a full-process and all-round supervision system. In terms of improving internal supervision mechanisms, relying on the information-based platform, establish a full-process supervision mechanism of pre-judgment, in-process control and post-event inspection^[7]. Before the event, use big data analysis technology to predict the feasibility and rationality of fund use projects, accurately identify potential risk points, and formulate targeted prevention and control measures. During the event, use the information-based supervision platform to realize real-time monitoring of fund flow and financial data, and timely warn and intervene in abnormal situations such as exceeding the budget and irregular reimbursement. After the event, conduct a comprehensive inspection of the effect of fund use through the financial supervision system, forming a closed-loop supervision process of “pre-judgment-control- inspection-rectification”. At the same time, clarify the supervision responsibilities of financial departments and business departments, build an internal supervision collaboration module through the information-based platform, realize real-time sharing of supervision information and efficient flow of supervision tasks among all departments, avoid supervision overlap and gaps, and form an internal supervision joint force^[8].

In terms of the construction of external collaborative supervision mechanisms, promote the establishment of an information-based collaborative supervision platform between external regulatory subjects such as finance, audit, discipline inspection and supervision and public institutions, realizing unified regulatory standards and interconnection and sharing of data. Through platform docking, public institutions can timely submit financial data and business data to external regulatory subjects, and external regulatory subjects can obtain relevant information of public institutions in real time through the platform to carry out precise supervision and reduce duplicate inspections^[9]. At the same time, establish an external supervision information feedback mechanism. External regulatory subjects can timely feedback the problems found in supervision through the platform, and public institutions can track the rectification progress on the platform to ensure that the problems are rectified in place, forming a positive interaction between external supervision and internal rectification. In addition, explore the establishment of an inter-departmental joint supervision mechanism. For major fund use projects, finance, audit and other departments and public institutions jointly carry out information-based supervision to realize the integration of regulatory resources and improve the accuracy and authority of supervision.

3.3. Upgrade supervision methods and build an information-based supervision platform

Relying on information technologies such as big data, cloud computing and artificial intelligence, upgrading supervision methods and building a fully functional information-based supervision platform is the core support for innovating the financial supervision model. For instance:

- (1) Build an integrated information supervision platform, integrate data resources of existing financial systems, business systems, asset management systems, etc., realize the deep integration of financial data with business data and asset data, break data barriers, and provide data support for full-chain supervision. The platform should have core functions such as data collection, intelligent analysis, risk early warning,

supervision inspection and rectification tracking, and be able to realize real-time monitoring and intelligent analysis of the entire process of fund use^[10]. For example, use artificial intelligence technology to intelligently review reimbursement vouchers and automatically identify problems such as false vouchers and irregular reimbursement; use big data analysis technology to analyze fund flow trends and budget execution to accurately predict potential risks;

- (2) Promote the application of advanced information-based supervision tools to improve the intelligence level of supervision work. Introduce financial supervision software, data mining tools, etc., to realize the rapid processing and in-depth analysis of massive financial data and business data, replace the traditional manual inspection method, and improve supervision efficiency and accuracy^[11]. At the same time, explore the application of blockchain technology to encrypt and store financial data to ensure the authenticity, completeness and immutability of data, providing a reliable data basis for supervision work;
- (3) Build a mobile supervision platform to support supervisors to view financial data in real time, receive risk early warning information and carry out on-site inspections through mobile terminals, breaking the limitations of time and space and improving the flexibility and timeliness of supervision work.

In the process of building the information-based supervision platform, attention should be paid to data security guarantee, a sound data security management system should be established, data access rights should be clarified, and full-process security control over data collection, transmission, storage and use should be strengthened to prevent risks such as data leakage and tampering^[12]. At the same time, attention should be paid to the compatibility and scalability of the platform to ensure that the platform can adapt to the changes in the business development and supervision work of public institutions and realize continuous optimization and upgrading.

3.4. Strengthen team building and improve professional quality

Building a compound supervision team with solid financial professional knowledge and mastering advanced information technology is the talent guarantee for the innovation of the financial supervision model under the background of informatization as outlined:

- (1) Optimize the professional structure of the supervision team: Through open recruitment, internal selection and other methods, introduce compound talents with knowledge in multiple fields such as finance, informatization and risk management to enrich the supervision team. At the same time, strengthen the training of internal personnel and encourage existing supervisors to take the initiative to learn information-based knowledge and improve their technical application capabilities^[13];
- (2) Establish a systematic training system, formulate targeted training plans, and regularly organize supervisors to carry out training on information technology application, new supervision models, laws and regulations, etc.: The training method can adopt a combination of online and offline modes. For online mode, carry out regular learning through online courses and live lectures. For offline mode, organize practical exercises, case studies, exchange forums and other activities to improve the training effect. For example, invite information technology experts to carry out special training on big data analysis and artificial intelligence application, and organize supervisors to exchange and learn from units with remarkable informatization construction results to learn advanced experience^[14];
- (3) Establish and improve an incentive mechanism to stimulate the learning enthusiasm and innovation awareness of supervisors; Incorporate information technology application capabilities and supervision work results into the performance appraisal system, and give commendations, rewards and promotion

opportunities to outstanding performers to fully mobilize their work enthusiasm; Establish a fault-tolerance and error-correction mechanism to encourage supervisors to boldly explore new models and methods of information-based supervision, and create a working atmosphere of courage to innovate and break through ^[15];

- (4) Strengthen cooperation with universities and scientific research institutions, carry out industry-university-research collaborative education, provide continuous knowledge update and skill improvement support for the supervision team, and ensure that the professional quality of the supervision team can always meet the development needs of financial supervision work under the background of informatization.

4. Conclusion

The rapid development of information technology has provided new opportunities for the innovation of the financial supervision model of public institutions, and also put forward higher requirements for supervision work. The current problems such as lagging concepts, imperfect mechanisms, traditional methods and insufficient team quality in the financial supervision model of public institutions restrict the effective play of supervision functions. Based on the development trend of informatization, the innovative paths such as updating supervision concepts, improving supervision mechanisms, upgrading supervision methods and strengthening team building can effectively solve the dilemmas of traditional supervision and build a precise, efficient, collaborative and linked new financial supervision model. In the future, public institutions should continue to deepen the application of informatization in the field of financial supervision, continuously optimize and innovate the supervision model, improve supervision efficiency, and effectively give play to the important role of financial supervision in standardizing financial management, preventing fund risks, ensuring the safety of public resources and improving the quality of public services, so as to contribute to promoting the modernization of the national governance system and governance capacity.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zhang H, Zhu Y, 2024, Research on the Informatization Construction of Internal Control in Public Institutions from the Perspective of Financial Supervision. *China Management Informationization*, 28(20): 106–108.
- [2] Hu X, Hao J, Li J, 2024, Research on the Path of Promoting the Informatization Construction of Financial Supervision in Scientific Research Institutions. *Fortune Today*, 2024(18): 193–195.
- [3] Ye P, 2024, Promote the Informatization Construction of Financial Supervision and Realize the Intelligent Transformation of Administrative Institutions. *Contemporary Enterprise World*, 2024(9): 74–76.
- [4] Li Y, 2024, Research on the Informatization of Financial Supervision in Scientific Research Institutions. *Management of Agricultural Scientific Research Economy*, 2024(2): 5–8.
- [5] Mei J, 2024, Research on the Informatization and Internal Control Construction of Public Institutions from the Perspective of Financial Supervision. *Caixun*, 2024(12): 170–172.
- [6] Liu Q, Cui Q, 2024, Research on the Optimization Path of Financial Supervision Work in Public Institutions: From

- the Perspective of Accounting and Asset Management Practice. *Chinese Agricultural Accounting*, 35(11): 63–65.
- [7] Yu X, 2024, Analysis of the Path for Public Institutions to Strengthen Financial Supervision Work. *Vitality*, 43(10): 103–105.
- [8] Li L, 2024, Research on the Application of Accounting Informatization Construction in the Financial Supervision of Public Institutions. *Caixun*, 2024(10): 176–178.
- [9] Li G, 2024, Research on the Path of Strengthening Financial Supervision in Grassroots Public Institutions. *Chinese Agricultural Accounting*, 35(9): 75–77.
- [10] Li H, Shi K, 2024, Research on the Path of Financial Supervision in Public Institutions Based on High-Quality Development. *Money China*, 2024(9): 81–83.
- [11] She Y, 2024, Research on the Integration of Informatization and Internal Control Construction in Administrative Institutions from the Perspective of Financial Supervision. *Money China*, 2024(25): 81–83.
- [12] Zhang W, 2024, Challenges and Countermeasures Faced by the Internal Control of Administrative Institutions Under the Informatization of Financial Supervision. *China Venture Capital*, 2024(24): 92–94.
- [13] Wang Z, 2024, Research on the Strengthening Path of Financial Supervision in Administrative Institutions Under the Background of Informatization. *Business News*, 2024(13): 57–60.
- [14] Chen L, 2024, Research on the Integration of Informatization and Internal Control Construction in Administrative Institutions from the Perspective of Financial Supervision. *Money China*, 2024(13): 108–110.
- [15] Jiang J, 2024, Exploration on the Informatization Construction of Internal Control in Administrative Institutions Under the Financial Supervision System. *Finance and Accounting*, 2024(4): 76–77.

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Research on TikTok's Negotiation Strategies to Respond to the U.S. Ban and Its Experience Enlightenment

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Abstract: By conducting an in-depth analysis of TikTok's negotiation strategies under the pressure of the U.S. ban, this paper explores how ByteDance successfully broke through the U.S. political siege through various strategies such as multi-party negotiations, legal challenges, flexible plan design, public opinion control, and international cooperation. Through the research on this case, the key experiences and strategic enlightenment for business negotiations in complex international environments are summarized, aiming to provide reference for other enterprises when facing similar challenges.

Keywords: TikTok; Negotiation strategies; U.S. ban

Online publication: February 10, 2026

1. Introduction

Since the COVID-19 pandemic, protectionism has been on the rise, voices against globalization and unilateralism have grown stronger, and global trade frictions have occurred frequently. In recent years, multinational enterprises in the process of globalization have faced increasingly complex challenges when confronting regulation and political pressure from different countries. As a born-global enterprise that takes globalization strategy as its core value, TikTok is more vulnerable to the compound impact of multiple external continuous suppressions, including conventional continuous suppressions such as commercial competition, cultural conflicts, and legal challenges, as well as unconventional continuous suppressions such as political oppression. When facing the ban pressure from the U.S. government, how to use various negotiation strategies to successfully break through the strong political siege has become an important case for enterprises to respond to cross-border political risks^[1].

2. Overview of TikTok and the U.S. ban incident

As a giant Chinese internet company, ByteDance not only holds a leading position in the domestic Chinese market but also continuously expands its overseas business as a global enterprise. As a short video social platform under

ByteDance, TikTok is one of the most popular short video social platforms in the world, with a large number of users in the United States. At the end of 2020, TikTok's monthly active users in the United States were about 100 million, surpassing other competitors such as Instagram Reels and Snapchat, and becoming the most popular social platform among young people in the United States ^[2]. With the continuous expansion of its market share, TikTok has encountered continuous suppression from the United States. In 2020, former U.S. President Trump signed an executive order requiring TikTok to sell its U.S. business, otherwise, it would be banned in the United States. This move triggered complex negotiations between TikTok and multiple potential acquirers, and also pushed TikTok to the forefront of international political and commercial games ^[3].

3. Analysis of TikTok's key negotiation strategies

3.1. Multi-party negotiation and game strategy

The multi-party negotiation and game strategy refers to that in negotiations involving multiple stakeholders, enterprises obtain the best results in negotiations by skillfully arranging strategies and playing games among different stakeholders. Unlike negotiations with a single party, multi-party negotiations are usually more complex because the negotiating party needs to simultaneously handle the needs, positions, and interaction relationships of different stakeholders ^[4]. Through multi-party games, enterprises can maximize their negotiation advantages, balance the interests of all parties, and achieve a win-win situation. Facing pressure from the U.S. government, ByteDance did not limit itself to negotiations with a single buyer but chose to conduct negotiations with multiple potential partners such as Microsoft, Oracle, and Walmart. This multi-party game strategy not only provided ByteDance with more choices but also enhanced its bargaining power at the negotiation table ^[5].

3.2. Legal challenge and time strategy

ByteDance adopted the delay strategy in time strategies. ByteDance challenged the U.S. government's ban order through legal means, attempting to postpone the execution of the executive order ^[6]. On August 24, 2020, TikTok officially sued the U.S. government, accusing the U.S. government of various illegal behaviors in the process of banning TikTok ^[7]. This legal challenge not only delayed the implementation of the ban but also won valuable negotiation time for ByteDance. In this process, ByteDance successfully obtained a stay of execution ruling through the court, thus gaining more negotiation space and transforming from a passive position to an active one.

3.3. Flexible cooperation plan design

The flexible cooperation strategy in business negotiations refers to that during the negotiation process, enterprises maintain flexibility, adjust cooperation plans and negotiation conditions based on actual situations, while ensuring that their core interests are not damaged. This strategy aims to meet the needs of different stakeholders through flexible adaptation, thereby achieving a win-win or even multi-win result ^[8]. ByteDance adopted the strategy of adjusting the cooperation model among flexible strategies during the negotiation process. To avoid being banned by the U.S. government, seeking external cooperation during the negotiation period can integrate internal and external resources of the enterprise, cooperate with enterprises in the same industry and upstream and downstream, and exert positive synergy effects ^[9]. TikTok did not abandon the basic interests of the enterprise in the process of seeking external cooperation. During the cooperation negotiations with U.S. local enterprises Oracle and Walmart, ByteDance proposed a more flexible cooperation plan. Finally, the agreement reached between ByteDance, Oracle, and Walmart was not a complete sale of TikTok's U.S. business, but to meet the U.S. requirements for data

security through cooperation while retaining control over core technologies ^[10].

3.4. Utilization of public opinion and public influence

Throughout the negotiation process, ByteDance actively used the media and public opinion to gain support for itself ^[11]. TikTok actively assumed social responsibilities, promising to create 10,000 new jobs in the United States within three years, and calling on competitor enterprises to jointly assume social responsibilities, reduce competition, and increase cooperation. Furthermore, emphasizing fair competition ^[12]. During the process of TikTok being banned by the U.S. government, some people used the patriotic feelings of the American people to guide them to deliberately smear TikTok. Therefore, ByteDance publicly called for fair competition, set an example, and achieved openness and transparency. By disclosing information and conveying TikTok's extensive user base in the United States, ByteDance successfully used public opinion to exert pressure, and with the help of moral public opinion, forced the U.S. government to consider the public opinion response when handling the incident.

3.5. International cooperation and multilateral support

The support-seeking strategy in business negotiations refers to that during the negotiation process, enterprises or individuals enhance their negotiation power and improve their right to speak and influence in negotiations by seeking support from external forces such as experts, third-party institutions, partners, the public, and the government. This strategy increases chips for one party in the negotiation by integrating external resources, alleviates one-sided pressure, and ultimately occupies an advantageous position in the negotiation. During business negotiations, leaving a way out for oneself, having other cooperation objects to choose from if the negotiation breaks down, can make the enterprise more active and at least not fall into a passive situation. While facing pressure from the United States, ByteDance also strengthened contacts with governments and enterprises of other countries to seek international support. Through this strategy, ByteDance not only gained more international solidarity but also enhanced its chips in the negotiations. This multilateral cooperation strategy enabled TikTok to obtain greater strategic maneuvering space globally.

4. Experience enlightenment

4.1. Enhance bargaining power through multi-party games

When facing complex international environments, multinational enterprises should seek multi-party cooperation as much as possible to enhance their bargaining power ^[13]. By conducting negotiations with multiple potential partners, enterprises can form a competitive environment, thereby obtaining more favorable negotiation conditions. Specifically, in a complex international environment, multi-party games can help enterprises achieve the following goals:

- (1) Increase negotiation chips: By conducting negotiations with multiple potential partners, enterprises can create competition and force all parties to offer better cooperation conditions;
- (2) Optimize resource allocation: Enterprises can allocate resources among multiple supply chains, avoid excessive dependence on a single supplier, and enhance their bargaining power;
- (3) Reduce risks: By gaming in different policy environments, enterprises can obtain more adjustment space when external factors such as laws and policies are uncertain.

4.2. Importance of legal means and time management

When facing unfair policies or executive orders, legal means often become an effective tool for multinational enterprises to protect their own interests. Legal means can not only directly challenge unfair regulations but also

win more time for enterprises to make adjustments by delaying the execution of decisions. Enterprises can rely on professional legal teams to challenge the legal environments of different countries or safeguard their own rights and interests through arbitration, litigation, and other means. At the same time, time is an important strategic resource in negotiations. By delaying the negotiation process, enterprises can consume the patience of the other party, especially when the other party is under great time pressure. On the contrary, enterprises can also force the other party to make decisions in a short time by compressing time, and use the other party's time pressure to gain advantages ^[14]. By flexibly using time management strategies, enterprises can effectively control the negotiation rhythm and ensure that they make the most favorable decisions at key nodes.

4.3. Respond flexibly and retain core interests

In negotiations, enterprises should maintain flexibility and adjust strategies according to actual situations, but at the same time clarify their bottom lines to ensure that core interests are not damaged. The design of flexible cooperation plans can help enterprises meet regulatory requirements while maintaining their competitive advantages. Enterprises should flexibly adjust details such as cooperation models and pricing mechanisms during negotiations, but should adhere to their positions when it comes to core interests such as technology protection and market ownership. The design of flexible cooperation plans can allow enterprises to have more room for maneuver in negotiations, and not lead to negotiation failure due to rigid positions ^[15].

4.4. The role and influence of public opinion are too significant to dismiss

In the context of globalization, public opinion and public support have become important forces in multinational enterprises' negotiations. Enterprises can convey positive corporate images and values through media, social platforms, and other channels to gain public understanding and support. Public opinion support can not only affect the position of negotiation opponents but also help enterprises obtain more policy support. Enterprises should take the initiative to guide public opinion and win social support by publicly releasing statements, cooperating with the media, and other ways. For example, when facing government regulatory pressure, enterprises can strive for more public support by promoting their contributions to society, thereby reversing the impact on government decisions.

4.5. Conduct multilateral cooperation and seek international support

When facing pressure from a single country, multinational enterprises should actively seek international cooperation and support. Through cooperation with other countries, enterprises can form a broader support network globally, thereby enhancing their negotiation power. On one hand, multilateral cooperation can enhance enterprises' own competitiveness. In different countries and regions, there are significant differences in resources, technologies, market demands, and regulations. Enterprises can make up for their own shortcomings through cooperation and obtain advanced technologies, resources, and market advantages from other countries. On the other hand, multilateral cooperation can also help enterprises diversify risks and improve their risk resistance capabilities. Multilateral cooperation means that enterprises will not concentrate resources and markets in one region. When problems arise in a certain market, enterprises can relieve pressure and reduce losses through other markets and partners.

Funding

Achievements of the Offline First-Class Course International Business Negotiation under the Project of Doubling the High-Quality Undergraduate Courses of Guangxi University in 2024; Project of the Reform of Academic

Disclosure statement

The author declares no conflict of interest.

References

- [1] Wang Z, 2025, Reconsidering “Equality and Reciprocity”: China’s Strategies and Anglo-American Coordination in the Negotiations of the 1943 Sino-British New Treaty. *Historical Review*, 2025(5): 1–14.
- [2] Zhang C, Zhao K, Luo Q, 2025, Research and Innovative Practice of Scientific and Technological Literature Resource Procurement Strategies. *Library and Information Service*, 69(10): 23–32.
- [3] Chen H, Yan F, Cheng S, 2025, Discriminatory Pricing and Uniform Pricing Strategies in Supply Chains Under Negotiation Games. *Journal of Systems Engineering*, 40(2): 279–294.
- [4] Shang Z, Zuo C, Wang C, et al., 2025, The Impact of Relative Negotiation Power on Unethical Negotiation Strategies in Negotiations. *Psychological Science*, 48(1): 140–152.
- [5] Wang P, Yu Y, Zhao Y, et al., 2025, Collaborative Participation in Market Optimization Strategies Between PV Prosumers and Shared Energy Storage Based on Nash Negotiation. *Power System Technology*, 49(2): 642–652.
- [6] Zhu J, Wang S, 2024, Research and Improvement Strategies on the Implementation Policy of National Medical Insurance Negotiated Drugs in Zhejiang Province Based on the DRG Payment System. *Chinese Journal of Modern Applied Pharmacy*, 41(21): 3037–3042.
- [7] Lou L, 2024, Negotiation Strategies for the Imposition of Electronic Transmission Tariffs and China’s Response: An Investigation Based on Law and Economics. *Social Scientist*, 2024(3): 126–139.
- [8] Cao M, Ze Q, Wang Y, 2024, Automatic Negotiation Model for Multilateral Multi-Attribute Procurement. *Systems Engineering-Theory & Practice*, 44(11): 3681–3699.
- [9] Li X, Xu J, 2024, Implementation Dilemmas and Promotion Strategies of the “Dual Channel” Management Policy for Medical Insurance Negotiated Drugs in China. *China Pharmacy*, 35(8): 906–911.
- [10] Yang K, Liu T, Bai L, et al., 2024, Optimal Configuration Strategy of Multi-Agent Shared Energy Storage Capacity for Microgrid Clusters Based on Negotiation Games. *Electrical Measurement & Instrumentation*, 61(3): 33–41.
- [11] Hu Y, Dou Z, Zhang Z, et al., 2024, Operation Optimization Strategy of Multi-Microgrid-Shared Energy Storage Based on Distributionally Robust and Improved Nash Negotiation. *Electric Power Construction*, 45(7): 100–112.
- [12] Feng Z, Li X, Tan C, 2023, Research on Oil Exploitation Strategies Based on Sequential Nash Negotiation Games. *Operations Research and Management Science*, 32(5): 78–84.
- [13] Liu S, Li Y, Wang B, et al., 2023, Challenges Faced by the Negotiations on the Global Goal on Adaptation at COP27 and China’s Response Strategies. *Progressus Inquisitiones de Mutatione Climatis*, 19(3): 389–399.
- [14] Pan Z, Liang N, Xu H, et al., 2023, Cooperative Operation Strategy of Wind Power-Virtual Hydrogen Plants Participating in Spot Markets Based on Nash Negotiation Theory. *Electric Power Automation Equipment*, 43(5): 129–137.
- [15] Xie X, Xie J, 2022, Cooperative Optimization Operation Strategy of Multi-Energy VPP Clusters Based on Nash Negotiation. *Energy Storage Science and Technology*, 11(12): 3937–3949.

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Institutional Mechanism Analysis of the Standardization of Interdepartmental Budget Fund Allocation Under Fiscal Digitization

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Abstract: Against the backdrop of advancing fiscal digitization, budget management methods and fiscal operation logic are undergoing changes. Existing studies mostly discuss the effectiveness of digital fiscal reforms from the perspective of technological application or efficiency improvement, but pay relatively insufficient attention to how it affects the standardization of interdepartmental budget fund allocation. Based on this, taking the integrated budget management reform as the entry point, this paper explores the action path of fiscal digitization on the standardization of interdepartmental budget fund allocation from two levels: institutional foundation and operational mechanism. The study holds that fiscal digitization does not directly determine the allocation result of budget funds among departments, but changes the institutional environment relied on by budget allocation behavior by unifying budget rules, connecting budget management processes, and reconstructing budget information structure, thereby forming more stable and enforceable institutional constraints on departmental budget allocation. On this basis, fiscal digitization further exerts institutional constraints during the budget execution stage by embedding supervision and auditing functions into the budget execution process and improving the transparency of budget operation, inhibiting arbitrariness and strategic adjustments in interdepartmental budget allocation. Thus, the standardization of interdepartmental budget fund allocation is gradually strengthened, and the improvement of allocation efficiency is more reflected as a natural result under standardized constraints. The analysis of this paper helps to understand the governance effect of fiscal digitization from the perspective of institutional operation and provides theoretical reference for further improving the interdepartmental budget fund allocation mechanism.

Keywords: Fiscal digitization; Integrated budget management; Interdepartmental budget fund allocation; Standardization of budget allocation; Fiscal governance

Online publication: February 10, 2026

1. Introduction

With the gradual integration of digital technology into public governance, fiscal management is shifting from

an experience-based and decentralized operation to a digital governance form characterized by data integration and system collaboration. Existing studies point out that digital finance is not a simple application of information technology, but triggers systematic adjustments in fiscal governance methods by reconstructing fiscal operation logic and budget management processes, and has become an important institutional path to improve the standardization of fiscal operation and governance capacity^[1,2].

In institutional practice, integrated budget management is regarded as an important institutional carrier of fiscal digitization. Relevant studies believe that by unifying budget management rules (such as the unification of core links such as project library management and performance-based budget management), connecting budget formulation and execution processes, and integrating fiscal business and data information, integrated budget management provides basic institutional conditions for the standardization of budget operation, and to a certain extent alleviates the problems of fragmentation and information fragmentation in traditional budget management^[3,4].

However, practice shows that fiscal digitization has not necessarily translated into a synchronous improvement in budget allocation efficiency. Insufficient institutional supporting measures, poor system collaboration, and constraints on personnel capabilities still restrict the exertion of reform effectiveness, and the problem of inefficient interdepartmental fund allocation still exists^[5]. Existing studies have pointed out that budget allocation efficiency depends not only on the scale of funds, but also on the information structure and operation mode of the budget management system. When budget information is scattered within departments for a long time, interdepartmental resource allocation is prone to deviate from overall constraints^[6]. This problem needs to be analyzed from the perspective of institutional operation and information structure to explore the impact mechanism of fiscal digitization on the efficiency of interdepartmental budget fund allocation.

2. Research on integrated budget management and modernization of fiscal governance

Existing studies generally believe that integrated budget management is a key institutional arrangement to promote the modernization of fiscal governance under the condition of digital finance. Relevant literature points out that by unifying budget management rules (such as the unification of core links such as project library management and performance-based budget management), connecting budget formulation and execution processes, and integrating fiscal business and data information, integrated budget management alleviates the problems of fragmentation and information fragmentation in traditional budget management at the institutional level, and improves the standardization and transparency of budget operation^[7].

From the perspective of digital fiscal governance logic, the institutional value of integrated budget management is not only reflected in efficiency improvement, but also in reducing interdepartmental information asymmetry by reconstructing the budget information structure (such as integrating budget application, approval, and execution data scattered in various departments into a unified platform) and operation logic, forming a transformation of fiscal governance from post-event control to whole-process governance^[8,9]. The centralized presentation and process visualization of budget information provide necessary conditions for financial departments to carry out cross-departmental coordination and dynamic regulation.

However, practical research also shows that the operation of integrated budget management is still restricted by factors such as incomplete coverage of elements (for example, government procurement, asset allocation and other links in some regions have not been fully incorporated into the integrated system) and insufficient system integration. Some key matters have not been effectively incorporated into the unified management framework,

affecting the full exertion of institutional effectiveness^[10]. Although integrated budget management provides an important institutional foundation, this problem needs to be analyzed at a more detailed institutional and process level.

3. Institutional foundation for fiscal digitization to reshape interdepartmental budget fund allocation

The standardization of interdepartmental budget fund allocation essentially depends on the stable and enforceable constraints formed by the budget management system on allocation behavior, such constraints need to run through the entire chain from budget formulation to execution. The consensus of existing literature is that fiscal digitization does not directly intervene in fund allocation results, but reshapes the governance environment attached to budget allocation through institutional reconstruction, promoting the transformation of resource allocation logic from experience-based judgment to rule-oriented and procedure-constrained direction.

Under the traditional budget management system, budget rules are fragmented, the accounting standards for various funds lack unified standards, and budget application materials among departments are difficult to compare horizontally due to inconsistent standards. Financial departments often rely on historical bases and experience judgments in allocation decisions, which leaves room for interest games and discretion among departments, and ultimately weakens the standardization of budget allocation^[11]. Through the integrated budget management reform, fiscal digitization incorporates budget items, project classification, and fund uses into a unified rule system, compressing the discretionary space of departments in budget allocation at the institutional level^[12].

At the same time, integrated budget management breaks down the barriers between budget formulation, execution, and supervision processes, eliminating the long-standing problem of separation among “formulation, execution, and supervision” in traditional budget management. This makes budget allocation no longer an isolated pre-event decision, but embedded in the whole process of budget execution and subject to procedural constraints in dynamic operation, thereby enhancing the consistency and predictability of allocation results. Furthermore, by centrally storing and standardizing budget information, fiscal digitization effectively alleviates the problem of information asymmetry among departments. Financial departments are able to conduct horizontal comparisons and overall judgments at the macro level, thereby inhibiting the strategic behavior of departments to distort allocation results by virtue of information advantages^[13].

In summary, through the three paths of unifying the rule system, connecting management processes, and reconstructing the information structure, fiscal digitization has built a clear and rigid institutional boundary for interdepartmental budget fund allocation. Under the synergy of normalized supervision and execution mechanisms, such institutional constraints are gradually solidified into stable constraints in budget allocation^[14].

4. Operational mechanism for fiscal digitization to promote the standardization of interdepartmental budget fund allocation

After the institutional foundation of budget management is reshaped, the realization of the standardization of interdepartmental budget fund allocation depends on the role of institutional constraints in the budget execution process. The significance of fiscal digitization at the operational level is not to replace administrative decisions, but to transform rules, procedures, and constraints into sustainable operational institutional mechanisms through technical embedding, so that interdepartmental budget allocation no longer relies on temporary coordination and

individual intervention^[15]. The strategies are as follows:

- (1) By embedding supervision functions into the budget management system, fiscal digitization strengthens the practical binding force of budget rules during the execution stage. Compared with the traditional supervision method relying on post-event verification, under the digital condition, budget execution data is synchronously connected with the supervision system, and the flow, use, and execution progress of budget funds can be continuously recorded and tracked during operation. Thus, behaviors of interdepartmental budget allocation deviating from rules are no longer only identified after the event, but subject to institutional constraints during operation, and budget rules are transformed from static requirements to dynamic execution standards;
- (2) Budget execution auditing under the digital condition changes the way budget allocation constraints function. Budget execution auditing is no longer limited to compliance judgment, but gradually embedded into the whole process of budget execution, forming a feedback linkage mechanism with the budget management system. Through in-operation supervision and result application, the auditing mechanism strengthens the external constraints on departmental budget execution behavior, weakens the space for departments to redistribute by adjusting fund rhythm or uses during the execution stage, and thus stabilizes the operational order of interdepartmental budget fund allocation;
- (3) By improving the transparency of budget operation, fiscal digitization changes the behavioral expectations of departments in budget allocation. Under the unified platform, the budget execution status of departments can be compared horizontally, and allocation results are more likely to be subject to institutional inspection. This improvement in transparency makes departments more inclined to follow established rules rather than relying on strategic games in budget allocation and execution, strengthening the standardization of budget allocation at the behavioral level.

Fiscal digitization realizes the standardization of interdepartmental budget allocation not through a single institutional design, but through operational mechanisms such as supervision embedding, auditing linkage, and transparent operation, continuously strengthening rule constraints in the budget execution process. The role of this mechanism is not completed at one time, but exerts its effect in budget operation, enabling the standardization of budget allocation to be stably maintained.

At the operational level, fiscal digitization provides a sustainable constraint mechanism for interdepartmental budget fund allocation, making the standardization of budget allocation gradually shift from institutional rules to normalized behaviors in the budget execution process. This operational mechanism is connected with the institutional foundation discussed in the previous chapter, jointly forming a complete logic for fiscal digitization to promote the standardization of interdepartmental budget fund allocation.

5. Conclusion

This paper systematically analyzes the action logic of fiscal digitization in promoting the standardization of interdepartmental budget fund allocation from two levels: institutional foundation and operational mechanism. The study shows that fiscal digitization reshapes the budget management system environment, changes the constraint conditions of interdepartmental budget allocation, and thus promotes the transformation of allocation behavior from experience-based judgment and departmental games to rule and procedure constraints. From the institutional level, through the integrated budget management reform, fiscal digitization unifies budget rules, connects

management processes, and reconstructs the information structure, providing a stable institutional boundary for interdepartmental budget fund allocation. This institutional foundation compresses the discretionary space of departments, gradually embedding budget allocation into a unified rule system. From the operational level, through supervision embedding, auditing linkage, and transparent operation, fiscal digitization enables institutional constraints to play a role in the budget execution process. The standardization of budget allocation gradually shifts from relying on pre-event design to continuous strengthening through dynamic supervision in the execution process, thereby avoiding the amplification of allocation deviations during the operation stage.

The improvement of budget allocation efficiency is not a direct goal of fiscal digitization, but a natural result after the gradual realization of budget allocation standardization. This problem needs to be understood from the perspective of standardization rather than mere efficiency to grasp the governance effect of fiscal digitization. Based on the above conclusions, fiscal digitization reform should pay more attention to the coordinated advancement of institutional construction and operational constraints, preventing digital reform from staying at the system integration level. Only when the institutional foundation and operational mechanism form a joint force can fiscal digitization achieve the standardized transformation of interdepartmental budget fund allocation.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Xie Y, Xu J, Xu H, 2021, Digital Finance: Local Practice, Theoretical Analysis and Transformation Thinking. *Local Fiscal Research*, 2021(4): 14–21.
- [2] Wang Y, Ji H, 2023, Some Thoughts on Improving Digital Fiscal Supervision. *China Finance*, 2023(4): 70–72.
- [3] Xu N, 2024, Empowering the Modernization of Fiscal Governance with Integrated Budget Management. *Money China*, 2024(14): 9–11.
- [4] Kong D, Liu H, 2022, Research on the Dilemmas and Countermeasures of Digital Fiscal Construction. *Journal of Liaoning Administration College*, 2022(5): 41–45.
- [5] Li Z, Zhang R, 2021, The Coordinated Development of Digital Economy and Fiscal Governance. *Local Fiscal Research*, 2021(4): 8–13.
- [6] Li Z, 2024, Reform Path of Integrated Budget Management Under the Background of Digital Finance. *Business News*, 2024(8): 143–146.
- [7] Wang Z, 2021, Practice and Thinking on Digital Fiscal Construction. *Fiscal Science*, 2021(11): 41–46.
- [8] Wang Z, Li X, 2021, Digitalization Helps the Modernization of Fiscal Governance. *Local Fiscal Research*, 2021(11): 34–39.
- [9] Zhao S, 2023, The Digital Fiscal Governance Logic of Integrated Budget Management. *Fiscal Supervision*, 2023(15): 19–25.
- [10] Kong D, Liu H, 2022, Research on the Dilemmas and Countermeasures of Digital Fiscal Construction. *Journal of Liaoning Administration College*, 2022(5): 41–45.
- [11] Wang Y, 2024, Practice and Exploration of Big Data in Digital Fiscal Construction. *China Electronic Business Journal*, 2024(4): 91–93.
- [12] Zhao B, Chen C, Sun Q, 2020, Digital Finance: Transformation Constraints and Comprehensive Digitalization

Countermeasures. *Local Fiscal Research*, 2020(10): 4–11.

- [13] Cheng Q, 2023, Research on Grassroots Supporting Systems and Personnel of Fiscal Cloud Systems Under the Background of Digital Finance. *Western Finance and Accounting*, 2023(3): 10–13.
- [14] Ou Y, 2024, Research on Financial Management of Public Institutions Under the Digital Fiscal System. *Chinese Agricultural Accounting*, 34(11): 64–66.
- [15] Zhou Z, 2011, On the Reasonable Allocation of Macroeconomic/Microeconomic Responsibilities Among Departments. *Journal of Public Administration*, 4(4): 85–100.

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Exploration of the Pathways for Enterprises to Strengthen Cost and Budget Management through Managerial Accounting

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Abstract: Against the backdrop of intensified market competition and increasingly complex business environments, cost control and budget management have become pivotal for enterprises seeking to reduce costs, enhance efficiency, and ensure the successful implementation of their strategies. In this context, managerial accounting, as a crucial branch of the accounting system, effectively bolsters an enterprise's core competitiveness. This article delves into the application of managerial accounting in enterprise cost and budget management, clarifying its value within enterprises. Addressing existing issues in utilizing managerial accounting to strengthen cost and budget management, it proposes targeted practical pathways. The aim is to provide feasible solutions for enterprises grappling with difficulties in cost control and weak budget execution, thereby assisting them in elevating the precision of their financial management, achieving the dual objectives of cost reduction and efficiency enhancement, and ensuring the successful implementation of their strategies.

Keywords: Enterprise; Managerial accounting; Cost management; Budget management; Practical pathways

Online publication: February 10, 2026

1. Introduction

Currently, domestic enterprises are confronted with multiple challenges, including fluctuations in raw material prices, volatile market demands, and intensified industry competition. Against this backdrop, management accounting, with its unique advantage of integrating strategy, operations, and finance, has gradually emerged as a crucial tool for enterprises to optimize their cost structures and enhance the effectiveness of budget management. Unlike financial accounting, which focuses on external reporting, management accounting places greater emphasis on supporting internal management decision-making. It can permeate the entire process of cost and budget management through data integration, model analysis, and process embedding. Therefore, an in-depth exploration of the pathways through which enterprises utilize management accounting to strengthen cost and budget management holds significant practical implications for optimizing cost management and improving budget

execution outcomes.

2. Application value of enterprises using management accounting to strengthen cost and budget management

2.1. Enhancing the scientific and precise nature of internal decision-making

In terms of budget management decision-making, management accounting effectively bridges an enterprise's short-term operational needs with its long-term development goals, facilitating a transition in budget preparation models from traditional base increment approaches to those based on business planning. By comprehensively reviewing and integrating the business plans of various departments within the enterprise, management accounting enables the rational allocation of budgetary resources, clarifies the correspondence between budget items and business objectives, and ensures that budget decisions align with the overall operational logic of the enterprise. This decision-making model centered on management accounting significantly reduces subjective judgments in the decision-making process, making cost and budget-related decisions more attuned to the actual operational needs of the enterprise. It lays a solid foundation for improving resource allocation efficiency and provides a basis for subsequent resource adjustments, thereby facilitating enhanced resource allocation efficiency ^[1].

2.2. Strengthen the full-process control capabilities of cost and budget management

Traditional cost and budget management models tend to focus primarily on post-event accounting and performance evaluation, with significant shortcomings in managing the process itself. This often leads to issues such as cost overruns and a disconnect between budgets and business operations. Management accounting effectively addresses the flaws of traditional models by establishing a full-process management system encompassing “pre-event planning–in-event control–post-event review,” thereby comprehensively enhancing a company's ability to control the entire process of cost and budget management. During the pre-event planning phase, management accounting formulates clear cost control objectives and budget preparation plans aligned with the company's overall operational goals. It breaks down cost objectives into various business segments and refines budget indicators for each responsible entity, setting clear standards and directions for subsequent management activities to avoid execution confusion caused by vague planning. In the in-event control phase, management accounting relies on real-time information collection and analysis tools to dynamically monitor cost incurrence and budget execution, promptly identifying deviations from the plan. Through a dynamic early warning mechanism, it issues alerts at the early stages of issues such as cost overruns and budget execution delays, assisting companies in adjusting their operational behaviors in a timely manner. During the post-event review phase, management accounting comprehensively summarizes the effectiveness of cost control and budget execution through variance analysis and performance evaluation, thoroughly analyzing the causes of deviations and distinguishing between subjective and objective, controllable and uncontrollable factors. This provides a basis for optimizing subsequent management plans and forming a closed-loop management system.

2.3. Promote deep synergy between cost and budget management and corporate strategy

As the core elements of internal corporate management, cost and budget management must have goals that are highly aligned with corporate strategic objectives. Otherwise, issues such as “reducing costs for the sake of cost reduction” and “budgeting being out of sync with strategy” are likely to arise, affecting the company's long-term development. Management accounting serves as a bridge connecting strategy with cost and budget, promoting

deep synergy between the two and making cost and budget management an important tool for supporting the implementation of strategy.

Management accounting can decompose the overall corporate strategic objectives into quantifiable and executable cost objectives and budget indicators during the strategic goal dissection process. It clarifies cost control requirements and budget resource allocation standards for each business department and operational segment, ensuring that cost and budget management objectives correspond to strategic objectives at every level. This ensures that every cost control measure and budget allocation serves the implementation of strategy. Through a synergy mechanism, it effectively prevents cost and budget management from becoming disconnected from strategic objectives, enabling both to work together to drive the implementation of corporate strategy and assist the company in achieving sustainable development in long-term market competition.

3. Existing problems in enterprises using management accounting to strengthen cost and budget management

3.1. Lack of adaptability and systematicness in the application of management accounting tools

Some companies, when selecting management accounting tools, do not fully consider their own industry attributes, operational scale, and management needs, leading to a phenomenon of “blindly following trends.” This results in tools that are disconnected from actual business scenarios. For instance, some enterprises overlook the unique characteristics of their business processes and directly apply standardized cost accounting models, or they simply replicate the tools and methods of other companies in budget management without adjusting the application logic of these tools according to their own business fluctuations and resource structures. On the other hand, the application of management accounting tools in enterprises often remains confined to a single stage or objective, lacking systematic integration. This results in management accounting struggling to form a cohesive force for end-to-end process control, failing to fully leverage data integration and decision-making support functions, and instead increasing management complexity and resource consumption.

3.2. Weak cross-departmental collaboration mechanisms and disconnection between business and finance

During the application of management accounting, some enterprises still encounter information barriers and have not established effective cross-departmental collaboration mechanisms. Specifically, some business departments within these enterprises have insufficient understanding of management accounting, viewing cost and budget management as the exclusive responsibility of the finance department. As a result, their participation is low, and they lack initiative in providing data and cooperating in processes, leading to delayed or inaccurate business data obtained by the finance department, which affects the accuracy of management accounting analysis results. Moreover, there is a lack of a unified communication language and data standards between business and finance. Cost analysis reports and budget execution feedback from the finance department are difficult for business departments to understand and utilize for optimizing business decisions because they are not interpreted in the context of actual business scenarios. Conversely, the operational needs and adjustments of business departments are not promptly communicated to the finance department, resulting in management accounting tools adjusting lagging behind business changes. Consequently, management accounting cannot be deeply integrated into business processes, making it difficult to achieve dynamic control over costs and budgets.

3.3. Lack of institutional guarantees and insufficient technical support

Some enterprises have not yet established an institutional framework suitable for the application of management accounting, lacking clear implementation norms, mechanisms for delineating rights and responsibilities, and assessment criteria for management accounting. For instance, the specific responsibilities of each department in cost data collection and budget preparation and execution are not clearly defined, leading to mutual shirking of responsibility when problems arise. The absence of an assessment mechanism for the application of management accounting results resulted in a lack of motivation to implement cost optimization suggestions and budget adjustment plans, making it difficult to translate them into actual management effectiveness. On this basis, insufficient technical support capabilities constrain the effectiveness of management accounting applications. Some enterprises lag in their informatization construction, with financial systems and business systems failing to achieve data interoperability, necessitating manual data integration, which is not only inefficient but also prone to data errors; the lack of professional management accounting tools makes it difficult to achieve multi-dimensional data mining and dynamic monitoring, preventing the timely identification of underlying causes of cost fluctuations and budget deviations, resulting in delayed responses in management accounting's control over costs and budgets.

4. Practical pathways for enterprises to strengthen cost and budget management through management accounting

4.1. Scientifically adapting and systematically integrating management accounting tools to enhance application efficiency

When using management accounting to strengthen cost and budget management, enterprises should first and foremost achieve scientific adaptation and systematic integration of management accounting tools, avoiding blindness in tool selection and fragmentation in application. In the tool selection phase, enterprises need to fully consider their own industry characteristics, business scale, complexity of business processes, and core management objectives, and establish a tool system that is highly aligned with actual business scenarios. Specifically, in terms of cost management, if an enterprise's business processes involve multiple steps, with complex cost structures and diverse cost drivers, priority should be given to applying Activity-Based Costing (ABC). By comprehensively reviewing core activities across production, procurement, sales, and other areas, resources consumed in each activity can be accurately allocated, and cost drivers for different activities can be clearly identified. This enables precise tracing of costs from resources to activities and ultimately to final products or services, providing a clear direction for subsequent cost optimization. Alternatively, if an enterprise is market-oriented and focuses on new product development and enhancing market competitiveness, the focus of cost control should shift forward to the research and development (R&D) and design phase. The Target Costing method should be adopted, whereby the total target cost is derived by working backward from an acceptable selling price determined through market research, combined with the enterprise's preset target profit level. This target cost is then broken down into specific costs for each stage, including R&D and design, raw material procurement, and production, forming a cost control logic that covers the entire product lifecycle. This approach continuously improves and refines the cost management system, promotes the establishment of a modern target cost management system, and lays a solid foundation for enhancing the enterprise's cost control efficiency^[2].

During the process of tool application, enterprises should further overcome the limitations of using a single tool and promote the systematic integration and coordinated use of multiple tools. In the field of cost management,

enterprises can organically combine ABC with Target Costing. By leveraging the ineffective activities and cost waste links identified through ABC, they can optimize the decomposition criteria for target costs. This ensures that target costs not only meet market competition demands but also precisely avoid cost waste. In the realm of budget management, an application model that synergizes strategic budgeting with rolling budgeting should be established. This involves constructing an overall budget framework fundamentally guided by the enterprise's long-term strategic objectives, clarifying the correlation between each budget item and strategic goals. Simultaneously, utilizing rolling budgets to regularly review and adjust budget execution, promptly correct budget deviations in response to changes in the market environment and business progress, and ensure that the budget remains aligned with the strategic direction and actual operational needs. This macro perspective on enterprise development and operations facilitates the formulation of more effective budget management mechanisms ^[3].

4.2. Establishing a cross-departmental collaboration mechanism to promote deep integration of business and finance

The effective application of management accounting in cost and budget management hinges on the collaboration and cooperation among various departments. Establishing an efficient cross-departmental collaboration mechanism and achieving deep integration of business and finance are crucial. Enterprises must first break down barriers between departments, clarify the roles and responsibilities of each department in cost and budget management, and establish a collaborative management framework where the finance department takes the lead and business departments actively participate. This involves integrating the business processes of multiple departments, strengthening inter-departmental connections, and ensuring that comprehensive budget management based on management accounting can be organically embedded across all departments ^[4].

To eliminate communication barriers between business operations and finance, enterprises need to establish unified data standards and a common communication language. Enterprises should standardize the collection criteria and recording requirements for cost data and budget data, clarify the scope of data collection, statistical methods, and submission deadlines for each business process to ensure that the business data obtained by the finance department is authentic, complete, and timely, providing a reliable data foundation for management accounting analysis ^[5]. On the other hand, the finance department needs to transform its traditional professional expression methods, translating complex cost accounting results and budget execution analyses into information that is easily understandable for business departments. It should interpret the reasons for cost changes using business indicators and correlate budget execution progress with business objectives, enabling business departments to clearly understand the guiding significance of management accounting analysis results for business optimization and thereby better integrating management accounting requirements into daily business operations.

4.3. Improve institutional safeguards and technological support to consolidate the management foundation

A sound institutional system and efficient technological support are crucial guarantees for the effective implementation of management accounting in cost and budget management. Enterprises need to consolidate their management foundation by focusing on both institutional construction and technological upgrades. At the institutional construction level, it is necessary to establish a system that covers the entire process of management accounting application as follows:

- (1) Enterprises should formulate detailed implementation rules for managerial accounting, clarifying

specific methods for cost accounting, procedural steps for budget preparation, and adjustment criteria for deviations between costs and budgets. This provides operational guidelines for the standardized application of managerial accounting tools, preventing management chaos caused by inconsistent operations;

- (2) Enterprises should refine the rights and responsibilities of each department and position in cost and budget management, specifying the specific responsibilities of business departments in data provision, cost control, and budget execution, as well as the responsibilities of the finance department in cost analysis, budget supervision, and result feedback. This ensures that every task has a clearly defined responsible party, avoiding the passing of blame when problems arise;
- (3) Enterprises should, in accordance with the needs of managerial accounting application, make information transparency one of the important indicators for performance evaluation, clarifying the requirements for transparency of comprehensive budget management information in performance evaluations. This encourages departments to regularly disclose comprehensive budget management information on internal platforms and consciously accept supervision from other departments ^[6].

5. Conclusion

In summary, managerial accounting, as a crucial tool that connects finance and business operations and coordinates short-term operations with long-term development, can help enterprises maintain profitability and achieve strategic implementation. Enterprises should correctly recognize the application value of managerial accounting in cost and budget management and, based on their own realities, comprehensively promote the implementation of various approaches to truly unleash the value of managerial accounting. Looking ahead, with the continuous development of digital technologies and the ongoing upgrading of enterprise management needs, enterprises need to maintain a dynamic optimization mindset towards managerial accounting tools and methods, adjusting practical strategies in response to changes in the internal and external environment. This ensures that managerial accounting remains in sync with enterprise operational objectives, providing stable and powerful support for enterprises to achieve cost reduction, efficiency enhancement, and sustainable development.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Han Q, 2024, Research on Strategies for Enterprises to Strengthen Cost and Budget Management Using Management Accounting. China Conference & Exhibition (China Conference), 2024(12): 106–108.
- [2] Guo M, 2023, The Application of Management Accounting in Strengthening Enterprise Cost Control. Modern Enterprise, 2023(8): 183–185.
- [3] Yin A, 2023, Discussion on the Application Strategies of Management Accounting in Comprehensive Budget Management of Enterprises. Enterprise Reform and Management, 2023(20): 139–141.
- [4] Han L, 2023, The Application of Management Accounting in Comprehensive Budget Management of Enterprises. Business 2.0, 2023(35): 84–86.

- [5] Xu J, 2023, Reflections on the Application of Management Accounting in Enterprise Budget Management. Bohai Economic Rim Outlook, 2023(10): 101–103.
- [6] Wan S, 2023, Discussion on the Application of Management Accounting in Comprehensive Budget Management of Enterprises. Management & Technology of SME, 2023(16): 127–129.

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Research and Forecast of the Third-Level Real Estate Market in Shenzhen (2026–2030)

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Abstract: This paper analyzes the various problems faced by the third-level real estate market in Shenzhen, studies their origins, formation processes, and related factors. The main contents include: investigating and analyzing the current situation and marketization degree, analyzing the causes of the formation of the real estate bubble in Shenzhen, researching the impacts of real estate on the economy, society, politics, and other aspects, and proposing effective policies and suggestions for the real estate market.

Keywords: The third-level real estate market; Trend chart; Second-hand housing prices; Economic crisis

Online publication: February 10, 2026

1. Introduction

Shenzhen is a pioneer zone for China's reform and opening-up and special economic zone system. With its advantageous geographical location and huge market, it has attracted a large amount of domestic and foreign investment. The scale and growth rate of the real estate market are also much higher than other cities^[1]. In recent years, Shenzhen has also faced problems of overinvestment and real estate foam, which have had a profound impact on the urban economy, residents' lives and financial risks. With the construction of various municipal projects and the promotion of the "homeowners do not speculate" policy, the real estate market in Shenzhen has attracted high attention from all aspects. This paper deeply analyzes the problems faced by the third-level real estate market in Shenzhen, and its impact on the economic, political and other aspects, and to put forward reference decisions to provide reference for the governance of the real estate market in other cities.

2. Shenzhen have created many firsts in real estate market

Why do we need to study the real estate in Shenzhen? Shenzhen has played a pioneering role in China's real estate industry, and major changes in the country's real estate history in recent decades have always come first from

Shenzhen. The representative events are as follows:

- (1) The first real estate company in China: Shenzhen Special Economic Zone Real Estate Company was established on January 8, 1980;
- (2) The first commercial housing community in China: Donghu Liyuan, which is also the first joint venture real estate project, has set a precedent for selling buildings in Chinese Mainland, 18 years earlier than the concept of commercial housing after China's monetization of housing distribution;
- (3) The first property management company in China: In 1981, Shenzhen Property Management Company was established;
- (4) The first public auction of land use rights in Shenzhen: the first public auction of state-owned land use rights since the founding of the People's Republic of China was held as scheduled on the afternoon of December 1, 1987. This event is enough to be recorded in the history of China's real estate development;
- (5) The first real estate brokerage, consulting, and appraisal company in China: In 1988, Shenzhen International Real Estate Consulting Co., Ltd. was established, which was the first real estate brokerage, consulting, and appraisal company in China.

The above "firsts" not only mark the important position of Shenzhen in the history of China's real estate development, but also provide guidance for real estate research in other regions of China.

3. The three-level real estate market structure

Since its establishment, Shenzhen Special Economic Zone has boldly carried out a series of fruitful reforms and created a remarkable "Shenzhen Speed". Especially in the real estate industry, Shenzhen has been at the forefront of the country. An outstanding performance of the real estate market in developed countries is that the transaction volume of the third-level market is much higher than that of the second-level market. In the past 35 years, Shenzhen's tertiary real estate market is gradually maturing. Under such circumstances, it is undoubtedly of great help to study the real estate market in Shenzhen with caution, and sum up useful experience from it.

3.1. About the three-level real estate market structure

The three-level real estate market is structured as follows:

- (1) The primary market for real estate, also known as the land primary market, is the market for the transfer of land use rights, where the state, its designated government departments, transfers urban state-owned land and rural collective land to users after expropriating them as state-owned land. Therefore, the primary market for real is a state-monopolized market;
- (2) The secondary market for real estate is the market where the land user, after development and construction, sells or leases the newly built estate;
- (3) The third-level market of real estate is a market where units and individuals who buy real estate transfer or lease real estate again. That is to say, the market formed by real estate re-entering the circulation field for transactions, including the exchange of houses ^[1].

3.2. The importance of studying the third-level market structure

The total area of Shenzhen is only more than 1,900 square kilometers, which is pitifully small compared to Beijing, Shanghai, and Angzhou. For a region like Shenzhen, which is relatively small in size, has a large population, and

is well-developed, revitalizing the third-level estate market is essential. At present, the transaction of the third-level real estate market in Shenzhen is in a low state. In such a situation, a careful study of third-level real estate market in Shenzhen will undoubtedly be of great help to the recovery and development of the third-level real market throughout the country.

4. The house prices drastic change in the past decade (2015–2025)

In the course of 35 years development in Shenzhen, Shenzhen has developed from a small fishing village to a first-level city with nine administrative districts, among which the second-hand housing prices (CNY) in Nanshan District are relatively the highest, while those in Pingshan District are relatively the lowest ^[2].

Figure 1 shows the trend chart of second-hand housing prices (CNY) in Nanshan District from 1999 to 2020. We can see that the second-hand housing prices are on the rise.



Figure 1. The second-hand house price in Nanshan District from 1999 to 2020.

Figure 2 shows the trend chart of second-hand housing prices in Pingshan District from 2015 to 2020.



Figure 2. The second-hand house price in Pingshan District from 2015 to 2020.

Since the end of 2015, the housing prices (CNY) in Shenzhen have skyrocketed from 30000 CNY per square meter to 45000 CNY by the end of 2016. Subsequently, the housing prices in Shenzhen rapidly surpassed 50000, 60000, 70000, and 80000 CNY, one by one.

Just almost when everyone thought that the housing prices in Shenzhen were going to soar, on February 8, 2021, Shenzhen took the lead in introducing a second-hand housing guidance price policy nationwide, announcing detailed guidance prices for 3595 residential communities in Shenzhen. The guidance price played a strong emergency braking effect on the rising housing prices in Shenzhen, so the guidance price policy was called “the most

regulatory policy in history”. Since then, housing prices in Shenzhen have been falling, which has also directly opened the curtain of falling housing prices across the country, and Shenzhen has once again become the leader of major adjustments in housing prices.

At the beginning, the suggested housing price was lower than the actual market transaction price, at 80% or even 70% of the actual transaction price. Faced with the uncontrollable continuous decline in housing prices, the Shenzhen Municipal Government hopes to control housing prices at a reasonable level, in order to achieve the effect of stopping the decline and stabilizing housing prices. The Chinese government also released important real estate policies (referred to as the “517” policy and the “924” policy) on May 17, 2024 and September 24, 2024, respectively, but neither the “517” policy nor the “924” policy has fundamentally changed the overall downward trend of the real estate industry.

By June 2025, the average home price in Shenzhen had dropped to 40,000 CNY per square meter, to the level of the second half of 2016.

5. Multiple factors for the decline in house prices in Shenzhen in the past four years (2021.9–2025.8)

There are many factors that have caused the continuous decline of housing prices in Shenzhen in the past four years^[3]. The main factors are as follows.

5.1. The coming economic crisis

The economic crisis has been brewing quietly since the first half of 2021, but it didn’t receive widespread attention at the time due to the pandemic. Starting in 2023, China’s economy has officially entered the stage of economic crisis. As a city heavily dependent on foreign trade and imports and exports, Shenzhen has experienced a rapid weakening in its tertiary real estate market. In comparison, Beijing and Shanghai, which are also first-level cities but less dependent exports, have experienced a slower decline in housing prices. Due to the economic crisis, the income of ordinary people, which accounts for the vast majority of the population, began to decline, which directly led to the decline in house prices.

Most ordinary people borrow money from banks when they buy a house, and many of them make false statements about their monthly income, with the aim of increasing the loan amount. They simply don’t realize that 1/3 of their real monthly income is the best debt. Therefore, in cases of economic crisis, many people can’t afford to pay their mortgage. In fact, even high-income groups, which account for a small population, are now reducing consumption, buying cheaper goods and shopping in low-price supermarkets^[3].

5.2. Declining employment rate among college graduates

In 1998, the enrolment of Chinese universities was 1.08 million, and in 1999, the proportion of expanded enrolment reached 47%. The number of college students enrolled can increase dozens or even hundreds of times in a short period of time, but there are not as many university professors and research resources. Helpless, universities began to add many unpopular majors and humanities majors with extremely low training costs.

By 2024, there will be more than 10 million college graduates in China every year, but the employment rate is less than 20%. In 2025, the number of college graduates nationwide reached 12 million, a record high, and the employment competition was particularly fierce. At present, financial constraints prevent some young people from meeting basic living needs, rendering homeownership unattainable.

5.3. The decline in the marriage rate among young people has triggered a series of problem

The decline in the number of young people getting married has a significant impact on the real estate market. Based on past experience, buying a house and getting married is the main demand of most people. The decline in the marriage rate means that there will be fewer young people buying houses and getting married in the future. This is also the key reason for the decline in the transaction of the real estate market in recent years.

The decline in the marriage rate has also directly led to a decline in the birth rate. A decrease in the birth population means a decrease in the demand for housing the future. Additionally, real estate developers are still building houses at this moment, which will inevitably lead to oversupply in the long run. With the decline in fertility rates, it will also lead to increasingly severe problems such as aging and a decrease in the labor force among young and middle-aged people. With the continuous death of elderly people, there will be a large number of idle houses ^[4].

5.4. The public's willingness to purchase houses has dropped to low level

Due to the rapid implementation of financing coordination mechanisms, the risk of housing delivery has begun to significantly decrease. As of July 2025, the risk of unfinished housing projects has significantly decreased, accounting for about 26%, a decrease of 4.4 percentage points from September 2024.

Recently, Shenzhen's real estate policies have emerged one after another, including interest rate cuts, down payments, relaxation of purchase restrictions, and reductions in deed tax and value-added tax for home buyers. That said, we know that the top three main factors that constrain real estate are: unstable income, falling housing prices, and high repayment pressure. Given the continued decline in housing prices and the sluggish market conditions, the most prudent approach is to continue waiting and observing. The housing prices in Nanshan District and Pingshan District are typical, representing the highest and lowest prices in Shenzhen respectively. As for Dapeng District, its housing price is not representative because of the small transaction volume ^[5].

Figure 3 is the trend chart of second-hand housing prices (ten thousand CNY) in Nanshan District from August 2025 to October 2025 displayed on the Anjuke website.

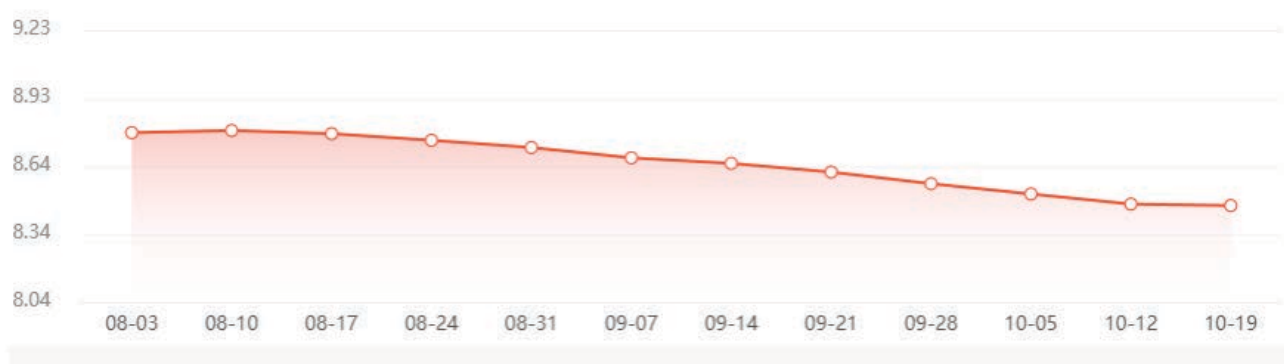


Figure 3. The second-hand housing prices in Nanshan District.

Figure 4 is the trend chart of second-hand housing prices (ten thousand CNY) in Pingshan District from August 2025 to October 2025 displayed on the Anjuke website.

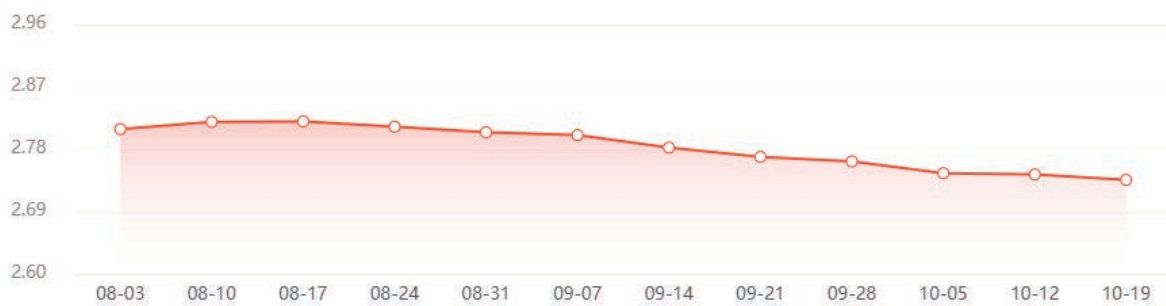


Figure 4. The second-hand housing prices in Pingshan District.

It can be clearly seen that the second-hand housing prices (ten thousand CNY) in Shenzhen are in a downward trend recently, and the rate of decline is obviously accelerated. Notably, there is a certain difference between the price displayed on the website of Anjuke and the actual transaction price. Normally, the actual transaction price is about 70% of the price displayed on the website.

5.5. The “Three-No” lifestyle of young people

The “three-no” lifestyle, namely “no savings accumulation, no property ownership, and no family burden”, not only reflects the profound changes in the consumption concepts, housing concepts and fertility concepts of contemporary youth, but also reveals the diversified development of social structure and values.

6. Shenzhen real estate future forecast

Since the establishment of Shenzhen, real estate has been the pillar industry of its economic development, and even played a dominant role in economic development to a great extent.

6.1. Housing prices in Shenzhen will continue to decline for 3–5 years

Housing price adjustment is the inevitable result of economic development to a certain stage. Japan, South Korea and other countries have experienced a long-term adjustment period of the real estate market after rapid economic development. After Japan’s housing prices peaked in 1991, it took nearly 20 years to bottom out and stabilize. Since the financial crisis in 2008, South Korea’s housing prices have also experienced a seven-year adjustment period.

Although similar laws are worthy of vigilance, it does not mean that China’s real estate market will repeat the mistakes of Japanese and Korean. The differentiation of China’s real estate market will be the main trend in the next five years. Due to industrial agglomeration and population siphon effect, housing prices in first-and second-level core cities may remain relatively stable in the short term. However, the downward trend of housing prices in most third-and fourth-tier cities is a high probability event, and some cities with exhausted resources and serious population outflows may even experience 30% of the peak period of housing prices.

The “China Housing Development Report” released by the Chinese Academy of Social Sciences predicts that by 2030, housing prices in China may decrease by 15–30% compared to 2025. In the next five years (from 2026 to 2030), the housing price in Shenzhen may decline even more, and it is predicted that it will also decline by 25–35%, because the bubble in Shenzhen’s real estate market remains severe.

6.2. Building ‘Good Houses’ is the real estate development trend

Recently, the Chinese Ministry of Housing and Urban Rural Development proposed the concept of “good houses” and included “raising floor height” in mandatory regulations. This not only significantly improves indoor lighting and ventilation conditions, but also provides more ample space for central air conditioning, ducted fresh air systems, and underfloor heating equipment in northern regions. The criteria are as follows:

- (1) The height of ordinary residential buildings should not be less than 3 meters;
- (2) The height of improved residential buildings should not be less than 3.1 meters;
- (3) Improved residential buildings equipped with underfloor heating, ducted fresh air, or centralized central air conditioning systems should have a floor height of no less than 3.15 meters.

6.3. Reduce dependence on real estate and flow back to the real economy

China local government gradually realized that “land finance” was unsustainable. In the first half of 2025, the national land transfer income decreased by 23.6% year-on-year, and local governments are accelerating industrial transformation and looking for new economic growth points. Shenzhen has focused on high-end manufacturing and digital economy, reducing its dependence on real estate. This shows that Shenzhen’s financial resources are returning from the real estate sector to the real economy, which is an inevitable choice for healthy development.

6.4. The focus of real estate development shifted to Pingshan district

The low-price sale of housing prices in Pingshan District is its biggest feature. In 2024, the transaction volume of second-hand houses in Pingshan District increased by 82% year-on-year, ranking first in Shenzhen. In addition, with a large number of high-tech enterprises such as new energy automobile industry and biomedical high-tech, Pingshan District has the potential to become the next scientific and technological innovation center in Shenzhen, which will attract a large number of technical talents to work and live in Pingshan District.

7. Conclusion

In summary, the general trend of Shenzhen’s real estate development in the next 5 years is reflected in several aspects, including the cost of purchasing a house for residents will be further reduced, and the value-added tax and income tax on the sale of second-hand houses will be further reduced. At the same time, the investment of housing finance funds will further match the trend of market supply and demand changes. In addition, in order to prevent housing financial risks, banks will increase the capital of commercial banks to effectively prevent and control financial risks in the housing market. The macro-economic market is unlikely to experience ups and downs that are not conducive to residents’ lives.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Research Report on the Development Situation Planning of Shenzhen Real Estate Industry in China from 2024 to 2030, 2025, <https://max.book118.com/html/2025/0117/5221133230012033.shtm>

- [2] Unveiling the Impact of Shenzhen's New Urban Renewal Policy on the Real Estate Market, 2025, https://www.sohu.com/a/878689651_122001006
- [3] Shenzhen's 14th Five-Year Plan for Housing Development, 2022, <http://www.sz.gov.cn/attachment/0/940/940604/9513747.pdf>
- [4] Shenzhen Housing Price Trend Chart for 20 Years: Summary of Housing Price Trend Charts in Various Districts of Shenzhen, 2025, <https://m.jiwu.com/sz/gonglve/592.html>
- [5] The Trend Chart of Second-Hand House Prices in Various Districts of Shenzhen in the Past Six Months, 2025, https://m.anjuke.com/sz/taofang/quyufang/longhuaqu_5513/

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Research on the Mechanism and Pathways of Low-Altitude Economy Empowering New Quality Productive Forces Driven by Digital-Real Integration

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Abstract: This paper systematically explores how the low-altitude economy, through deep integration with the real economy and the digital economy (“Digital-Real Integration”), collaboratively promotes the formation of new quality productive forces, and analyzes the critical role of Specialized, Sophisticated, Distinctive, and Innovative (SSDI) small and medium-sized enterprises (SMEs) within this context. Research indicates a bidirectional and mutually reinforcing relationship between the low-altitude economy and digital-real integration, where the development of the low-altitude economy relies on enabling digital technologies such as high-precision navigation, intelligent air traffic management, and digital twins; simultaneously, the massive data and diverse scenarios it generates provide a crucial testing ground for digital technology innovation and implementation. SSDI SMEs demonstrate significant vitality in niche UAV sectors, specialized solutions, and regional service network construction. To foster the ternary synergy among the low-altitude economy, digital-real integration, and new quality productive forces, efforts should focus on building data trading markets and secure channels, constructing intelligent integrated infrastructure, and creating comprehensive management platforms. Current challenges include technology maturity, safety regulation, airspace supply, and business model sustainability. Future work requires enhanced systematic planning, optimized regulatory environments, the construction of a collaborative ecosystem, and the promotion of new quality productive forces development.

Keywords: Low-altitude economy; Digital-real integration; New quality productive forces; Specialized; Sophisticated; Distinctive; Innovative (SSDI) SMEs

Online publication: February 10, 2026

1. Introduction

Entering the period of the “15th Five-Year Plan,” China’s economic development faces profound structural

adjustment and kinetic energy transformation. The “15th Five-Year Plan” outlines the need to accelerate the development of strategic emerging industrial clusters, including the low-altitude economy, while strengthening national security capacity-building in emerging fields such as low-altitude^[1]. This marks the elevation of the low-altitude economy from localized industrial exploration to a major national-level strategy, with its development entrusted with multiple expectations to promote high-quality economic development and serve the national strategic landscape. The low-altitude economy is not a simple extension of the traditional general aviation industry. Instead, it is a comprehensive economic system centered on various low-altitude flight activities (both manned and unmanned) within low-altitude airspace (typically within 3,000 meters above ground), radiating to drive the integrated development of fields such as high-end manufacturing, artificial intelligence, next-generation communication technology, and advanced materials^[2]. Characterized by high technology, high efficiency, and high quality, with innovation playing a leading role, the low-altitude economy is regarded as a typical representative of new quality productive forces.

Simultaneously, the deep integration of the real economy and the digital economy (referred to as “digital-real integration”) serves as a strategic pivot for constructing a new development pattern and is becoming a critical path for advancing new industrialization and establishing a unified national market. The essence of digital-real integration lies in using real-world demand to pull digital innovation and using digital empowerment to feedback and upgrade the real economy, achieving a spiral development of “real foundation building-digital empowerment-value co-creation”^[3]. Against this macro background, the low-altitude economy, with its inherent dual attributes of “three-dimensional physical space” and “digitalized operation management,” provides digital-real integration with an exceptionally profound field of practice. The manufacturing, operation, and services of low-altitude aircraft are typical real economic activities, while their safe, efficient, and large-scale operation fundamentally relies on the comprehensive support of digital technologies such as high-precision navigation, real-time communication, intelligent sensing, and big data analytics. As a result, exploring how the low-altitude economy becomes a key link connecting digital-real integration and new quality productive forces holds significant theoretical value and practical meaning^[4-6].

2. The ternary synergistic mechanism of low-altitude economy, digital economy, and new quality productive forces

The low-altitude economy, digital-real integration, and new quality productive forces constitute a mutually driven, tightly coupled synergistic development system^[7]. New quality productive forces are the goal and outcome, with their core residing in revolutionary technological breakthroughs, innovative allocation of production factors, and deep industrial transformation and upgrading, moving away from traditional economic growth models to form an advanced productive force characterized by high technology, high efficiency, and high quality. Digital-real integration is the pathway and means, emphasizing the deep embedding of data, a new type of production factor, into the entire chain of the real economy’s R&D, production, distribution, and services. It uses digital technology to amplify the efficacy of the real economy while providing the soil for digital technology iteration and upgrading through real-world scenarios. The low-altitude economy is both an important component of new quality productive forces and a “natural testing ground” for generating and validating the outcomes of digital-real integration.

From a theoretical perspective, the development of the low-altitude economy profoundly illustrates the innovative allocation of production factors. There exist diversified paths to stimulating urban low-altitude

economic vitality, which can be categorized into different models such as resource-technology co-driven, digital-real integration propelled, digital-intelligent economy oriented, and technology-market enabled ^[7]. Among these, technological factors constitute a necessary condition for stimulating the entrepreneurial vitality of the low-altitude economy. This indicates that beyond traditional factors like land, capital, and labor, the addition and recombination of new factors such as technology, data, and airspace form the basis for the emergence of the low-altitude economy as a new quality productive force. Digital-real integration plays the roles of “catalyst” and “reorganizer” in this process. For example, the operation of the low-altitude economy generates massive amounts of flight trajectory, environmental perception, equipment status, and mission payload data. The collection, transmission, processing, and modeling analysis of this data are themselves core activities of the digital economy. When this data is used to optimize flight routes, predict equipment failures, and improve operational efficiency, it directly empowers the quality and efficiency improvement of real economic activities like low-altitude logistics, inspection, and passenger transport, realizing value transformation.

Conversely, the complex application scenarios and stringent safety requirements faced by the low-altitude economy also impose higher and more specific demands on digital technology, thereby driving digital innovation in reverse ^[8]. For instance, ensuring the safety of integrated drone and manned aircraft flight in urban environments requires the development of high-precision real-time positioning, ultra-low latency communication, and intelligent conflict resolution algorithms that far exceed the needs of ground transportation. This kind of technology development driven by real-world scenario pain points vividly exemplifies the “real driving digital” aspect of digital-real integration. Ultimately, this bidirectional, mutually reinforcing fusion gives rise to entirely new products (e.g., eVTOLs), new services (e.g., urban air mobility), and new business formats (e.g., low-altitude data trading), which are direct manifestations of the “qualitative” leap of new quality productive forces. Therefore, the low-altitude economy can be seen as an efficient converter that transforms the process of digital-real integration into outputs of new quality productive forces. Together, the three constitute a positive feedback loop driven by technological innovation and factor restructuring ^[9].

3. Multi-dimensional characteristics of low-altitude economy driving new quality productive forces development

As a typical representative and important engine of new quality productive forces, the low-altitude economy will exhibit systematic innovation at the industrial, technological, economic, and social efficacy levels, fully aligning with the core features of new quality productive forces.

At the industrial level, the low-altitude economy exhibits significant characteristics of high technology, long chains, and strong integration. It aggregates high-end equipment manufacturing, new-generation information technology, new energy, new materials, and modern services, forming an industrial chain covering the entire process of R&D, manufacturing, and operation. It possesses powerful industrial radiation and synergistic upgrading capabilities, which constitute the industrial foundation required for cultivating new quality productive forces.

At the technological level, the development of the low-altitude economy relies on the integrated innovation of frontier technologies such as eVTOLs, highly reliable flight control systems, intelligent perception and obstacle avoidance, and high-energy-density batteries ^[10]. Relevant technologies have significant spillover effects, empowering related industries like new energy vehicles and robotics, continuously injecting technological

momentum into new quality productive forces.

At the economic level, the low-altitude economy creates new supply in areas like urban air mobility, instant logistics, and low-altitude tourism, opening up a trillion-level market space. It drives a virtuous cycle of “technology-market-capital-innovation,” providing a sustainable market foundation for cultivating new quality productive forces.

At the social efficacy level, its applications in areas like emergency response and urban governance not only enhance the efficiency and precision of public services but also promote the systematic renewal of social operation and governance models, reflecting the deeper value of new quality productive forces as “high efficiency, high quality.”

4. The digital development pathways of low-altitude economy driven by digital-real integration

In practice, the low-altitude economy and digital-real integration exhibit a symbiotic and co-evolutionary relationship, manifested as a systematic reliance on and deep integration with digital technologies, data elements, and digital infrastructure, promoting the comprehensive digital reconstruction of the low-altitude economy from its foundational architecture and operational system to its industrial ecosystem.

4.1. Constructing a digital foundation, consolidating integration bedrock

The construction of the digital foundational architecture for the low-altitude economy is the physical prerequisite for digital-real integration. Low-altitude flight activities occur in a three-dimensional airspace without physical attachments, where their safe and orderly management entirely depends on digital and intelligent means. This has given rise to the concept of the “Low-Altitude Digital Foundation.” Taking Guangdong Province as an example, by integrating multi-source data such as real-scene 3D models, building/road networks, and meteorology to construct a “Low-Altitude Data Basemap,” it has achieved an upgrade of airspace management from static 2D to dynamic 3D, providing a digital basis for route planning and flight navigation.

4.2. Achieving intelligent operation, deepening the integration core

The intelligent evolution of the low-altitude operation system is the core manifestation of digital-real integration. The operation of low-altitude aircraft, especially unmanned aerial vehicles (UAVs), is a typical data-driven, software-defined process. Data permeates the entire flight lifecycle: from front-end intelligent route planning and simulation verification based on the digital foundation, mid-end real-time data closed loops via “Beidou + 5G-A + Sensors,” to back-end data analysis. Through “integrated air-space-ground monitoring” and AI decision-making, airspace management is propelled from “human-led” to “intelligent-led,” achieving dynamic optimization and allocation of airspace resources.

4.3. Promoting data circulation, unleashing integration value

The valorized circulation of low-altitude data elements is an advanced form of digital-real integration. Data generated from low-altitude operations, such as flight status, environmental perception, and mission payload, not only concern flight safety but also hold high commercial value. Promoting their productization and assetization for circulation in data exchanges under safe and compliant conditions, and fostering new data service business formats, marks the transformation of low-altitude data from an internal element to a market production factor,

completing value co-creation at the factor level between digital and real.

5. The systemic framework for empowering low-altitude economy and new quality productive forces through digital-real integration

5.1. Taking data elementization as the pivot, driving value multiplication across the low-altitude industrial chain

Data is the “blood” driving digital-real integration and the “fuel” for the low-altitude economy’s intelligence. Promoting the transformation of low-altitude data from a resource to an asset is a key pivot for cultivating new quality productive forces. For instance:

- (1) Advance data standardization and assetization: Establish unified data standard systems for geographic information, flight status, equipment health, etc., and improve mechanisms for data property rights definition, value assessment, and registration, laying the foundation for compliant data circulation;
- (2) Build a trusted low-altitude data space: Under the premise of ensuring security and privacy, establish institutional and technical environments that support trustworthy and controllable exchanges among data owners, users, and processors. Through this, enterprises can obtain desensitized operational data to optimize products, insurance companies can develop risk-based insurance products, and government departments can achieve cross-system data collaboration to enhance governance efficiency;
- (3) Innovate data products and services: Developing “congestion prediction” products for flight routes based on meteorological and traffic flow data, or training AI models for identifying power line defects using drone inspection images for external service provision. The development and trading of such data products will catalyze new business formats like the “low-altitude data industry,” becoming new growth points for the low-altitude economy and fully embodying the “digital-driven” characteristic of new quality productive forces.

5.2. Building scalable safe operation capabilities through low-altitude intelligent integrated infrastructure

The unleashing of new quality productive forces requires scalable application scenarios for support. The large-scale, high-density, and regularized operation of low-altitude aircraft is inseparable from a robust new infrastructure system, the low-altitude intelligent integrated infrastructure. This infrastructure system transcends traditional landing sites and ground control towers, as it is an intelligent system integrating communication, navigation, surveillance, computing, and services. In terms of communication, promoting the deep integration of 5G-A/6G networks with low-altitude scenarios is necessary to meet the high bandwidth, low latency, and high reliability communication demands for UAV beyond-visual-line-of-sight flight control and HD video streaming. In navigation, building a nationwide Beidou Ground-Based Augmentation Network is required to provide centimeter-level or even millimeter-level high-precision positioning services for low-altitude flights, which is fundamental for achieving precise takeoff/landing, dense formation flying, and obstacle avoidance in complex environments. In surveillance, integrating multiple sensing methods is needed to achieve “visibility, reachability, and controllability” over all legal aircraft. The completion of this infrastructure system will make low-altitude airspace a standardized, planable, measurable, and operable public service network, akin to ground road networks, significantly lowering entry barriers and operational costs for businesses, thereby stimulating numerous commercial innovations and propelling new quality productive forces across the critical leap from “demonstration pilots” to “scaled

application.”

5.3. Optimizing factor allocation and industrial synergy with a “low-altitude industrial brain” as the central hub

Drawing on the concepts of “Industrial Internet Platforms” and “Industrial Brains,” constructing a “Low-Altitude Industrial Brain” serving the low-altitude economy is a key pathway to achieve global resource optimization and industrial chain synergy. Based on cloud computing, big data, and AI technologies, this platform builds a digital governance system covering a “micro-meso-macro” three-layer architecture as follows:

- (1) At the micro level, it interfaces with real-time “Air-Intelligence-Network” data to dynamically optimize airspace resource allocation, achieve intelligent flight traffic scheduling, and alleviate regional congestion;
- (2) At the meso level, it aggregates production capacity, orders, inventory, and logistics information from upstream and downstream industry chains, promoting efficient collaboration between complete vehicle manufacturing, component supply, and operational services to enhance industrial chain resilience;
- (3) At the macro level, it provides the government with a panoramic view of industrial operations, supporting policy simulation and scientific decision-making. For example, by analyzing eVTOL vertiport usage frequency and regional demand heat, it can assist in the precise layout of infrastructure investment planning.

Through data intelligence, the “Low-Altitude Industrial Brain” integrates dispersed airspace resources, manufacturing capabilities, service demands, and regulatory systems into an organically synergistic whole, promoting the innovative allocation of production factors across a broader scope, reflecting the systematic transcendence of new quality productive forces over traditional production organization models.

6. The innovation positioning and development strategies for specialized, sophisticated, distinctive, and innovative (SSDI) SMEs

Within the emerging field of the low-altitude economy, SSDI SMEs, characterized by their specialization, sophistication, distinctiveness, and innovativeness, have become a significant force driving technology implementation, enriching application ecosystems, and activating regional development. Although they do not occupy a dominant position, their flexible mechanisms, deep cultivation capabilities, and innovative vitality play an irreplaceable structural role in the industrial value chain, specifically manifested in three following aspects:

- (1) SSDI SMEs are core explorers of niche scenario innovation and business validation. Facing highly differentiated vertical demands in areas such as agricultural plant protection, energy inspection, emergency surveying and mapping, and cultural-tourism performances, they leverage focused technical accumulation and agile responsiveness to continuously develop specialized UAV systems, intelligent operation algorithms, and customized solutions. They translate cutting-edge technologies into viable, operable business scenarios, injecting sustained application vitality into the low-altitude economy;
- (2) SSDI SMEs are deep enablers of key industry chain segments and foundational capabilities. In critical areas such as high-end sensors, high-precision navigation, lightweight structures, specialized flight control software, and testing/certification services, these enterprises often possess profound technical expertise and process accumulation, becoming indispensable “supporting experts” and “hidden champions” within the industry chain. By providing highly reliable and high-performance components and services, they strongly support the overall technological advancement and supply chain security of the entire industry;

- (3) SSDI SMEs are important promoters of regional characteristic development and ecosystem synergy. Relying on a deep understanding of local industrial foundations, resource endowments, and policy environments, they can swiftly respond to regional public service needs (e.g., river patrol, forest fire prevention) and the upgrade requirements of characteristic industries (e.g., scenic area low-altitude tours, logistics distribution within industrial parks). They promote the formation of service networks deeply integrated with the local economy, fostering the coordinated development and digital transformation of the low-altitude economy at the regional level.

However, SSDI SMEs still face multiple constraints in participating in the development of the low-altitude economy. For example, significant R&D investment, lengthy airworthiness certification cycles, shortage of interdisciplinary talent, complex airspace usage approval processes, and limited access to data channels. Therefore, a systematic support system needs to be constructed, including establishing special innovation funds, optimizing approval and access processes, promoting the orderly opening of public low-altitude data, and encouraging leading enterprises to engage in supply chain collaboration and technology sharing. This will help build an integrated innovation ecosystem characterized by “large enterprises leading small ones, small ones promoting large ones,” fully unleashing the critical role of SSDI SMEs in the process of the low-altitude economy empowering new quality productive forces.

7. Conclusion

This study systematically explores the mechanism and pathways of the low-altitude economy empowering new quality productive forces driven by digital-real integration, revealing the synergistic relationships and implementation logic among the low-altitude economy, digital-real integration, and new quality productive forces. The main conclusions are as follows:

There exists an intrinsic relationship of bidirectional mutual promotion and symbiotic co-evolution between the low-altitude economy and digital-real integration. On one hand, the development of the low-altitude economy relies on the comprehensive empowerment of digital technologies such as high-precision navigation, intelligent air traffic management, and digital twins, driving its complete digital reconstruction from foundational architecture and operational systems to the industrial ecosystem. On the other hand, the massive data and diverse scenarios generated by the low-altitude economy also provide an important testing ground and demand-pull for the iterative innovation and commercial landing of digital technologies, forming a virtuous cycle of “real driving digital, digital strengthening real.”

With its industrial attributes of high technology, long chains, and strong integration, the low-altitude economy, relying on the cluster breakthroughs and integrated innovation of frontier technologies, comprehensively aligns with and powerfully promotes the formation and development of new quality productive forces by creating new supply, opening new markets, and enhancing social operational efficiency. It is not merely a new industry but a key carrier connecting real-world demand with digital technology to achieve a qualitative leap in productive forces.

The realization of the low-altitude economy empowering new quality productive forces depends on a systematic pathway with data elementization as the pivot, intelligent integrated infrastructure as the support, and an industrial smart brain as the central hub. These three pathways are interlinked and work synergistically, collectively propelling the low-altitude economy from “demonstration pilots” to “scaled application,” completing a profound transformation from resource-driven to innovation-driven, and from localized exploration to systematic

advancement.

SSDI SMEs play an irreplaceable role in the development of the low-altitude economy. They are core explorers of niche scenario innovation, deep enablers of key industry chain segments, and important promoters of regional ecosystem synergy. Stimulating their innovative vitality and building an integrated innovation ecosystem characterized by “large enterprises leading small ones, small ones promoting large ones” is of great significance for enhancing industrial chain resilience and overall competitiveness.

However, the low-altitude economy still faces multiple challenges on its path towards high-quality development, including technology maturity, regulatory standards, infrastructure, business models, and data security. In the future, it is necessary to strengthen systematic planning at the strategic level, break through key bottlenecks at the technological level, optimize the regulatory environment at the institutional level, and promote synergistic integration at the ecosystem level. Particular attention should be paid to providing precise support for SSDI SMEs, fortifying the bottom line of safe development, and promoting the sustained and healthy evolution of the low-altitude economy, thereby injecting a robust “low-altitude kinetic energy” into the construction of Chinese modernization.

Funding

General Project of the Hunan Provincial Department of Education (Project No.: 24C0411)

Disclosure statement

The author declares no conflict of interest.

References

- [1] Chai Y, Liu J, Zhang Y, et al., 2026, How Sci-Tech Finance Empowers China’s Low-Altitude Economy: Mechanisms and Countermeasures. *Finance Research Letters*, 2026(91): 109465.
- [2] Hu Y, Zhao N, Shangguan X, et al., 2025, How Does Regional Financial Development Affect the Investment and Financing Behaviors of Low-Altitude Economy Enterprises? An Empirical Study Based on the Expansion of City Commercial Banks. *International Review of Economics and Finance*, 2025(104): 104694.
- [3] Tang J, 2026, Can Low Altitude Economy Development Bring Economic and Environmental Dividends? Evidence from Chinese Cities. *Journal of Air Transport Management*, 2026(131): 102919.
- [4] Zhou W, Zhang D, 2025, First-Mover Alliance: Mission-Oriented Innovation Policy Implementation in Shenzhen’s Low-Altitude Economy. *Cambridge Journal of Regions, Economy and Society*, 18(3): 647–662.
- [5] Ren X, Wang J, 2025, Symbiotic Evolution Mechanism of Urban Air Mobility Industrial Innovation Ecosystem: Evidence from Low Altitude Air Mobility in Shenzhen. *Journal of Air Transport Management*, 2025(124): 102750.
- [6] Li C, Wang M, 2025, Industrial Upgrading and New Quality Productive Forces: Evidence from Chinese Industrial Parks. *Frontiers in Public Health*, 2025(13): 1683019.
- [7] Liu Y, Lin C, 2025, Converting Knowledge into Productivity: The Role of Intellectual Property Empowerment and Digital Economy in Enhancing Regional New Quality Productivity Forces: Evidence from China. *International Review of Economics and Finance*, 2025(102): 104316.
- [8] Li X, Li S, Wu Q, et al., 2025, Influence Mechanism of Digital Economy on Urban Green Development Efficiency:

A Perspective on New Quality Productive Forces. *Sustainability*, 17(10): 4539.

- [9] Zhang B, Peng B, 2024, Artificial Intelligence and the Development of “Specialized, Refined, Unique, and Innovative” Small- and Medium-Sized Enterprises. *Managerial and Decision Economics*, 46(2): 843–861.
- [10] Liu D, Yang J, Zheng P, et al., 2024, Research on the Impact Exerted by Green Innovation Corporations’ Internationalization Depth on Innovation Performance and Sustainability: An Empirical Analysis Based on Data from China’s Specialized, Fine, Special, and Innovative Enterprises. *Sustainability*, 16(21): 9457.

Publisher’s note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Policy Recommendations for Optimizing the Business Environment in the Process of High-Quality Development: Evidence from Guangxi, China

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Abstract: High-quality development is the primary task in comprehensively building a modern socialist country, and advancing it requires a high-quality business environment. Focusing on the Guangxi border ethnic region that is both coastal and adjacent to national borders, this paper examines the significance of optimizing the business environment for promoting high-quality development in Guangxi. It then analyzes the current state of the business environment from three perspectives: attracting foreign investment, promoting investment, and reforming government services. The analysis identifies several salient problems, including low efficiency in administrative service approval, a lack of overall coordination and interdepartmental linkage, difficulties and high costs for micro and small enterprises to obtain financing, shortages of human resources, challenges in attracting and retaining talent, an insufficient level of digitalization, and limited resource sharing. Drawing on international experiences from Singapore and Ireland as well as domestic cases from Hong Kong and Zhejiang, this paper proposes policy measures such as deepening the “streamlining administration, delegating powers, improving regulation, and optimizing services” reform, ensuring that pro-enterprise policies are implemented in a targeted and effective manner, strengthening science- and technology-enabled financial services, enhancing mechanisms for talent cultivation and recruitment, and improving the regulatory framework and transparency. These recommendations provide a reference for building a high-quality business environment in Guangxi.

Keywords: High-quality development; Business environment; Guangxi

Online publication: February 10, 2026

1. Introduction

In his report to the 20th National Congress of the CPC, Xi Jinping made high-quality development the main goal for building a modern socialist country^[1]. During his April 2021 tour in Guangxi, he called for new methods to achieve high-quality development in border ethnic regions^[2]. On October 17, 2022, at the 20th CPC National Congress, he told the Guangxi delegation to meet the “Five Greater” requirements, stressing greater progress in high-quality development in border ethnic regions^[1]. These instructions highlight the importance of high-quality

development in Guangxi, known for its ethnic diversity and its location on China's coast and at its borders. Guangxi also leads by example for high-quality development in China's border ethnic areas.

Advancing high-quality development requires the support of a high-quality business environment. The business environment is the fertile ground for nurturing a market economy and the vital oxygen sustaining market entities. Only by further optimizing the business environment can productive forces be genuinely unleashed and competitiveness enhanced^[2]. The strengths of optimizing the business environment are threefold as follows:

- (1) It helps clarify the relationship between government and the market, enabling a better coupling of the “visible hand” and the “invisible hand,” with clearer boundaries, thereby forming an effective market and a capable government;
- (2) It helps rationalize intergovernmental relations. Vertical streamlining of administrative procedures across levels enables the delegation of administrative approval authority to grassroots departments. In key processes such as business registration and project commencement, administrative approvals have continuously lowered entry thresholds and reduced procedures and documentation requirements, substantially cutting firms' operating costs and markedly strengthening market entities' sense of gain^[3];
- (3) It helps improve relations among market entities by creating a more open and equitable market environment, further invigorating market actors and promoting fair competition and survival of the fittest^[3]. It follows that the business environment constitutes a locality's “soft power” that underpins its development “hard power”; building a sound business environment thus serves as a crucial catalyst for high-quality economic development.

Accordingly, this paper conducts an in-depth examination of how Guangxi can achieve high-quality economic development through optimizing its business environment. By analyzing the problems and challenges in Guangxi's current business environment, the paper offers targeted policy recommendations, drawing on innovative perspectives and practical guidance to support Guangxi's high-quality development. At the same time, it provides feasible experiences and insights for other ethnic regions, thereby contributing to efforts to promote more prosperous economic development in these areas.

2. The importance of optimizing the business environment for advancing high-quality development in Guangxi

High-quality development is the overarching theme of China's current development agenda and an imperative requirement for building a modern socialist country. This, in turn, places higher demands on Guangxi as a border ethnic region. A full understanding of the interactive relationship between the business environment and high-quality development is therefore of great significance for advancing high-quality development in Guangxi.

2.1. Optimizing the business environment as a key driver of Guangxi's economic transformation and upgrading

The quality of the business environment bears directly on firms' survival and development. A sound business environment can attract more high-quality enterprises to locate in Guangxi, thereby promoting the optimization and upgrading of the industrial structure. By deepening the reform of “streamlining administration, delegating powers, improving regulation, and optimizing services”, simplifying administrative approval procedures, reducing corporate costs, and improving administrative efficiency, Guangxi can further unleash market vitality and inject new momentum into its high-quality economic development.

2.2. Optimizing the business environment as a driving engine for Guangxi's innovation-driven development

A sound business environment provides essential fertile ground for innovation-driven development. By optimizing the business environment, Guangxi can stimulate firms' innovative spirit and creativity, thereby accelerating the growth of new technologies, emerging industries, and novel business models. Moreover, an improved business environment can facilitate deeper integration among industry, academia, and research, promoting the commercialization and application of scientific and technological achievements and injecting robust innovation momentum into Guangxi's high-quality development.

2.3. Optimizing the business environment as an important safeguard for enhancing Guangxi's international competitiveness

Optimizing the business environment enhances Guangxi's influence in the ASEAN region. A sound business environment can strengthen Guangxi's attractiveness to ASEAN countries, positioning it as a preferred gateway for ASEAN enterprises to enter the Chinese market. Improving the business environment can also promote deeper integration between Guangxi and ASEAN economies, particularly in industrial and supply chains. Through measures such as optimizing industrial spatial layout, improving infrastructure, and strengthening talent development, Guangxi can work with ASEAN countries to build a more closely connected industrial and supply chain system and achieve mutually beneficial, win-win development. This, in turn, will help elevate Guangxi's position in global value chains and strengthen its competitiveness in international markets.

3. The current state of business environment development in Guangxi and existing problems

3.1. Progress achieved in improving Guangxi's business environment

In recent years, Guangxi has prioritized business environment optimization as a key focus of government work. It has issued a series of policy documents, including an action plan to improve the business environment, and has implemented a range of major initiatives, such as launching the "Smart Governance Cloud" monitoring platform for Guangxi's business environment, to further enhance the region-wide business environment. The main progress can be summarized in the following three aspects.

3.1.1. Investment promotion and attraction has continued to gain momentum

In 2023, the total amount of investment actually utilized through investment promotion in Guangxi increased by 15.2% year on year. Notably, funds allocated to manufacturing projects accounted for 57.6%. As a result, the share of fixed-asset investment associated with investment-promotion projects in the region's total fixed-asset investment rose from 35.3% in 2022 to 43.0% in 2023. Among the newly added above-designated-size industrial enterprises, those introduced via investment promotion accounted for 55.2%. Furthermore, across the seven sub-areas of the China-ASEAN Industrial Cooperation Zone, 77 major projects each exceeding RMB 1 billion were newly signed, and 291 investment projects involving "four categories of '500-strong' enterprises" were concluded^[4].

3.1.2. Foreign investment in key industries has increased steadily

According to a report by the Guangxi Department of Commerce, by the end of 2023, the region's actual utilized foreign investment amounted to RMB 8.68 billion. By sector, manufacturing accounted for RMB 3.83 billion,

representing 44.12% of the total, while high-technology industries attracted RMB 3.244 billion, accounting for 37.37%. By source economy, foreign investment mainly came from Hong Kong (61.72% of the regional total), the United Kingdom (26.46%), and Singapore (7.26%)^[5].

3.1.3. Administrative and government service reforms have continued to deepen

Guangxi has continued to deepen “Internet + government services” reforms. It has established a unified regional public service platform for corporate electronic seals, issuing 16,000 electronic seals to 3,189 enterprises across Guangxi and providing e-seal signing services across government, public, and community services. In addition, the platform for implementing and delivering pro-enterprise and pro-people policies has cumulatively released 3,063 relevant policy items, offering features such as intelligent recommendations and enterprise-dedicated web portals, thereby providing enterprises with “one-stop” policy implementation services.

3.2. Existing problems and challenges

Although Guangxi has made measurable progress in improving its business environment, several issues remain and require further optimization. Based on the China Provincial Business Environment Evaluation Database, **Table 1** is compiled accordingly^[4]. The results show that Guangxi’s overall business environment index increased continuously from 2017 to 2019, indicating sustained improvement, with relatively strong performance in the market environment and government service environments. However, from 2020 to 2021, the business index declined, particularly in the government service environment and the socio-cultural environment. In terms of rankings, Guangxi still places relatively low compared with other provinces, suggesting that further strengthening is necessary.

Table 1. Business environment index and ranking in Guangxi (2017–2022)

Indicator		2017	2018	2019	2020	2021	2022
Overall business environment index		40.36	41.23	51.05	47.47	42.23	49.34
Rank		25	25	15	20	20	20
First-level indicators	Market environment	25.51	27.23	30.38	30.16	29.65	24.40
	Government services environment	51.58	46.56	63.49	60.02	44.98	54.60
	Legal and policy environment	19.79	41.29	35.68	30.07	44.48	56.96
	Humanistic environment	71.74	66.49	69.65	61.67	55.32	63.46

*Source: Peking University Open Research Data Platform.

3.2.1. Low efficiency in administrative service approvals and insufficient overall coordination

Driven by reforms to “streamlining administration, delegating powers, improving regulation, and optimizing services” and the development of e-government, the Guangxi government has made notable progress in improving the efficiency and modalities of administrative services. Although administrative approval procedures have gradually become more standardized, process optimization has mainly focused on individual departments’ approval stages, while comprehensive integration and information sharing across the end-to-end approval chain have yet to be fully realized. In practice, enterprises still encounter situations in which they must wait for one department to complete its approval before submitting materials to other departments for subsequent review and approval, resulting in long approval cycles and relatively complex procedures. Despite achieving full coverage of government service halls at the autonomous region, municipal, and county levels, departments continue to rely on

their own standalone approval systems. As a result, process improvements are largely confined to departmental stages, with insufficient cross-departmental integration and coordination ^[5].

3.2.2. Financing constraints for micro and small enterprises and high financing costs

Guangxi’s micro and small enterprises (MSEs) face significant financing constraints, shaped by the financial system’s structure. Traditional financial institutions tend to extend credit to large firms because these firms typically exhibit more stable profitability and higher credit ratings. By contrast, MSEs are smaller in scale and perceived as higher risk, making it difficult for them to obtain adequate financing through conventional channels. Credit-related issues also constitute a major driver of financing difficulties for MSEs. Owing to information asymmetries, financial institutions often struggle to accurately assess the creditworthiness of MSEs and therefore adopt a more cautious stance toward their financing needs. Consequently, even MSEs with strong growth potential may find it challenging to access sufficiently low-cost financing from the traditional financial system. According to the 2023 Statistical Communiqué on the National Economic and Social Development of the Guangxi Zhuang Autonomous Region, as of the end of 2023, the outstanding loan balance of financial institutions totaled RMB 4.98 trillion, while the outstanding balance of inclusive finance credit loans to micro and small enterprises was RMB 157.406 billion. Inclusive finance lending to MSEs accounted for only 3.16% of Guangxi’s total outstanding loans, indicating a relatively low share.

3.2.3. Insufficient human resources and difficulties in attracting and retaining talent

Based on data from the Seventh National Population Census Communiqué, this study compiles the number of people with higher education attainment in western China (**Table 2**). The results show that Guangxi has 10,806 persons per 100,000 population with a university education. Compared with other provinces in western China, this level is relatively low, lagging even behind Tibet and Guizhou. Three main factors contribute to this situation as follows:

- (1) Limited career development opportunities mean that highly qualified talent may perceive constraints on professional advancement locally and thus be more easily attracted to other regions;
- (2) Guangxi lags behind other regions in urban environments, educational resources, and healthcare services; even when talent is successfully recruited, dissatisfaction with living conditions may lead to outmigration;
- (3) The talent development system remains underdeveloped: The region lacks high-quality training and educational institutions, and talent may be unable to access local training resources aligned with their career needs, which further undermines retention.

Table 2. Number of persons with higher education in western regions. Persons / 100,000

Province	University (college and above)	Province	University (college and above)
Guangxi	10806	Shaanxi	18397
Sichuan	13267	Gansu	14506
Yunnan	11601	Qinghai	14880
Guizhou	10952	Xinjiang	17340
Tibet	11019	Ningxia	16536
Chongqing	15412	Inner Mongolia	18688

*Data source: Seventh National Population Census Bulletin

3.2.4. An insufficient level of digitalization and limited resource sharing

Guangxi's relatively low level of digitalization and constrained resource sharing are manifested in several following respects:

- (1) There are bottlenecks in digital infrastructure: Network coverage remains insufficiently widespread, particularly in some remote areas, where limited access to digital technologies restricts the smooth flow of information;
- (2) The digital transformation of both government and enterprises has progressed relatively slowly. The government's adoption of digital governance and service applications remains limited, resulting in less efficient circulation of administrative information. Meanwhile, firms' digital capabilities vary considerably; in some industries, the application of digital technologies is still limited, with insufficient digital agility and efficiency;
- (3) There is a lack of digital education and training systems. Digital literacy remains comparatively low, and employees and the public often have a limited understanding of how to apply digital technologies, which constrains progress in digital transformation;
- (4) "Information silo" problems persist: Information systems across different industries and departments lack effective interoperability, thereby limiting information sharing. Cooperation mechanisms and shared platforms among government, enterprises, and social organizations remain relatively weak, impeding cross-domain resource sharing and collaboration.

4. Lessons from domestic and international experience

This paper draws on international experience from Singapore and Ireland, and on domestic experience from Hong Kong and Zhejiang.

4.1. Singapore's "Big Government" model: A pathway of efficient governance and control

Singapore's favorable business environment, efficient legal system, highly skilled workforce, advanced shipping and logistics sector, stable political and economic conditions, and pleasant living environment are all factors that attract enterprises to choose Singapore as an operating base. According to the Economist Intelligence Unit (EIU)'s Q2 2023 business environment rankings, Singapore maintained its position as having the best business environment over the next five years. The key lessons that can be drawn are summarized as follows.

4.1.1. Electronic office operations and efficient government services

CorpPass is a digital identity authentication system provided by the Singapore government for enterprises. CorpPass enables enterprises to access multiple government and business services with a single, unique digital identity, eliminating the need to use different credentials across platforms. Moreover, enterprises can use CorpPass to assign differentiated access rights to employees, thereby enabling multi-tier authorization. This helps ensure that only authorized personnel can access sensitive information and perform specific tasks. CorpPass supports online submission of documents and applications for licenses and permits, facilitating the digital management of business processes. This improves efficiency, reduces reliance on paper-based documentation, and enables enterprises to better adapt to the requirements of the digital era.

4.1.2. Attractive tax system

Non-resident companies are exempt from corporate income tax on their taxable income for the first three years. The Singapore government has also introduced a “Double Taxation Avoidance Agreement” to protect profits earned overseas by Singaporean suppliers from double taxation. In addition to the repatriation system. Dividends, profits from foreign branches, and service fee income originating outside Singapore may be repatriated tax-free, provided such income has been taxed in the foreign tax jurisdiction in the year of repatriation or deemed repatriation, and the foreign tax jurisdiction’s income tax rate is at least 15%.

4.1.3. Strong intellectual property protection

Singapore’s intellectual property regime has ranked among the world’s leading systems for many years. Singapore has an integrated legal framework covering patents, trademarks, copyrights, and other areas, ensuring comprehensive and clearly defined legal protection for different categories of IP. The Intellectual Property Office of Singapore (IPOS) is a specialized agency dedicated to promoting innovation and strengthening IP protection. By offering expedited examination, training, and support services, IPOS helps foster enterprise innovation. For example, while obtaining a patent typically takes an average of 2 to 4 years, under Singapore’s “AI patent fast-track programme”, China’s e-commerce giant Alibaba reportedly secured an artificial intelligence patent in just 3 months. Furthermore, Singapore has institutional arrangements for the rapid resolution of IP disputes, including a court system and dispute-resolution bodies such as the Singapore International Arbitration Centre and the Singapore office of the World Intellectual Property Organization (WIPO) Arbitration and Mediation Center. The international arbitration center has also established an IP expert panel composed of IP professionals to handle various types of IP disputes.

4.2. The Irish “Demand-Driven” approach

Ireland is widely recognized as one of the world’s best destinations for foreign investment. In the World Bank’s October 2020 release of the Doing Business 2020 report, Ireland ranked 24th out of 190 economies in ease of doing business. Key lessons worth learning include as outlined.

4.2.1. Highly developed infrastructure

Ireland’s substantial investment in telecommunications and transport infrastructure has delivered on its commitment to the efficient movement of information, goods, and people. Full deregulation and a competitive telecommunications infrastructure enable enterprises to build advanced business networks. A modernized road and rail system, together with well-developed air and port networks, ensures that exports of goods and services are convenient and cost-effective.

4.2.2. Highly attractive low tax rates

Ireland’s corporate income tax rate is only 12.5%. Compared with the higher tax rates prevailing in many other countries, this has made Ireland a popular destination for multinational corporations seeking to establish headquarters or undertake investment. A lower corporate income tax rate enhances firms’ profit potential from operating in Ireland. Ireland also applies a zero capital gains tax policy for non-resident companies and for specific categories of assets, including capital gains on equities and real estate. This creates a more attractive investment environment for investors and encourages capital inflows.

4.2.3. Talented human resources

Ireland has a highly educated population, including talent with specialized training in fields such as science, technology, engineering, and mathematics. This educational profile provides enterprises with a deep pool of human capital, particularly for innovation- and high-technology-intensive sectors. As an English-speaking country, Ireland's workforce typically has strong English-language communication skills. This lowers communication barriers in cross-border collaboration and international markets, thereby facilitating the expansion of global business operations.

4.3. Hong Kong's path to freedom and openness through "Small Government"

Hong Kong's financial market is open and highly efficient, supported by a mature legal and regulatory framework, which has positioned it as one of the world's leading financial centers. Its strengths in finance, trade, and the rule of law contribute to a world-class business environment that attracts enterprises and investors from around the globe. The key lessons are as listed.

4.3.1. Open and free trade system

Hong Kong has long been committed to maintaining an open and liberal trade regime, and external trade has consistently been a pillar of its economy. Hong Kong operates a simple, transparent tariff system with no import tariffs, no goods and services tax, and no related quotas. This has made Hong Kong one of the world's most free-trade-oriented cities, enabling enterprises to engage in international trade more easily. For example, as one of Asia's largest air-cargo hubs, Hong Kong serves as a critical node in global logistics and trade, attracting many multinational corporations to establish local branches.

4.3.2. Low tax rates and tax incentives

At present, Hong Kong's standard corporate tax rate is 16.5%; for small companies, the rate is lower at 8.25% profits tax. In addition, Hong Kong implements a range of tax incentives, including tax credits, reductions, and exemptions. To encourage corporate innovation and R&D, the Hong Kong government has introduced multiple tax deduction schemes for eligible R&D expenditures. Enterprises may apply for tax deductions for R&D investments, thereby effectively reducing R&D costs.

4.3.3. A robust legal system and intellectual property protection

Hong Kong's legal system is rooted in the British common law tradition. Its independent judiciary and clear regulatory framework provide enterprises with legal stability and predictability. Hong Kong also has a well-developed regime for intellectual property protection, which supports innovation and technological advancement. Hong Kong has become one of the preferred venues for resolving international commercial disputes: through efficient and professional arbitration mechanisms, it has attracted a large number of international commercial arbitration cases to be handled in the city.

4.4. Zhejiang's reform pathway for "Getting Things Done Without Need for Connections"

As one of China's economically advanced regions, Zhejiang Province has accumulated extensive experience in optimizing the business environment. In 2023, 108 Zhejiang enterprises were listed among the "Top 500 Chinese Private Enterprises", ranking first nationwide for 25 consecutive years. Zhejiang was also among the first provinces in China to introduce a regulation on promoting the private economy. The main lessons that can be

drawn are as addressed.

4.4.1. Reform centered on the “run at most once” initiative

The Zhejiang Provincial Government spearheaded the drafting of the “Zhejiang Regulations on Ensuring the ‘One-Visit-Maximum’ Reform,” reviewed legislative proposals including the “Zhejiang Regulations on Promoting Private Enterprise Development” and the “Zhejiang Regulations on Promoting the Digital Economy,” and systematically reviewed and eliminated existing policy documents that restrict competition. These efforts aim to foster a stable, fair, transparent, and predictable business environment.

4.4.2. Promoting a close yet clean relationship between government and business

Zhejiang Province has articulated principles for government-business interactions as “closeness without overstepping boundaries, integrity without estrangement; smooth two-way communication with clear boundaries; being proactive yet mindful of constraints.” This principle requires officials, in their dealings with entrepreneurs, to maintain a constructive and supportive relationship, facilitating enterprise development and addressing practical difficulties, while also preserving integrity and probity. They must not act out of greed or self-interest, nor abuse public power for private gain. Additionally, Zhejiang has introduced a series of policies and measures to institutionalize “close and clean” government-business relations. For example, it has regulated such interactions through the “three lists” approach, which specifies prohibited behaviors and recommended practices, thereby providing clear behavioral guidance for both officials and private entrepreneurs.

4.4.3. Intelligent and precise government services

Zhejiang Province has successfully established an integrated public data exchange and sharing platform spanning provincial, municipal, and county levels. It has granted access to numerous provincial-level units and public data items for government agencies. Sharing permissions for numerous provincial units and public data items have been opened to government agencies. This has not only enhanced data sharing efficiency within the government but also strengthened the scientific rigor and precision of administrative decision-making. Simultaneously, Zhejiang has pioneered nationwide the implementation of “one-stop” online processing and electronic supervision for provincial, municipal, and county-level administrative approvals. This has not only improved operational efficiency but also facilitated convenience for citizens and businesses, achieving a transformation in government services from passive to proactive, from management-oriented to service-oriented, and toward precision-driven service delivery.

5. Policy measures for optimizing Guangxi’s business environment under high-quality development

5.1. Continuously deepening the “Streamlining Administration, Delegating Powers, Improving Regulation, and Optimizing Services” reform

The strategies are as follows:

- (1) The intensity of “delegation” should be increased by reviewing and abolishing unnecessary administrative approval items and lowering market entry barriers so that more enterprises and individuals can participate in market competition. The “separation of business licenses and permits” reform should be advanced by applying four differentiated approaches—direct cancellation of approvals, conversion of approvals to filing/

recordation, implementation of the notification-and-commitment mechanism, and optimization of market access services, so as to achieve “fewer permits after licensing” and address the long-standing problem of “being allowed to enter but not allowed to operate”;

- (2) The effectiveness of “regulation” should be enhanced by strengthening in-process and ex post supervision. A sound regulatory system for in-process and ex post oversight should be established, and the supervisory framework improved to ensure that decentralization does not lead to lax governance and that supervision is not absent. This requires building a multi-department linkage system that enables system interoperability, shared information, and joint review and approval, thereby realizing one-time processing for “one enterprise-one matter”;
- (3) The quality of “services” should be improved by advancing the standardization of government services. Government service standards should be formulated, service processes standardized and service quality and efficiency ensured. “Internet + government services” should be promoted by leveraging technologies such as the internet and big data to enable online processing of government services, so as to “let data run more and let people run less”.

5.2. Promoting the effective and fine-grained implementation of pro-enterprise policies

The measures are as listed:

- (1) A dedicated implementation mechanism should be established by setting up a specialized leading group to coordinate and advance the rollout of pro-enterprise policies. This helps ensure policy coherence and coordination, avoiding gaps or duplication during implementation;
- (2) Policy communication and training should be strengthened. Pro-enterprise policies should be widely publicized through multiple channels and formats-such as government websites, official WeChat accounts, and news media-to increase awareness. In parallel, targeted policy training should be provided for enterprises to help them better understand policy content and application procedures;
- (3) Interdepartmental coordination should be reinforced to build implementation synergy. For policies involving multiple agencies, responsibilities and division of labor should be clearly specified to prevent both “blind spots” and redundant efforts in policy execution;
- (4) A feedback mechanism should be put in place by establishing dedicated channels to collect enterprises’ opinions and suggestions regarding pro-enterprise policies. Reported problems and operational difficulties should be addressed in a timely manner, ensuring that the policies genuinely benefit enterprises.

5.3. Strengthening science- and technology-enabled financial services

Promoting deeper integration among industry, universities, and research institutes; strengthening the cultivation of technology-based enterprises; and advancing the development of science and innovation platforms can build momentum and provide strong enabling support for high-quality development through technological innovation. A one-stop “Science and Technology+” service system should be established, including dedicated science-and-technology finance service stations and a “government-university-bank-enterprise” matchmaking and cooperation platform. In addition, science-and-technology financial products should be innovated, service dossiers for technology enterprises should be developed, and collaborative “industry-university-research-finance” innovation activities should be carried out, thereby providing enterprises with science-and-technology financial services featuring “inclusive relief”, “direct support”, and “drip-irrigation-style assistance”.

5.4. Strengthening mechanisms for talent development, recruitment, and retention

Efforts should be made to “cultivate fertile soil” and to implement major talent programs. Guangxi should vigorously advance “project + team” talent initiatives through a “relocation with supporting conditions” approach, improve supporting policies, and build demonstration platforms and pilot zones for recruited talent teams, while encouraging employing organizations to innovate in the ways they recruit talent and teams. Enterprises, universities, and research institutes should be encouraged to train urgently needed and scarce talent. The training of young scientific and technological talent should be strengthened by improving a full-chain cultivation system for outstanding young professionals and continuously increasing the share of major science and technology projects led by young talents. In addition, Guangxi should explore new mechanisms for the identification, selection, cultivation, and long-term stable support of young talent, thereby enabling high-caliber human capital to inject new momentum into Guangxi’s development.

5.5. Improving the regulatory framework and enhancing transparency

Establishing a transparent and stable regulatory framework is crucial for attracting investment and strengthening business confidence. Guangxi can enhance the regulatory system and improve regulatory transparency to clarify the operating environment for enterprises and strengthen protections for their legitimate rights and interests, thereby reducing business risks arising from regulatory changes. In particular, with respect to intellectual property, Guangxi should strengthen the awareness and understanding of IP protection among law enforcement personnel, enterprises, and the general public; expand cooperation with RCEP member economies in the field of intellectual property; and align with the new RCEP trade and economic rules by promoting the establishment of local “general centers” and branch centers for overseas IP risk prevention and control. Moreover, Guangxi should further promote a service-oriented government by carrying forward the “shop assistant” ethos, implementing “nanny-style” and “smiling” services to provide enterprises with personalized, professional, and precision-targeted support, and delivering one-stop services across the entire business lifecycle.

6. Conclusion

In the course of high-quality development, formulating and implementing measures to optimize Guangxi’s business environment is a critical task, bearing directly on economic growth and innovation-driven development. Achieving this goal requires concerted efforts from the government, enterprises, and broader society to attract greater investment and foster more distinctive local industries. Only through joint action can Guangxi make more solid progress on the path toward high-quality development and make greater contributions to economic prosperity and social harmony.

Funding

Key Research Project (General Program) of the Guangxi Social Sciences Think Tank, 2025 (Project No.: Zkybkt202581)

Disclosure statement

The author declares no conflict of interest.

References

- [1] Li X, 2023, Firmly Shouldering the Heavy Responsibility of High-Quality Development. *Contemporary Guangxi*, 2023(14): 25–26.
- [2] Xi J, 2021, Xi Jinping Stresses During an Inspection Tour in Guangxi: Further Emancipate the Mind, Deepen Reform, Unite Hearts and Strength, Take Responsibility and Work Solidly, and Build a Magnificent Guangxi in the New Era of Socialism with Chinese Characteristics, *People's Daily*, April 28, 2021.
- [3] Ma L, 2022, Achievements and Experience in Optimizing the Business Environment. *China Foreign Investment*, 2022(17): 46–47.
- [4] Zhang S, Zhang Z, 2023, China Provincial Business Environment Evaluation Database 2023. Peking University Open Research Data Platform.
- [5] Wu S, 2023, A Study on High-Tech Enterprises' Satisfaction Evaluation of Guangxi's Government Affairs and Business Environment, thesis, Guangxi Minzu University.

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Virtual-Physical Symbiosis: A Study on the Sustainable Path of Digital Transformation in the Exhibition Industry

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Abstract: The traditional model of China's exhibition industry faces challenges such as high resource consumption and severe environmental pollution. Digital transformation has become an inevitable direction for the industry's high-quality development. However, the current transition is constrained by the absence of "virtual-physical symbiosis" scenarios and the lack of real-time interaction between physical and digital exhibition booths. Centered on "virtual-physical symbiosis," this paper constructs a four-dimensional theoretical framework encompassing technology, management, experience, and sustainability. By integrating the linkage mechanism between the sustainable development goals (SDGs) and the digital transformation of the exhibition industry, it analyzes the China International Import Expo as a case study. The research clarifies the technological underpinnings and tool applications for exhibition digital transformation, proposes diverse pathways for SDG implementation, and ultimately provides theoretical foundations and practical guidance for government policy formulation and corporate digital practices. This contributes to achieving green, smart, and inclusive high-quality development in the exhibition industry.

Keywords: Digital transformation of the exhibition industry; Virtual-physical symbiosis; Sustainable development; Artificial intelligence (AI); China International Import Expo

Online publication: February 10, 2026

1. Introduction

1.1. Research background

While China's exhibition industry has driven economic and trade exchanges, its traditional model faces pressing challenges such as high resource consumption and environmental pollution. Cai and Si incisively observed that the conclusion of an exhibition marks the birth of a landfill, profoundly highlighting the urgency of industry transformation^[1]. Against this backdrop, national policies such as the "14th Five-Year Plan for the Development of the Digital Economy" explicitly advocate digitalization, intelligentization, and green transformation to empower

the high-quality development of the exhibition industry. In practice, flagship events like the China International Import Expo (CIIE) have pioneered the integration of online and offline experiences by establishing the “Digital CIIE” platform. However, despite dual drivers of policy and technology, the exhibition industry’s digital transformation still faces critical research gaps. While existing studies have established preliminary analytical frameworks, deficiencies remain, namely, the absence of symbiotic virtual-physical scenarios and the lack of real-time linkage mechanisms between physical and digital booths. These shortcomings constrain the depth and sustainability of digital transformation.

1.2. Research questions and significance

Given these gaps, the exhibition industry must further explore how to achieve systematic and sustainable development during digital transformation. Specifically, how can real-time interaction mechanisms supporting “virtual-physical symbiosis” scenarios be established through technological empowerment? Addressing this question is crucial not only for the depth and breadth of the industry’s digital transformation but also for achieving synergistic economic, social, and environmental benefits.

Grounded in national strategic priorities and industry realities, this study focuses on the core theme of “virtual-physical symbiosis” within the MICE sector’s digital transformation. It aims to construct a systematic analytical framework at both theoretical and practical levels. The research outcomes are expected to provide theoretical foundations and practical guidance for government policy formulation and the digital advancement of exhibition enterprises. This work holds significant theoretical and practical implications for driving the digital transformation of the exhibition industry while contributing academic insights to promote China’s exhibition sector toward green, smart, and inclusive high-quality development.

2. Theoretical basis and analytical framework

2.1. Theoretical basis

2.1.1. The connotation and path of exhibition digital transformation

Digital transformation is a paradigm shift triggered by digital technology. It reconstructs organizational operation and value creation through the deep integration of culture, labor and technology ^[2]. In the exhibition industry, the digital transformation is reflected in the trend of online and offline integration of exhibitions, technology-enabled operations, and digitization of service processes, which promotes the evolution of exhibitions from the traditional model to the collaborative system of “virtual and real symbiosis ^[3].”

Based on the theoretical framework, the digital transformation of exhibition can be regarded as a system of co-evolution of four dimensions: technology, management, experience and sustainability. Technology drives new productivity, management realizes intelligent operation, experience meets personalized needs, and sustainability integrates green concepts. Through the keyword-exhibition digital transformation, this paper retrieves about 393 Chinese literatures in CNKI, and uses CiteSpace to analyze the co-occurrence of topics related to the keyword ‘exhibition digital transformation’. From the entire co-occurrence network map, it can be seen that the exhibition industry, digital economy, and digital exhibition are still current research hotspots (**Figure 1**). From the results of keyword emergence, it can be seen that the research heat of keywords such as ‘exhibition industry’ and ‘AI’ has increased significantly in recent years, reflecting that the digital transformation of exhibition has formed a clear research path and practical focus, which further verifies the realistic trend of multi-dimensional linkage of ‘technology-management-experience-sustainability’ (**Figure 2**).

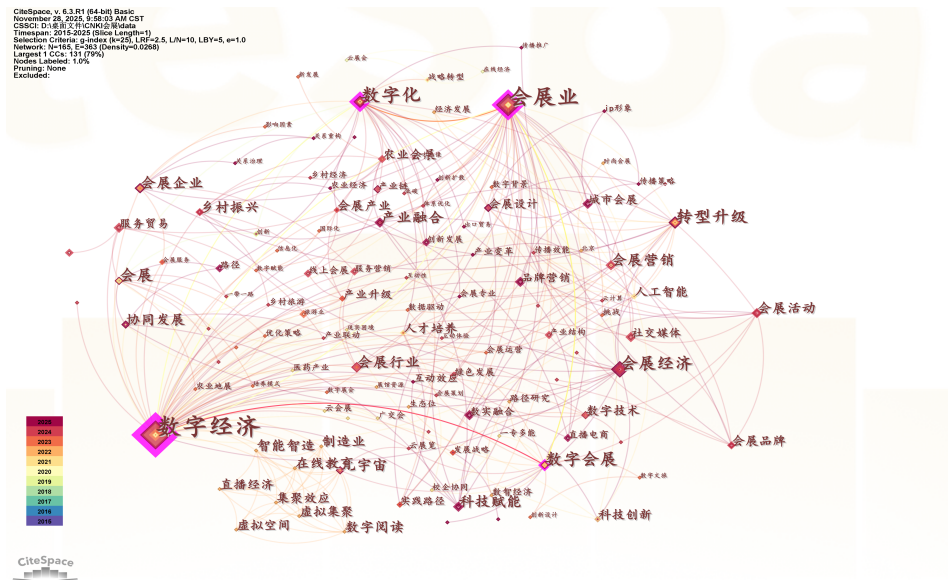


Figure 1. Keywords clustering view of digital transformation research of exhibition.

Top 7 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2010 - 2025
人工智能	2020	1.6	2020	2022	<div><div></div><div></div><div></div></div>
会展行业	2023	1.16	2023	2025	<div><div></div><div></div><div></div></div>
会展	2019	1.01	2019	2021	<div><div></div><div></div><div></div></div>
产业升级	2023	0.61	2023	2025	<div><div></div><div></div><div></div></div>
会展服务	2023	0.41	2023	2025	<div><div></div><div></div><div></div></div>
转型升级	2021	2.5	2022	2023	<div><div></div><div></div><div></div></div>
人才培养	2021	1.01	2021	2022	<div><div></div><div></div><div></div></div>

Figure 2. Research keywords emergent results (2020–2025).

2.1.2. Sustainable development theory

The theory of sustainable development emphasizes that ‘it not only meets the needs of contemporary people, but also does not constitute a harmful development to the ability of future generations to meet their needs’^[4]. In the field of exhibition, the theory extends to the comprehensive consideration of resource utilization, ecological protection and social responsibility. Taking Canton Fair as an example, Cai constructs an evaluation system of exhibition sustainable development covering six dimensions of economy, society, resources, environment, exhibition and community, and points out that economic sustainability and social sustainability are particularly important at this stage^[5]. Liu further proposed that sports exhibitions should expand their sustainable development path through market-oriented operation, brand building and ‘Internet +’ integration^[6]. From the perspective of ‘cost-benefit’, Pei *et al.* pointed out that the transformation of digital intelligence is conducive to the optimization of resource allocation and the improvement of operational efficiency of exhibition enterprises, so as to achieve the balance between economic benefits and environmental responsibilities^[7]. It can be seen that the sustainable

development of the exhibition industry not only depends on policy support and technology empowerment, but also needs to systematically integrate multiple objectives at the strategic level to promote the industry to move towards green, efficient and inclusive high-quality development.

2.2. The definition of the concept of “virtual and real symbiosis”

In the field of exhibition, “virtual and real symbiosis” refers to the “real” of physical venues, physical exhibits and real people’s participation, and the “virtual” of digital twin pavilions, virtual exhibitors and data assets. Through AI, digital twin and other technologies, the two can achieve a closed loop of “real-time mutual reflection (spatial structure with virtual reality and virtual reality)-flow mutual promotion (offline passenger flow and online flow mutual diversion)-experience mutual integration (the audience can obtain seamless experience in the continuous experience of virtual and real)”, which provides a “ theory + technology” integration path for the development of exhibition industry ^[8,9].

2.3. Construct theoretical framework

Taking “virtual and real symbiosis” as a meta-concept, the digital transformation of exhibition is regarded as an adaptive system that combines four dimensions of “technology-management-experience-sustainability” and co-evolves online and offline.

2.3.1. Technological dimension

New technology is the core engine of “new quality productivity”. New productivity emphasizes technological innovation and digital transformation, which promotes the exhibition industry to accelerate the introduction of AI, digital twin and other technologies, realize new forms such as intelligent exhibition and virtual exhibition, and improve the efficiency of the industry ^[10].

2.3.2. Management dimension

Technology empowers and reshapes the operation and management model. Li points out that digital technology is a key means of supply-side reform, which is conducive to promoting the overall transformation of the industrial chain, transforming management in the direction of intelligence, reshaping organizational management capabilities, and improving the innovation ability of the exhibition industry. Mining potential creativity plays a significant role in promoting ^[11].

2.3.3. Experience dimension

The experience economy emphasizes the relationship between the three elements of “audience-space-exhibition” to promote the integration of modern exhibition design and technology culture. The experience economy provides a path to meet the personalized and diversified consumer demand for the exhibition, enhances the audience’s sense of participation and satisfaction, and thus enhances the exhibition effect ^[12].

2.3.4. Sustainability dimension

Professor He Jun puts forward three ways to promote green exhibition design. In the whole society, we should establish green value concept, cover system norms and management system guarantee system, take “3R” principle and human care as the core level, enrich the innovative ways of green exhibition design, and help the exhibition industry to achieve sustainable development ^[13].

2.4. Basic technical support

2.4.1. Virtual reality: Creating immersive exhibition experiences

A digital technology applicable to the convention and exhibition field, which can provide participants with a brand-new online digital experience and enable exhibitors and audiences to obtain an immersive experience.

2.4.2. Augmented reality: Overlaying digital information on the real environment

A digital technology that can overlay digital information on the real environment, applicable to scenarios such as exhibition navigation and exhibit display, providing precise services and immersive experiences for exhibitors.

2.4.3. Artificial intelligence: Intelligent recommendation, customer service, and data analysis

Based on machine learning algorithms, it analyzes the data of exhibitors and professional audiences to conduct precise matching, greatly improving trade efficiency and reflecting the core logic of digital economy empowering the value creation of the convention and exhibition industry^[14]. Chatbots and virtual assistants using natural language processing technology can answer common questions at any time, freeing up human resources to focus on high-value services. Furthermore, AI can conduct in-depth mining of massive data generated during exhibitions, such as pedestrian flow and stay time, providing a scientific basis for organizers to evaluate exhibition effects, optimize venue layout, and predict future trends.

2.5. Classification and practice of application tools

Table 1 summarizes the major categories of digital tools applied in the convention and exhibition industry, including exhibition and display tools, intelligent management systems, business matching tools, data analysis tools, and safety management tools. For each category, the table outlines representative application cases, target user groups, and core functions. Overall, these tools demonstrate how digital technologies enhance immersive exhibition experiences, optimize operational management, improve business matching efficiency, support data-driven decision-making, and strengthen on-site safety management across the entire exhibition lifecycle.

Table 1. Digital tools and application scenarios in the convention and exhibition industry

Tool type	Specific applications	Target users	Main functions
Exhibition and display tools	1. Taobao Creation Festival disseminates through short videos and other media ^[15] ; 2. Louvre Museum in France builds a digital exhibition platform using high-definition image collection technology to realize immersive online display of cultural relics ^[16] ; 3. Mio Exhibition's "Net Exhibition & Trade MAX" platform realizes 3D online display of exhibits through digital modeling ^[17] .	Exhibitors, audiences	Provide immersive experience of exhibits or cultural content; break time and space limitations to display exhibition content; enhance exhibition participation experience
Intelligent management systems	1. Cloud Native Conference realizes online ticket purchase, DingTalk face-scan authentication, and paperless meetings, building a digital conference management system ^[18] ; 2. Mio Exhibition launches OA, CRM, ERP and other systems, decomposing the exhibition process into modular assembly lines to realize informatization of operation and business management; 3. Xiamen International Convention and Exhibition Center builds an intelligent energy management system, dynamically adjusting energy consumption such as venue air conditioning and lighting through AI.	Exhibition organizers, venue operators	Process automation, data integration, intelligent energy consumption regulation; improve the operational efficiency of conventions and exhibitions

Table 1 (Continued)

Tool type	Specific applications	Target users	Main functions
Business matching tools	1. Mio Exhibition's "Net Exhibition & Trade MAX" establishes an O2O shared database, integrating customs bill of lading data from 154 countries around the world to realize two-way information sharing and precise matching between buyers and sellers; 2. Mio Exhibition's "Net Exhibition & Trade Meta" adopts an online-offline dual exhibition mode, collecting the list of intended buyers from exhibitors before the exhibition and inviting precise buyers to attend.	Exhibitors, professional audiences	Precise business matching; pre-match supply and demand information; improve trade docking efficiency; reduce exhibitors' customer acquisition costs
Data analysis tools	1. The Data Command Center of Cloud Native Conference displays real-time data such as the number of participants, crowd characteristics, and venue environment through LED screens, predicting the peak of visits and exits; 2. The convention and exhibition audience flow prediction model based on big data integrates historical exhibition, social media, and macroeconomic data, predicting audience flow through algorithms such as linear regression and random forests ^[19] .	All roles	Data collection, trend analysis, decision support
Safety management tools	1. Convention and exhibition centers deploy infrared sensors, video surveillance, and AI intelligent security systems to monitor crowd density in real time, identify abnormal behaviors such as fighting and gathering, and issue early warnings; 2. The convention and exhibition audience flow early warning mechanism based on big data adopts green/yellow/orange/red graded early warning and initiates corresponding diversion and flow restriction measures.	Risk and safety management managers	Risk early warning, emergency response; ensure on-site safety of conv

3. The correlation mechanism between SDGs and the digital transformation of the exhibition industry

3.1. The corresponding relationship between SDGs and digital transformation

Digital transformation drives the innovation and upgrading of exhibition marketing models, with the help of digital technologies such as VR/AR virtual display and big data analysis, we can build online promotion systems and virtual exhibition platforms. These platforms break geographical restrictions to expand the scope of communication, and realize targeted promotion through accurate user profiles. Driven by technological innovation, this model reform not only optimizes the promotion ecosystem, but also promotes the in-depth integration of the exhibition industry and the digital industry .

The digital transformation of the exhibition industry is deeply linked to the construction of smart cities. Functions like intelligent traffic scheduling and online community interaction can be better integrated into urban development. At the same time, online exhibition platforms also provide more convenient channels for community residents. In the marketing and promotion stage, online publicity can replace traditional paper materials such as posters and brochures, and cloud exhibition halls and online live broadcasts can be used to reduce the consumption of promotion materials. This digital green marketing model not only conforms to the sustainable development concept of SDG 12, but also reduces the operation costs of exhibition marketing .

3.2. The implementation paths of SDGs in the digitalization of the exhibition industry

To put SDGs into practice, the government should formulate incentive policies and improve relevant laws and

regulations; industry associations should play a linking role and build communication platforms; exhibition enterprises should integrate the concept of SDGs into their digital strategies; and the public's awareness and acceptance of SDGs need to be raised at the social level. Technological innovation is the key point for the implementation of SDGs. We should speed up the construction of digital infrastructure, provide technical support for the achievement of SDG goals, and form a synergistic effect between green technology and digital technology. The exhibition industry needs to build a broader and more efficient service system. We should optimize online platforms by adding barrier-free functions to protect the right of special groups to participate in exhibitions; provide training and low-cost solutions for small and medium-sized enterprises to narrow the gap between different market players. Upstream and downstream industries should work together to build a sustainable development ecosystem of the industrial chain through digital transformation. We can use digital platforms to promote information sharing and resource coordination, and popularize the circular economy model.

3.3. Theoretical framework of “Master Teacher Studio”

Theoretical framework is the basis and purpose of all research. Thus, researchers are trying to find an appropriate theoretical perspective to analyze the construction process of Master Teacher Studios. According to relevant literature and monographs, the commonly used theoretical analysis perspectives in existing studies include Professional Learning Community, Learning Organization Theory, Cooperative Learning Theory, situational learning theory, Group Dynamics Theory, etc., or some researchers adopt Professional Capital Theory, Social Constructivist Theory, Distributed Leadership Theory, Action Learning Theory, Plan-Do-Check-Act Theory, etc. From the further review of relevant literature, it can be seen that most researchers tend to position the theoretical basis of Master Teacher Studio in the community model, that is, the Master Teacher Studios are essentially a kind of professional learning community, which is the localization practice in China.

4. Case analysis: China International Import Expo

4.1. Case background

Hosted by the Ministry of Commerce of the People's Republic of China and the Shanghai Municipal People's Government, the first China International Import Expo (CIIE), personally planned, proposed, deployed and promoted by President Xi Jinping, was successfully held in Shanghai, China from November 5 to 11, 2018 . China's entry into the Expo is a major decision made by China to promote high-level opening-up in the new era. A new round of scientific and technological revolution and industrial change are advancing by leaps and bounds. New technologies such as artificial intelligence and green low-carbon are developing at an unprecedented speed and scale. They have become an important force in cultivating new quality productivity, promoting quality change, efficiency change and dynamic change, and promoting industrial transformation and upgrading, economic growth, social progress and sustainable development .

4.2. Case analysis

The digital transformation of the CIIE revolves around the concept of “virtual and real coexistence”, systematically advancing from four dimensions: technology, management, experience, and sustainability. It has constructed a new exhibition ecosystem that is seamlessly integrated between online and offline, data-driven, and efficiently collaborative.

4.2.1. Technical dimension

Relying on cutting-edge technologies such as cloud computing, big data, AI, and 5G, the CIIE has built a powerful “Digital CIIE” online platform. Cloud display and cloud publishing functions break the constraints of physical space, while big data precision matching enhances the effectiveness of exhibitions. Cloud live streaming and cloud negotiation enhance interactivity. With full coverage of 5G networks, 84 base stations provide a peak rate of 10 Gbps, and AI intelligent scheduling ensures zero congestion. The unified network management platform achieves intelligent scheduling, providing a solid guarantee for the efficient operation of the exhibition.

4.2.2. Management dimension

Digital transformation has profoundly changed the operation and management model of exhibitions, enabling refined management throughout the entire process. Exhibitor registration, review, booth allocation, and other aspects have been moved online, reducing labor costs. The construction of a data platform has made data a core asset, and AI has deeply mined audience behavior data to provide market insights for organizers and optimize the layout of exhibitions.

4.2.3. Experience dimension

Digital transformation has created a new immersive, personalized, and real-time interactive participation model for all exhibitors. Exhibitors achieve “dual-channel exposure” by combining online new product launches with offline physical exhibitions. Online live streaming attracts traffic and enhances brand awareness. VR/AR technology provides a new interactive experience, and digital virtual technology expands real-life scenes. Technology products such as hearing-aid glasses allow audiences to experience the charm of technology, significantly enhancing their sense of participation and satisfaction, making the CIIE a feast of technology and culture.

4.2.4. Sustainability dimension

Promoting the zero-plastic standard, leveraging digital means to achieve paperless operations and low-carbon travel, thereby reducing the use of paper materials and carbon emissions from travel. The venues fully adopt green electricity, with 10 million kWh of green electricity reducing carbon emissions by approximately 4,200 tons. Online platforms enable more enterprises from developing countries and least developed countries to participate in global trade, promoting the construction of an open world economy.

5. Conclusion

This research takes the digital transformation of the convention and exhibition industry as the core of the research, and takes the concept of “virtual and real symbiosis” in the field of convention and exhibition as the core. That is, through AI and other technologies, the “real” elements such as exhibition physical venues and exhibits are integrated with “virtual” elements such as virtual exhibitors and data assets to form an interactive closed-loop system, and based on this, build a four-dimensional theoretical framework of “technology-management-experience-sustainability”. Taking the CIIE as a case, it relies on cloud technology, AI, etc. to realize digital transformation, build an online platform in technology, realize the refined management and operation of the whole process, create an immersive experience model, and practice the sustainable green and low-carbon concept. At the same time, the application of digital tools such as VR/AR, AI systems, etc. in all aspects of the conference and exhibition has promoted the efficiency improvement and resource optimization of the convention and exhibition

industry. And the digitalization of the convention and exhibition industry. Transformation is deeply related to SDGs, and it is also necessary to promote its implementation through policies, technologies, service systems and other paths.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Cai L, Si L, 2016, Development of Evaluation Indicators for Sustainable Exhibition and Convention Practices: A Case Study of the Canton Fair. *Journal of Guangzhou University (Social Sciences Edition)*, 15(1): 73.
- [2] Li M, Li M, Zeng B, et al., 2022, Digital Transformation of Higher Education in Developing Countries in the Post-Epidemic Era: Connotation, Dilemma and Path. *Journal of Beijing University of Technology (Social Science Edition)*, 22(1): 35.
- [3] Steud Group, 2022, Research on Business Model Innovation of Exhibition Industry Under the Background of Digital Transformation. *China Business Review*, 2022(24): 137.
- [4] Wang J, Wu J, 2014, Sustainable Development: Concept and its Significance: Our Common Future Review. *Journal of Tongren University*, 16(6): 62.
- [5] Cai L, Si L, 2016, Construction of Evaluation Index of Sustainable Development of Exhibition-Taking Canton Fair as an Example. *Journal of Guangzhou University (Social Science Edition)*, 15(1): 79.
- [6] Liu G, 2021, Research on the Development of China Sports Exhibition. *Sports Culture Guide*, 2021(3): 20.
- [7] Pei L, Yin C, Li M, 2023, Research on the Sustainable Development of the Exhibition Industry Based on the ‘Cost-Benefit’ Perspective in the Context of Digital Intelligence. *Exhibition Economy*, 2023(15): 6.
- [8] Wang Z, 2025, Application of the Theory of “Interdependence of the Real and the Imaginary” in Chinese Painting to Landscape Design, thesis, Lu Xun Academy of Fine Arts, 27.
- [9] Li N, 2008, Research on Cooperation Models for Exhibition Venues in the Yangtze River Delta Region. *Jiangsu Business Review*, 2008(9): 73.
- [10] Yang Q, Chen G, Zhang X, 2024, Research on Long-Term Mechanisms for Accelerating the Formation of New Quality Productivity through Exhibition Industry Development. *Exhibition Economy*, 2024(10): 4.
- [11] Le L, Chen C, 2024, Research on Transformation and Innovation Strategies for Exhibition Operations Management in the Digital Context. *Exhibition Economy*, 2024(1): 13.
- [12] Song L, Chen W, 2020, Discussion on Strategies for Enhancing Exhibition Design from an Experience Economy Perspective. *Architecture and Culture*, 2020(8): 138.
- [13] He J, 2011, On the Implementation Pathways for Green Exhibition Design in China. *People’s Forum*, 2011(5): 177.
- [14] Zhu J, 2025, Digitalizing the Convention and Exhibition Economy: Exploring the Value of Digital Economy to the Convention and Exhibition Industry through the China International Big Data Industry Expo. *China Convention & Exhibition*, 2025(13): 43.
- [15] Hang Y, 2019, Research on the Innovation of Convention and Exhibition Digitalization Model Promoted by Alibaba Group. *China Business & Trade*, 2019(23): 84–85.
- [16] Wang B, Wang X, Wang C, 2025, Analysis of the Development Path and Driving Mechanism of Digital Transformation in France’s Convention and Exhibition Industry. *French Studies*, 2025(3): 106.

- [17] Zhou L, Zhu Q, 2024, Analysis of the Digital Transformation Path of Convention and Exhibition Service Enterprises under the Background of Globalization Strategy: A Case Study of Zhejiang Mio Business Exhibition Co., Ltd. Special Zone Economy, 2024(10): 56–65.
- [18] Zhang X, Jin X, 2025, The Application of Artificial Intelligence in the Intelligent Construction of Convention and Exhibition Centers. Popular Standardization, 2025(19): 27–29.
- [19] Zhang B, Zhu C, 2024, Research on Exhibition Audience Flow Prediction and Evacuation Algorithms Based on Big Data Analysis. China Convention & Exhibition (China Conference), 2024(24): 53–54.
- [20] Cai L, Si L, 2016, Construction of Evaluation Indicators for Sustainable Development of Exhibitions: A Case Study of the Canton Fair. Journal of Guangzhou University (Social Science Edition), 15(1): 79.
- [21] Huang J, Liu W, Liang W, et al., 2023, Paths and Countermeasures for the Digital Transformation of China's Modern Exhibition Industry in the New Era. Journal of Commercial Economics, 2023(1): 181.
- [22] Wei W, 2019, China International Import Expo: Promoting the Development of a Higher Level of Open Economy. International Trade, 2019(1): 24.
- [23] Zheng X, Zhong H, 2024, Quality: Cooperation for Win-Win, Openness and Sharing for a Better Future: The Transformation and Sustainable Development Path in the AI Era. The 7th China International Import Expo: International Quality Innovation Forum Held. Shanghai Quality, 2024(11): 12.

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Evaluation of Green Technology Innovation Efficiency, Regional Differences and Influencing Factors of Industrial Enterprises in China: Based on a Two-Stage Perspective

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Abstract: The symposium on industrial green and low-carbon development held by the Ministry of Industry and Information Technology in January 2024 emphasized the need to steadily promote carbon reduction in the industrial sector, and improving the efficiency of green technology innovation in industrial enterprises has important practical significance in promoting their green transformation and upgrading. Therefore, this article uses inter-provincial panel data from 2005 to 2022, and constructs super efficiency EBM model, ML index model, Dagum Gini coefficient model, and spatial Durbin model to measure, decompose, analyze the sources of differences and influencing factors in the two-stage efficiency of industrial enterprises. The results show that the efficiency of technology research and development is higher than the efficiency of technology transformation, and the efficiency level of each stage is directly proportional to the economic development level of the region. The scale efficiency level of each stage remains stable at 0.9 or above, and the low pure efficiency is an important reason for the significantly low efficiency. The efficiency level of each stage shows an increasing trend from 2005 to 2022, and the efficiency level of each stage in the eastern region is higher than that of other regions. The efficiency level of China's research and development stage shows a good development trend, but there is insufficient coordination between technological efficiency and technological progress in the transformation stage, and there are significant bottlenecks in the technological progress index. The differences in efficiency levels between different stages mainly come from the differences in efficiency levels between regions, with more significant differences between the eastern region and other regions. The industrial structure and market competitiveness have a significant promoting effect on efficiency levels, while environmental regulations have a significant inhibitory effect on efficiency levels.

Keywords: Green technology innovation efficiency; Super-efficient EBM-ML model; Dagum Gini coefficient model; Spatial Durbin model

Online publication: February 10, 2026

1. Introduction

The report of the 20th Party Congress clearly puts forward that by 2035, a new type of industrialization will be basically realized, which is defined as “industrialization + informatization + intelligentization + greenization”. In January 2024, the Ministry of Industry and Information Technology held a symposium on the green and low-carbon development of industry to comprehensively promote the deployment of industrial green and low-carbon development. The meeting highlighted the necessity to steadily promote carbon emission reduction in the industrial sector, vigorously support green and low-carbon industries, help traditional industries realize green upgrading, and accelerate the pace of synergies between pollution reduction and carbon reduction. New quality productivity is a living force that can promote scientific and technological innovation, integrate and utilize factor resources, and cultivate new advantages in industrial competition, which is spawned by revolutionary breakthroughs in technology, innovative allocation of production factors, and in-depth transformation and upgrading of industries.

Since September 2023, General Secretary Xi Jinping has repeatedly emphasized the need to focus on integrating scientific and technological innovation resources, leading the development of strategic emerging industries, and promoting the in-depth transformation and upgrading of industries, so as to accelerate the formation of new quality productivity. Against the background of an industrial value added of 30.1% of GDP in 2024, new industrialization remains the main battleground for new quality productivity. Therefore, research on the efficiency of green technological innovation of industrial enterprises is of great significance in boosting the transformation and upgrading of China’s industrial enterprises to green and low-carbon.

In existing studies, efficiency measurement methods mainly use frontier analysis. The frontier analysis method contains the parametric method represented by stochastic frontier analysis (SFA) and the nonparametric method represented by data envelopment analysis (DEA), which derives a variety of improved models such as SBM and EBM. Additionally, research targets measured by efficiency are abundant, Liu *et al.* used three-stage DEA to study the innovation efficiency of state-level high-tech industrial development zones in Sichuan and Chongqing regions ^[1]. Liang *et al.* used DEA Models to measure the Efficiency of New Urbanization and Logistics Industry in Three Provinces and One City in the Yangtze River Delta Region ^[2]. Tang measured the Circulation Efficiency of the Distribution Industry in 30 Provinces, Regions and Municipalities in China with DEA-Malmquist Indexes ^[3]. Liu analyzed the financing efficiency of listed companies in the textile industry with the SBM-Malmquist index model ^[4].

Regarding the object of green technology innovation efficiency measurement, scholars mostly focus on the regional, industry and enterprise levels. At the regional level, many scholars have measured the green technology efficiency value of industrial enterprises in 30 provinces in China ^[5-8]. Yuan and Dong evaluated the industrial green technology innovation efficiency of the provinces in the Yellow River Basin by using the super-efficiency EBM model, and explored the sources of regional efficiency differences through the Dagum Gini coefficient ^[9]. Huang *et al.* used a two-stage global network SBM-DEA model to measure the efficiency of green technology innovation in agriculture ^[10]. Cao and Su used the super-efficient SBM-DEA model to measure the efficiency of green technology innovation in 30 provinces in China ^[11]. Hou used the super-efficient SBM-DEA model to measure the innovation efficiency of green transportation technology in 16 cities of Chengdu-Chongqing city cluster from 2001 to 2020 ^[12]. At the industry level, Yu *et al.* measured the technological innovation efficiency of high-tech industries by using a non-radial SBM model ^[13]. Chen measured the green technology innovation efficiency of China’s manufacturing industry by using the super-efficiency SBM model, and categorized it into three categories based on the change trend ^[14]. At the enterprise level, Lv and Ma measured the green technology

innovation efficiency by using the SFA method based on a sample of 801 observations from A-share listed industrial enterprises in China ^[15]. Wang *et al.* measured the green technology innovation efficiency of new energy enterprises with the SBM model ^[16]. Zou used a three-stage DEA model to measure the green technology innovation efficiency of industrial listed companies in Shanghai and Shenzhen main boards ^[17].

In the study of influencing factors, Fang found that factors such as environmental regulation, external technology, and industry scale are the key factors affecting the efficiency of green technological innovation in China's heavily polluted industries, among which the impact of over-reliance on external technology and policy uncertainty on industrial green technological innovation is negative ^[18]. He and Cai found that the level of green economy development, government support, enterprise revenue, and foreign investment positively affect the efficiency of green technology innovation of industrial enterprises in 27 cities in the Yangtze River Delta ^[19]. Yan *et al.* found that the degree of openness to the outside world, science and technology innovation environment has a significant positive impact on the efficiency of industrial green technology innovation in 11 provinces and municipalities of the Yangtze River Economic Belt, the industrial structure has a significant negative impact on the efficiency, the dependence on foreign investment, the market competition environment also has a negative impact on the efficiency, but not significant ^[20].

The existing literature on the efficiency of green technology innovation is also rich, but there is still much room for expansion as follows:

- (1) In terms of research methodology, the EBM mixed distance function model is used to make up for the shortcomings of the radial and non-radial models in the measurement of input-output variables;
- (2) Focusing on the spatial imbalance of green technology innovation efficiency, the Dagum Gini coefficient is utilized to reveal the source of regional efficiency differences and to solve the problem of cross overlap between groups;
- (3) From a research perspective, spatial econometric models are employed to analyze the impact of various factors on pure green technological innovation at different stages to provide a reference for innovation-driven and green transformation policies.

Based on this, the article uses inter-provincial panel data from 2005–2022 to measure, decompose, analyze the sources of differences and influencing factors of efficiency in stages by constructing the super-efficiency EBM model, ML index model, Dagum coefficient model, and spatial Durbin model, its research value can be explored from both theoretical and practical perspectives. Theoretically, this multi-model integrated analytical framework enriches the quantitative research methodology within the field. Moreover, by precisely identifying key efficiency determinants using long-term inter-provincial data, it provides new empirical evidence for green technological innovation efficiency studies. Practically, the findings offer actionable pathways for industrial enterprises to advance green transformation through existing technological innovation. They also furnish robust empirical support for policymakers seeking to optimize regional green innovation resource allocation and facilitate industrial upgrading.

This paper is structured into five sections following a logical sequence of “background-methodology-analysis-conclusions” as listed:

- (1) The introduction clarifies the research significance, reviews existing findings, and delineates the innovative direction;
- (2) It details the research methodology, indicator system, and data processing;
- (3) It measures efficiency across R&D and transformation stages, analyzing efficiency variations and regional

disparities;

- (4) It examines influencing factors through regression, robustness, and heterogeneity analyses;
- (5) It summarizes conclusions and proposes policy recommendations.

2. Research methods and data processing

2.1. Research methodology

2.1.1. Super-efficient EBM model

The article measures efficiency using a super-efficient EBM model with **Equation (1)**.

$$K^* = \min_{\theta, \eta, \lambda, s^-, s^+} \frac{\theta + \varepsilon_x \sum_{i=1}^m \frac{W_i^- S_i^-}{x_{io}}}{\eta - \varepsilon_y \sum_{r=1}^s \frac{w_r^+ s_r^+}{y_{ro}} - \varepsilon_b \sum_{q=1}^p \frac{w_q^{b-} s_q^{b-}}{b_{qo}}} \quad (1)$$

$$s. t. \begin{cases} \sum_{t=1}^T \sum_{j=1, j \neq 0}^n x_{ij}^t \lambda_j^t - s_i^- \leq \theta x_{io}, i = 1, 2, \dots, m \\ \sum_{t=1}^T \sum_{j=1, j \neq 0}^n y_{ij}^t \lambda_j^t - s_i^+ \geq \eta y_{ro}, r = 1, 2, \dots, s \\ \sum_{t=1}^T \sum_{j=1, j \neq 0}^n b_{ij}^t \lambda_j^t - s_q^{b-} \leq \eta b_{qo}, q = 1, 2, \dots, p \\ \sum_{t=1}^T \sum_{j=1, j \neq 0}^n \lambda_j^t = 1 \\ \lambda \geq 0, s_i^- \geq 0, s_i^+ \geq 0, s_q^{b-} \geq 0 \end{cases}$$

Where k^* is the optimal efficiency value, $(w_i^-, w_r^+, w_a^{b-}, s_i^-, s_r^+, s_a^{b-}, m, s, p)$ are the input element, expected outputs, weights for non-expected outputs, non-zero relaxation measures and indicators, respectively; θ is the radial conditional efficiency values; η is the output expansion ratio; ε is key parameters, indicating the degree of combination of radial and non-radial, the value range is 0~1.

2.1.2. Dagum Gini coefficient model

The Dagum Gini coefficient is used to measure the degree of geospatial imbalance^[21]. The formulas for total Gini coefficient (G), intra-group Gini coefficient (G_{jj}), inter-group Gini coefficient (G_{jh}), intra-group contribution (G_w), inter-group contribution (G_{nb}) and hypervariable density contribution (G_t) are as follows:

$$G = \frac{\sum_{j=1}^k \sum_{h=1}^k \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|}{2n^2 \bar{y}}, G_{jj} = \frac{\frac{1}{2\bar{y}} \sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |y_{ji} - y_{jr}|}{n_j^2}, G_{jh} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|}{n_j n_h (\bar{y}_j - \bar{y}_h)} \quad (2)$$

$$G_w = \sum_{j=1}^k G_{jj} p_j s_j, G_{nb} = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} D_{jh} (p_j s_h + p_h s_j), G_t = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} (p_j s_h + p_h s_j) (1 - D_{jh}) \quad (3)$$

Where (n, k) represent the number of provinces and regions that is studied; $(\bar{y}, \bar{y}_j(\bar{y}_h), y_{ji}(y_{hr}))$ are the level of efficiency of i(r) industrial firms in each province, within j(h) region and j(h) region. $p_i = n_i/n, s_i = n_i \bar{y}/n \bar{y}, D_{jh} = m_{jh} - n_{jh}/m_{jh} + n_{jh}$ represents the relative impact between regions.

2.1.3. Malmquist-Luenberger exponential model

The Malmquist-Luenberger productivity index model is able to decompose the efficiency change into two components, technical progress and efficiency improvement, as follows ^[22]:

$$ML_t^{t+1} = EC * TC = \sqrt{\frac{D_t^G(x^t, y^t, b^t)}{D_t^G(x^{t+1}, y^{t+1}, b^{t+1})} \times \frac{D_{t+1}^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})}{D_{t+1}^{t+1}(x^t, y^t, b^t)}} \quad (4)$$

$$EC = \frac{\frac{D_{t+1}^G(x^{t+1}, y^{t+1}, b^{t+1})}{D_t^G(x^t, y^t, b^t)}}{\sqrt{D_t^G(x^{t+1}, y^{t+1}, b^{t+1})/D_t^G(x^t, y^t, b^t) \times D_{t+1}^G(x^{t+1}, y^{t+1}, b^{t+1})/D_{t+1}^G(x^t, y^t, b^t)}}$$

$$TC = \sqrt{\frac{D_t^G(x^{t+1}, y^{t+1}, b^{t+1})}{D_{t+1}^G(x^{t+1}, y^{t+1}, b^{t+1})} \times \frac{D_t^G(x^t, y^t, b^t)}{D_{t+1}^G(x^t, y^t, b^t)}}$$

Where $D_t^G(x^t, y^t, b^t)$ represents the generalized distance function that takes into account the non-expected output of $b^t, (x^t, y^t)$ is the vector of inputs and the vector of desired outputs in period t. When there is no non-desired output, i.e., when $b_t = b_{t+1} = 0$, the ML index degenerates into the M index. EC refers to the index of change in technical efficiency, and TC refers to the index of change in technical progress.

2.2. Selection of indicators and data sources

2.2.1. Selection of indicators

As shown in **Table 1**, carbon dioxide and the environmental pollution index of “three industrial wastes” calculated by entropy value method are used as non-expected outputs to measure the green technology innovation efficiency of industrial enterprises and then analyzed and researched. For the robustness test, the four pollutants are re-measured and empirically analyzed for efficiency as non-expected outputs.

Table 1. Green technology innovation efficiency index system of industrial enterprises

Phase	Indicator type	Indicator name	Indicator unit
Technology development phase	Input	RD personnel	(Person)
		RD expenditure	RD internal expenditure stock (RMB 10,000)
		New product development expenditure	New product development expenditure balance (RMB 10,000)
		Total costs for technology introduction, etc.	Total accumulated expenses for technology introduction, etc. (RMB 10,000)
	Intermediate input	Number of patent applications	Piece
		Number of valid invention patents	Piece
		New product development project	Item
Results conversion phase	Energy input	Total energy consumption	10,000 tons of standard coal
	Expected output	New product sales revenue	Deflated by the industrial producer price index (10,000 yuan)
	Unexpected output	Industrial wastewater	10,000 tons
		Industrial sulfur dioxide	10,000 tons
		Industrial solid waste generation	10,000 tons
		Industrial carbon dioxide	10,000 tons
		Industrial waste pollution index	-

2.2.2. Data sources

The article utilizes panel data from 30 provinces and cities outside of Hong Kong, Macao, Taiwan, and Tibet of China's state-owned industrial enterprises from 2005–2022 to develop the analysis. The data for the article are mainly from the EPS data platform, China Science and Technology Statistical Yearbook, China Environmental Statistical Yearbook, China Statistical Yearbook, China Carbon Accounting Database, National Bureau of Statistics and provincial statistical yearbooks.

In order to eliminate the effect of inflation and the cumulative effect of the funds, the funds are deflated by the research and development price index for the base period of 2005 and then calculated by using the perpetual inventory method. The methodology for the R&D price index is: R&D price index = 0.55*consumer price index + 0.45*fixed asset investment price index. The perpetual inventory method calculates the stock as follows: $K_{it} = (1 - \delta)K_{it-1} + I_{it}$. Where K_{it} , K_{it-1} are the capital stock of province i in year t and $t-1$, respectively. δ denotes the capital depreciation rate, which is set to be 20.8%, and I_{it} denotes the actual internal expenditure of funds in province i in year t . According to the formula: $K_{i0} = I_{i0}/(g + \delta)$ calculating the capital stock in the base period [23–26].

3. Measuring and analyzing green technology innovation efficiency of Chinese industrial enterprises

3.1. Measuring the efficiency of green technology innovation

Based on the index system constructed in the previous article, the article uses IDEA Ultra software to measure the green technology innovation efficiency of industrial enterprises in each province of China from 2005 to 2022.

3.1.1. Analysis of technological innovation efficiency in the R&D stage

As shown in **Table 2**, the average values of total green technology R&D efficiency, pure green technology R&D efficiency and scale efficiency of industrial enterprises are 0.848, 0.920 and 0.922 respectively. At the provincial level, seven of the top ten rankings for total technology R&D efficiency are in the east, two in the center, and one in the west. Among the ten provinces and cities ranked lower, six are in the west, two in the northeast, one in the center, and one in the east, indicating the spatial imbalance in the efficiency of green technology R&D in various regions of China. Scale efficiency is low in Guizhou, Gansu, Qinghai, Ningxia, Xinjiang and Hainan, especially in Qinghai and Hainan. The pure technology R&D efficiency levels in Hainan and Qinghai are 1.002 and 0.926 respectively, but the corresponding scale efficiencies are 0.798 and 0.773 respectively, with a serious mismatch between pure technology R&D efficiency and scale efficiency. Hainan, due to its relatively remote geographical location, making enterprises face certain difficulties in the expansion of off-island markets, to a certain extent, constraints on the scale of the efficiency of technology research and development in Hainan.

In addition, the relatively late start of Hainan's industry and the insufficient capacity of the industrial system and industrial support will also make it impossible to realize the economies of scale of technological research and development through large-scale industrialization. At the regional level, the technical efficiency of East continues to have the highest level. In terms of longitudinal evolutionary trends, all regions showed a more pronounced and consistent upward trend in technology R&D efficiency over the study period, as shown in **Figure 1**.

Table 2. Green technology R&D innovation efficiency of industrial enterprises

Province	Efficiency of scale	Pure technical R&D efficiency	Overall technical R&D efficiency	Ranking
Beijing	0.952	0.956	0.911	3
Tianjin	0.947	0.945	0.894	7
Hebei	0.935	0.901	0.843	17
Shanghai	0.977	0.923	0.902	6
Jiangsu	0.974	0.934	0.91	4
Zhejiang	0.968	0.948	0.918	2
Fujian	0.94	0.905	0.852	14
Shandong	0.969	0.921	0.893	8
Guangdong	0.968	0.982	0.951	1
Hainan	0.798	1.002	0.798	24
Shanxi	0.914	0.87	0.797	25
Anhui	0.941	0.959	0.903	5
Jiangxi	0.925	0.9	0.834	20
Henan	0.931	0.913	0.851	16
Hubei	0.938	0.92	0.864	12
Hunan	0.927	0.937	0.87	10
Liaoning	0.961	0.887	0.853	13
Jilin	0.941	0.865	0.816	23
Heilongjiang	0.914	0.901	0.825	22
Inner Mongolia	0.893	0.857	0.767	29
Guangxi	0.928	0.899	0.835	19
Chongqing	0.943	0.917	0.866	11
Sichuan	0.929	0.956	0.888	9
Guizhou	0.886	0.948	0.841	18
Yunnan	0.898	0.923	0.829	21
Shanxi	0.924	0.922	0.852	15
Gansu	0.882	0.903	0.795	26
Qinghai	0.773	0.926	0.715	30
Ningxia	0.842	0.939	0.79	27
Xinjiang	0.874	0.899	0.785	28
Eastern Region	0.943	0.942	0.887	
Central region	0.929	0.917	0.853	
Western Region	0.888	0.917	0.815	
Northeast Region	0.939	0.884	0.831	
National level	0.920	0.922	0.848	

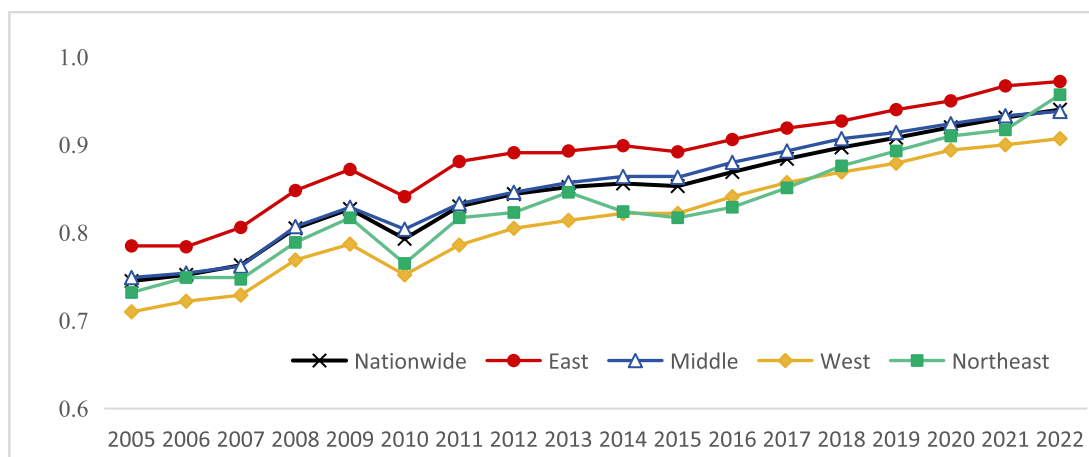


Figure 1. Trends in technology R&D efficiency by region.

3.1.2. Analysis of the efficiency of technological innovation at the transformation stage

As shown in **Table 3**, the average values of technology conversion efficiency, pure technology conversion efficiency and scale efficiency are 0.689, 0.752 and 0.920 respectively. The conversion efficiency is much lower than the efficiency of technology research and development, mainly caused by the low efficiency of pure technology conversion, and the value of conversion efficiency in each region from east to west shows a decreasing trend. At the provincial level, in the top ten regions ranked in terms of technology transformation efficiency, only the east accounted for eight, with the remaining two being Jilin Province in the northeast and Chongqing in the west, and among the bottom ten regions, the west accounted for eight, with the other two being Shanxi in the center and Heilongjiang in the northeast. The eastern part of the country continues to have significant advantages in technology transformation, but among them, Shanghai, Jiangsu, Zhejiang, Shandong and Guangdong are the five lowest ranked regions in terms of scale efficiency, which may be due to the fact that the eastern part of the country is rich in innovation resources, such as talents, scientific research institutes, and outstanding enterprises, which makes the resources dispersed.

In addition, the diversified and individualized market demands in developed regions make it difficult to achieve large-scale standardized production for technology transformation. At the regional level, the scale efficiencies of the central, western and northeastern regions are equal and slightly higher than those of the eastern region, but the pure technical transformation efficiencies of all three are significantly lower than those of the eastern region, with the largest difference between the pure technical transformation efficiencies of the eastern region and those of the western region. Compared with the eastern region, the western region's degree of opening up to the outside world, market development are relatively weak, information is relatively closed, access to cutting-edge technology and market information channels are limited, and there are few opportunities for international cooperation and exchanges, which hinders the transformation of technology.

The longitudinal evolution trend shows that the conversion efficiency in the eastern region remains high and oscillating, much higher than in the other regions, as shown in **Figure 2**. As of 2022, the Northeast's technology conversion efficiency has bounced back to exceed the national average and even surpassed that of the Central region. In recent years, Northeast China has accelerated the transformation of traditional industries into high-end, intelligent and green industries, and built growth points around strategic emerging industries, which provides a broad application prospect for technology transformation.

Table 3. Green technology transformation and innovation efficiency of industrial enterprises

Province	Efficiency of scale	Pure technical R&D efficiency	Overall technical R&D efficiency	Ranking
Beijing	0.94	0.874	0.822	1
Tianjin	0.905	0.897	0.811	3
Hebei	0.917	0.716	0.657	20
Shanghai	0.868	0.941	0.816	2
Jiangsu	0.891	0.863	0.768	7
Zhejiang	0.882	0.885	0.779	5
Fujian	0.929	0.804	0.748	10
Shandong	0.883	0.821	0.725	11
Guangdong	0.861	0.881	0.755	9
Hainan	0.934	0.841	0.781	4
Shanxi	0.94	0.660	0.621	22
Anhui	0.936	0.769	0.72	12
Jiangxi	0.937	0.750	0.7	15
Henan	0.922	0.734	0.677	17
Hubei	0.917	0.774	0.71	13
Hunan	0.918	0.772	0.708	14
Liaoning	0.917	0.745	0.684	16
Jilin	0.918	0.849	0.778	6
Heilongjiang	0.938	0.651	0.608	24
Inner Mongolia	0.931	0.662	0.614	23
Guangxi	0.946	0.711	0.672	18
Chongqing	0.922	0.823	0.76	8
Sichuan	0.927	0.716	0.665	19
Guizhou	0.952	0.607	0.577	28
Yunnan	0.951	0.631	0.600	25
Shanxi	0.95	0.666	0.633	21
Gansu	0.935	0.642	0.594	26
Qinghai	0.857	0.66	0.561	29
Ningxia	0.937	0.629	0.585	27
Xinjiang	0.93	0.579	0.536	30
Eastern Region	0.901	0.852	0.766	
Central region	0.928	0.743	0.689	
Western Region	0.931	0.666	0.618	
Northeast Region	0.925	0.748	0.690	
National level	0.920	0.752	0.689	

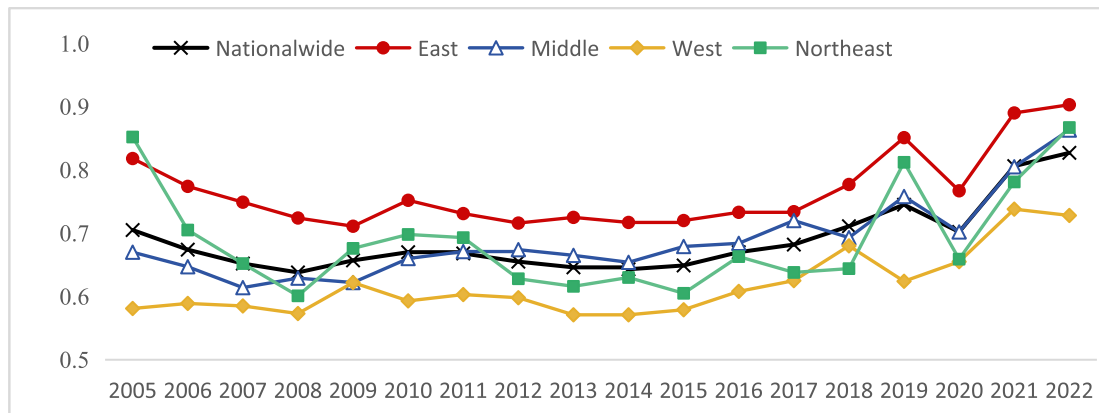


Figure 2. Trends in technology transfer efficiency by region.

3.2. Malmquist-Luenberger index analysis

The efficiency level was measured and analyzed in the previous section, and the ML index in this section is able to decompose the efficiency change into two parts: technological progress and efficiency improvement, which helps to clarify whether the increase in the efficiency of green technological innovation is originated from the improvement of the technological level or the improvement of the efficiency of resource utilization and other efficiency in the production process, so as to analyze the intrinsic mechanism of the efficiency change in a more in-depth manner.

3.2.1. Malmquist-Luenberger index analysis of the R&D phase

As shown in **Figure 3**, the ML index and technical progress index of the 30 provinces in the R&D stage are all greater than 1, and the efficiency change index and technical progress index are all distributed below the ML index, indicating that the relationship between technical efficiency and technical progress is coordinated in all regions in the R&D stage, and the overall development of China's green technology R&D efficiency is good.

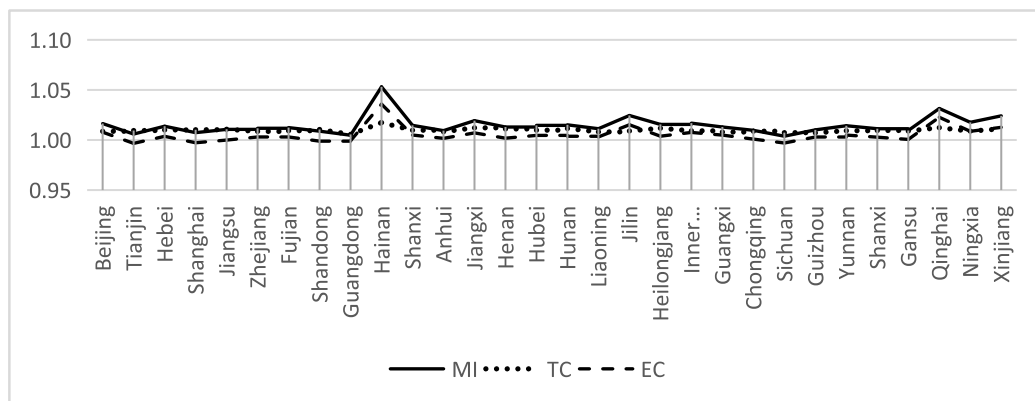


Figure 3. ML index decomposition of technology R&D efficiency in each province.

3.2.2. Dynamic analysis of the Malmquist-Luenberger index at the transformation stage

As shown in **Figure 4**, there are 18 provinces with ML indexes less than 1 at the transformation stage, of which 13 provinces, including Hebei, Fujian, Shanxi, and Jiangxi, are caused by the technical regression index less than 1. Hainan is caused by the technical efficiency index less than 1, mainly caused by the decline of technical efficiency, and Tianjin, Shanghai, and Jilin are caused by both the technical efficiency index and the technical progress index less

than 1, caused by the combination of technological regression and the decline of technical efficiency. The technical efficiency index is higher than the technical progress index in most regions, and the gap between the technical efficiency index and the technical progress index is more significant in the central, western and northeastern regions.

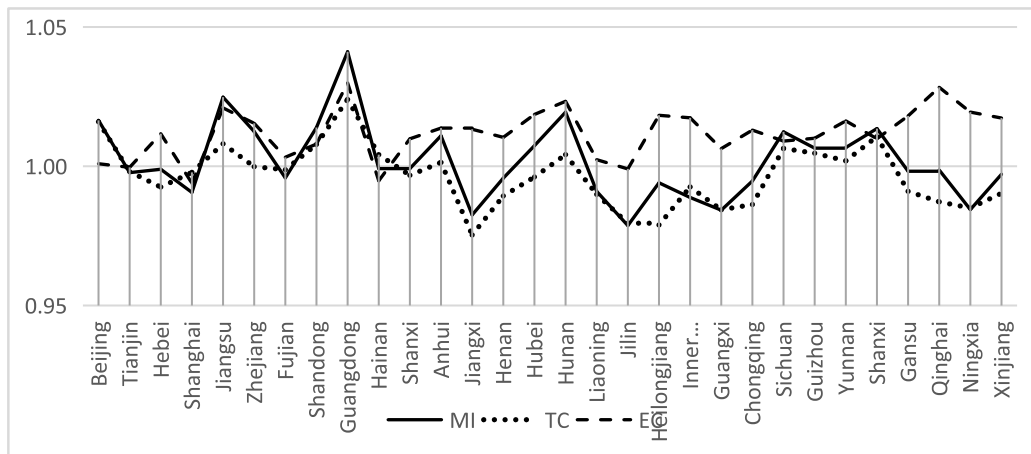


Figure 4. ML index decomposition of the efficiency of technological transformation in each province.

3.3. Decomposition of regional differences in green technology innovation efficiency

This section calculates and decomposes the regional differences in green technology innovation efficiency, R&D efficiency and transformation efficiency of industrial enterprises in 30 provinces of China from 2005 to 2022 by applying the Dagum Gini coefficient decomposition method through stata software.

3.3.1. Decomposition of regional differences in green technology R&D efficiency

As shown in **Table 4**, the total Gini coefficient shows a decreasing trend, which is from 0.053 to 0.023, and the efficiency differences within and between regions also show a decreasing trend, The degree of spatial differentiation of efficiency within the four regions is West > East > Center > Northeast, and differences in efficiency are the greatest between the eastern and western regions. The average contribution of interregional efficiency differences in the R&D phase (57.278%) remains much larger than the average contribution of intraregional differences (23.722%) and the average contribution of hypervariable density differences (19.002%).

Table 4. Gini coefficient and decomposition of green technology R&D efficiency in industrial enterprises

Year	Gini coefficient	Contribution		
		Gw	Gnb	Gt
2005	0.053	25.525	43.880	30.637
2006	0.060	25.830	31.533	42.637
2007	0.054	25.327	43.591	31.082
2008	0.044	24.434	50.710	24.856
2009	0.042	24.469	56.166	19.365
2010	0.045	24.658	57.574	17.768
2011	0.043	24.319	61.309	14.372
2012	0.039	24.659	59.631	15.709

Table 4 (Continued)

Year	Gini coefficient	Contribution		
		Gw	Gnb	Gt
2013	0.035	24.529	60.331	15.140
2014	0.037	24.064	57.799	18.137
2015	0.036	24.445	55.685	19.870
2016	0.033	23.819	57.277	18.904
2017	0.029	23.024	58.883	18.093
2018	0.026	23.100	60.437	16.463
2019	0.024	22.827	65.667	11.505
2020	0.021	21.872	68.249	9.880
2021	0.023	20.581	71.277	8.142
2022	0.023	19.519	71.007	9.474
Mean	0.037	23.722	57.278	19.002

3.3.2. Decomposition of regional differences in green technology transfer efficiency

As shown in **Table 5**, the average value of the total Gini coefficient, the average value of the Gini coefficient within each region and the average value of the Gini coefficient between regions are significantly larger in the technology transformation stage than in the R&D stage. The degree of spatial differentiation within each region is presented as Northeast > West > East > Center. The differences in the efficiency of technology transfer are the largest between the East and the West. Differences in conversion efficiency mainly come from inter-region, and the average contribution of inter-regional differences to the total differences even reaches 64.773%, which is much higher than the average contribution of intra-region (20.335%) and the average contribution of hypervariable density (14.897%).

Table 5. Gini coefficient and decomposition of green technology transformation efficiency of industrial enterprises

Year	Gini coefficient	Contribution		
		Gw	Gnb	Gt
2005	0.113	18.115	75.064	6.821
2006	0.097	20.636	66.422	12.942
2007	0.083	20.406	69.856	9.738
2008	0.076	16.940	71.101	11.958
2009	0.066	22.808	48.829	28.363
2010	0.079	17.691	70.058	12.251
2011	0.073	21.730	61.050	17.220
2012	0.070	22.278	60.068	17.653
2013	0.074	18.214	74.593	7.193
2014	0.074	19.292	70.471	10.237
2015	0.078	18.946	66.460	14.594

Table 5 (Continued)

Year	Gini coefficient	Contribution		
		Gw	Gnb	Gt
2016	0.071	21.110	61.037	17.853
2017	0.067	20.830	58.156	21.105
2018	0.060	24.855	58.646	16.499
2019	0.095	16.817	74.702	8.481
2020	0.064	22.674	57.723	19.603
2021	0.075	23.456	57.925	18.619
2022	0.077	19.234	63.744	17.022
Mean	0.077	20.335	64.773	14.897

4. Research on the influencing factors of green technology innovation efficiency of Chinese industrial enterprises

4.1. Variable selection

The government is the one who formulates and implements environmental protection policies, green development strategies and technical standards, the enterprise is the direct implementer of green technological innovation, and the market is an important testing ground for green technological innovation, and the three constitute a dynamic innovation ecosystem. Therefore, this paper researches the influencing factors of pure green technology innovation efficiency of industrial enterprises from these three aspects, and the specific indicators selected are shown in **Table 6**.

Table 6. Impact factors and their measurement indicators

Symbol	Variable	Variable measure	Unit
RDPI	Human resource investment	The ratio of personnel in R&D institutions of large-scale industrial enterprises to the number of R&D institutions in large-scale industrial enterprises	person/individual
RDI	Research and development expenditure	The proportion of internal expenditure on R&D funding above the specified standard in total industrial output value	%
SC	Company size	The ratio of total assets of large-scale industrial enterprises to the number of large-scale industrial enterprises	Ten thousand yuan per unit
GOV	Government support	Proportion of government funds in internal R&D expenditure of industrial enterprises above designated size	%
ST	Degree of nationalization	Main business income of state-owned and state-controlled industrial enterprises / Main business income of large-scale industrial enterprises within the region	%
ER	Environmental Regulation	Industrial pollution control investment as a percentage of GDP	%
MC	Market competitiveness	Number of industrial enterprises above designated size Take the logarithm	Individual
RDC	R&D competitiveness	Number of large-scale industrial enterprises with R&D institutions / Number of large-scale industrial enterprises with R&D activities	%
FDI	Foreign investment	Foreign direct investment as a percentage of GDP	%
IS	Industrial structure	Secondary industry GDP as a percentage of GDP	%
EL	Level of education	The proportion of undergraduate students enrolled in regular higher education institutions relative to the region's permanent resident population at year-end	%

4.2. Model construction

The general form of the Spatial Durbin Model (SDM) is as follows:

$$y_{it} = \alpha + \rho W_{ij} y_{it} + \beta x_{it} + \lambda W_{ij} x_{it} + \mu_i + v_t + w_{it} \quad (5)$$

Where α is constant term, (ρ, λ) are the spatial lag term coefficients, β is the coefficient of the explanatory variable, W_{ij} is spatial weighting matrix, the text refers to the spatial geographic distance square matrix and the spatial geographic distance matrix, $(\rho W_{ij} y_{it}, \lambda W_{ij} x_{it})$ represent the spatial lag term of the explained and explanatory variables, (μ_i, v_t, w_{it}) represent the individual, time fixed effects, and error terms, respectively.

4.3. Model checking

As shown in **Table 7**, the Moran's index test is significant at the 10% level, indicating that the non-spatial panel model regression results are not sufficiently reflective of the true state of the economy. The p-value of SEM test, robust SEM test, SAR test, and robust SAR test in the LM test is less than 0.1, indicating that both models are applicable. The LR model test p-value is less than 0.1 and the spatial Durbin model outperforms the spatial error model and the spatial lag model. Furthermore, the P -value in the LR time-individual fixed effects test was less than 0.1, and it was more reasonable to choose two-way fixed effects. The p-value in the Wald test is less than 0.1, confirming that the spatial Durbin model does not degenerate into a spatial lag and spatial error model.

Table 7. Green technology innovation efficiency spatial measurement model selection test

Spatial model testing	Research and development phase		Transformation stage	
	Value	P-Value	Value	P-Value
Moran's I	6.748	0.000	6.640	0.000
Lagrange multiplier	39.870	0.000	38.552	0.000
Robust Lagrange multiplier	10.910	0.001	12.700	0.000
Lagrange multiplier	82.640	0.000	26.252	0.000
Robust Lagrange multiplier	53.680	0.000	0.400	0.527
LR=SDM/SAR	88.480	0.000	41.29	0.000
LR=SDM/SEM	88.680	0.000	38.77	0.000
LR-both/time	62.190	0.000	253.51	0.000
LR-both/ind	378.640	0.000	48.71	0.000
Wald-SDM/SAR	153.610	0.000	26.53	0.005
Wald-SDM/SEM	164.720	0.000	26.85	0.005

4.4. Regression analysis

Through the above model test, the article used the spatial Durbin model with double fixed effects to analyze the various factors affecting the efficiency of green pure technological innovation of industrial enterprises in China, and the results are shown in **Table 8**.

The coefficients of human resource input (RDPI) at the stage of technology R&D and $W \cdot RDPI$ are 0.092 and 0.220, respectively, and both are significant at the 5% test level, indicating that the input of human resources at the stage of technology R&D not only promotes technology R&D in the region, but also promotes technology

R&D in neighboring regions. At the stage of technological transformation, the input of human resources has a non-significant facilitating effect on the region, but a very significant inhibiting effect on neighboring regions. The investment of human resources in the region may lead to the gathering of talents, promote knowledge sharing and cooperation, optimize resource allocation, and make technological innovation and transformation more efficient. Human resource inputs from neighboring regions often compete with resource allocations in their own regions, which may lead to brain drain and competition for resources, thereby inhibiting the efficiency of neighboring regions. While human resource investment in the region improves technological R&D and innovation capabilities, this knowledge and experience tends to spill over to neighboring regions through channels such as cooperation, exchanges, and industry conferences, leading to technological R&D and innovation in neighboring regions.

R&D capital investment (RDI) has an inhibitory effect on technological R&D in the region at the R&D stage, but has a significant role in promoting technological R&D in neighboring regions at the 1% test level. Local R&D funding may inhibit local technological R&D due to allocation imbalance and path dependence, while at the same time positively promoting technological R&D in neighboring regions due to the local innovation environment that attracts attention and cooperation from them. The promotion effect of R&D capital investment on technology transformation in the region and the inhibition effect on technology transformation in neighboring regions are not obvious at the transformation stage.

The coefficient of firm size (SC) in the R&D stage is -0.144, which is significant at the 5% test level, indicating that firm size has a significant inhibitory effect on the efficiency of technological research and development, while the effect of firm size on the efficiency of technological transformation is not significant. Large firms have a certain dominant position in the market by virtue of their existing technological advantages and product lines, which may lead to a weakening of competitive pressures in the industry, and lack pressure in innovation. Enterprise size has a significant inhibitory effect on the efficiency of both technological R&D and technological transformation in neighboring regions, and this inhibitory effect suggests that in the process of enterprise development due to the monopoly effect of the market, restricted technological diffusion, or competition for talents, the development of local enterprises will have a weakening effect on the development of enterprises in neighboring regions.

The effect of government support (GOV) on technology R&D efficiency and technology transfer efficiency is insignificant and it is significant at 5% level for neighboring regions. Due to the cooperation synergy effect, enterprises in neighboring regions are more likely to form cooperation with enterprises in their own regions and take advantage of their own technological resources, government support, etc. to realize the improvement of the efficiency of technological research and development and technological transformation.

The degree of nationalization (ST) and the efficiency of technological R&D and technological transformation are significant at the 1% and 5% levels with coefficients of 0.209 and 0.480, respectively. The degree of nationalization inhibits the level of technological innovation efficiency and the efficiency of technological research and development of industrial firms in neighboring regions. Although there are some long-term institutional barriers to state-owned enterprises, state-owned enterprises have a large number of key laboratories, technology centers, talent centers, etc., which still play a leading role in innovation.

The coefficients of environmental regulation (ER) at different stages are -0.098, -0.091 and are significant at 1%, 1% and 5% test levels, respectively, indicating that environmental regulation has a significant inhibitory effect on the efficiency of both the R&D stage and the transformation stage. Environmental regulation has a negative spillover effect, and it has a significant inhibitory effect on the efficiency of technology R&D in neighboring

regions and a non-significant effect on the promotion of transformation efficiency in neighboring regions. It can be seen that environmental regulation mainly manifests in increasing compliance costs for firms, which can have a depressing effect on the development and transformation of technology. In addition, strict environmental regulatory policies in the province and city will force enterprises with high pollution levels and more difficult transformation and upgrading to move their industries to neighboring provinces and cities where environmental control is easier, adding to the pressure of local environmental pollution.

The relationship between the degree of market competition (MC) and the efficiency of technological development is not significant, and the relationship with the efficiency of technological transformation is significant at the 1% level with coefficients of 0.200 and 0.169, respectively. The coefficients of $W*MC$ for the R&D stage and the technology conversion stage are -2.354 and -1.499, respectively, and both are significant at the 1% test level. The degree of competition in the market can motivate firms to continuously improve the efficiency of technological transformation, neighboring regions may inhibit technological R&D and transformation due to over-concentration of resources or shifting of competitive pressures.

R&D competitiveness (RDC) has a significant positive contribution to technology R&D efficiency with a coefficient of 0.073 and the coefficient is significant at 5% level, while R&D Competitiveness and the technology transformation efficiency are insignificant. There is a positive spatial spillover effect of local competitiveness in technology R&D, but the effect on the efficiency of technology R&D and technology transformation in neighboring regions is not significant, with coefficients of -0.156 and -0.051, respectively.

Foreign investment (FDI) does not play a significant role in the region's technology R&D and technology transformation efficiency, but the coefficient of FDI and technology transformation efficiency is 0.246, which is significant at the 10% level, indicating that the technology and management model of foreign enterprises can positively influence neighboring regions through the relationship of human capital flow and supply chain.

The coefficients of industrial structure (IS) in the R&D and transformation stages are 0.235 and 0.133 respectively, and are significant at the 5% and 1% levels, indicating that an increase in the share of value added of the secondary industry in GDP can promote the efficiency of technological research and development and the efficiency of technological transformation. The rapid development of the secondary industry often requires technological advances and innovations to enhance competitiveness, prompting firms to engage in green technological innovations to meet regulatory and market requirements for the environment. This demand drives the rapid development of green technologies. IS can have a positive spillover effect, significantly contributing to technology development and technology transformation in neighboring regions.

The coefficient of education level (EL) at the R&D stage is 0.259 significant at the 1% level, and the coefficient of $W*EL$ is not significant, indicating that the development of education in the region can effectively lead to the improvement of the quality of workers in the region. The coefficient of EL at the stage of transformation is -0.499, which is significant at the 1% level, and the coefficient of $W*EL$ is -0.027, which has a non-significant effect, and the level of education has an inhibitory effect on the efficiency of technological transformation in the region and neighboring regions. Highly educated R&D personnel may be more inclined to theoretical innovation research, neglecting practical application transformation, commercial application transformation thus inhibiting the efficiency of technology transformation.

Table 8. Spatial Durbin regression results

Variable name	PTEC1		PTEC2	
	Main	Wx	Main	Wx
RDPI	0.092** -2.116	0.220** -2.236	0.031 -0.682	-0.271*** -2.596
RDI	-0.117 -1.449	0.600*** -3.138	0.130 -1.531	-0.172 -0.856
SC	-0.144** -2.075	-0.667*** -4.662	0.008 -0.113	-0.293* -1.956
GOV	0.012 -0.32	0.217** -2.334	-0.006 -0.151	-0.215** -2.198
ST	0.209** -2.234	-0.875*** -4.111	0.480*** -4.874	0.081 -0.356
ER	-0.098*** -2.840	-0.352*** -3.466	-0.091** -2.498	0.085 -0.799
MC	0.200 -0.918	-2.354*** -4.980	1.690*** -7.376	-1.499*** -2.946
RDC	0.073** -2.237	-0.156 -1.495	0.024 -0.683	-0.051 -0.464
FDI	0.047 -0.952	0.109 -0.911	0.010 -0.191	0.246* -1.946
IS	0.235*** -4.141	0.113 -0.893	0.133** -2.201	0.492*** -3.796
EL	0.259** -2.157	-0.088 -0.287	-0.499*** -3.940	-0.027 -0.082

4.5. Robustness analysis

The article adopts two methods to conduct robustness tests on the pure efficiency values of the R&D stage and the transformation stage respectively to ensure the credibility of the empirical results, as shown in **Table 9**. The two methods are as follows:

- (1) Replacing weights: The previous article used a spatial geographic distance square matrix for the empirical study, this article replaces the matrix with a spatial geographic distance matrix for the empirical study again and finds that the sign and significance of the data remain consistent, indicating that the results are robust;
- (2) Replacing measures of efficiency: In the previous paper, the environmental pollution indexes of industrial carbon dioxide and “industrial three wastes” were used as non-expected outputs in the efficiency measurement, but here the non-expected outputs are replaced by “industrial three wastes” and industrial pollution to conduct empirical analysis after re-measuring the efficiency, and it is found that the sign and significance of the data are still the same as that of the data and the results are robust.

Table 9. Robustness test of pure green technology innovation efficiency

Variable name	Research and development phase				Transformation stage			
	Replace weights		Replacing measures of efficiency		Replace weights		Replacing measures of efficiency	
	Main	Wx	Main	Wx	Main	Wx	Main	Wx
RDPI	0.083* -1.912	0.622** -2.442	0.092** -2.116	0.220** -2.236	0.014 -0.299	-0.544** -1.963	0.044 -1.051	-0.232** -2.414
RDI	-0.069 -0.878	2.396*** -4.793	-0.117 -1.449	0.600*** -3.138	0.103 -1.199	-0.088 -0.163	0.087 -1.112	-0.069 -0.373
SC	-0.170** -2.520	-1.515*** -4.063	-0.144** -2.075	-0.667*** -4.662	-0.015 -0.200	-0.766* -1.893	-0.026 -0.386	-0.225 -1.633
GOV	0.011 -0.29	0.731*** -2.859	0.012 -0.32	0.217** -2.334	-0.019 -0.438	-0.547** -1.984	-0.006 -0.149	-0.163* -1.810
ST	0.193** -2.086	-2.151*** -3.759	0.209** -2.234	-0.875*** -4.111	0.502*** -5.013	0.507 -0.814	0.452*** -4.986	0.072 -0.348
ER	-0.114*** -3.264	-1.041*** -4.117	-0.098*** -2.840	-0.352*** -3.466	-0.080** -2.114	0.236 -0.865	-0.085** -2.530	-0.014 -0.145
MC	0.116 -0.55	-5.428*** -4.617	0.200 -0.918	-2.354*** -4.980	1.549*** -6.775	-3.201** -2.481	1.507*** -7.156	-1.425*** -3.059
RDC	0.018 -0.527	-1.150*** -3.869	0.073** -2.237	-0.156 -1.495	0.017 -0.466	-0.128 -0.397	0.010 -0.315	-0.093 -0.915
FDI	0.085* -1.674	0.191 -0.563	0.047 -0.952	0.109 -0.911	0.048 -0.865	0.832** -2.257	0.066 -1.378	0.243** -2.088
IS	0.238*** -4.214	0.482* -1.66	0.235*** -4.141	0.113 -0.893	0.143** -2.321	1.345*** -4.357	0.155*** -2.77	0.607*** -5.052
EL	0.270** -2.274	-0.046 -0.051	0.259** -2.157	-0.088 -0.287	-0.476*** -3.691	-0.074 -0.076	-0.367*** -3.146	-0.166 -0.557

4.6. Heterogeneity analysis

The 30 provinces in China were divided into four regions, East, Central, West and Northeast, and were empirically demonstrated with the spatial Durbin regression model respectively, and the analysis results are shown in **Table 10**.

R&D personnel and industry structure in the eastern region contribute significantly to the efficiency of technological R&D, while firm size inhibits the efficiency of technological R&D at the 1% level. In the transformation phase, both R&D expenditure and industry structure contribute significantly to the level of efficiency. R&D expenditure, government support, and the degree of R&D competition in the central region are all unfavorable to the improvement of R&D efficiency, and the factors that play a significant role in contributing to the improvement are the degree of market competition and the level of education. The degree of R&D competition may lead to fragmentation of resources and manpower, hindering the efficiency of technology development. In contrast, none of the influencing factors at the transformation stage had a significant effect on the level of efficiency. Human resource investment and education level in the western region contribute significantly to the efficiency of technological R&D, and R&D expenditure and industrial structure play a significant inhibitory role.

Government support, the degree of nationalization, and the degree of market competition can significantly promote the transformation of technology, while environmental regulations and the degree of R&D competition

can hinder the transformation of technological achievements. Environmental regulation requires firms to comply with relevant environmental standards, which often requires firms to consider issues such as the cost of pollution control associated with the use of technology, and may lead to relatively less transformation of innovations for commercialization. Foreign investment, education level, degree of nationalization and environmental regulation all have a significant effect on R&D efficiency in the Northeast at the 1% level, with the first two being promotional and the latter two being inhibitory.

In the transformation stage, the investment of R&D personnel and the degree of R&D competition will inhibit the transformation of technological achievements, while the degree of nationalization, the degree of market competition and industrial restructuring will significantly promote the transformation of technology. Traditional industries in the northeast region account for a large proportion of the overall transformation and upgrading is slow, its slow economic development and high-quality talent loss make the overall quality of RD personnel to reduce, thus inhibiting the level of regional transformation efficiency level, and the improvement of the market environment can effectively promote the commercialization of technological achievements.

Table 10. Spatial heterogeneity regression results

Variable name	Eastern region		Central region		Western region		Northeast region	
	PTEC1	PTEC2	PTEC1	PTEC2	PTEC1	PTEC2	PTEC1	PTEC2
RDPI	0.103*	0.235	0.086	0.154	0.183**	0.080	0.122	-0.787***
	-1.749	-1.217	-1.259	-1.408	-2.181	-0.867	-1.125	-2.843
RDI	0.244	1.148***	-0.265**	0.003	-0.599***	0.052	0.287	-0.623
	-1.586	-3.479	-2.489	-0.017	-5.207	-0.408	-1.367	-1.192
SC	-0.499***	-0.305	-0.341	0.413	0.019	-0.022	-0.328	0.434
	-3.661	-1.141	-1.623	-1.076	-0.099	-0.103	-0.736	-0.371
GOV	0.047	-0.006	-0.127**	0.023	0.053	0.194**	-0.024	0.146
	-1.035	-0.029	-2.452	-0.289	-0.665	-2.211	-0.362	-0.86
ST	-0.124	0.139	0.193	-0.048	0.206	0.366*	-1.019***	0.947**
	-1.113	-0.292	-1.226	-0.15	-1.078	-1.741	-4.618	-2.034
ER	-0.054	-0.1	-0.026	0.195	-0.079	-0.115*	-0.200***	0.16
	-1.159	-0.453	-0.364	-1.58	-1.306	-1.713	-2.752	-0.989
MC	0.25	-1.685	0.596**	0.531	-0.175	1.195***	-0.538	3.219**
	-0.655	-0.949	-2.497	-1.645	-0.433	-2.672	-0.938	-2.148
RDC	-0.025	0.267	-0.176**	-0.045	0.075	-0.368***	-0.176	-0.934***
	-0.542	-0.993	-2.44	-0.411	-0.831	-3.737	-1.621	-3.162
FDI	-0.023	-0.272	-0.075	-0.025	-0.041	0.037	0.417***	0.499
	-0.342	-1.18	-1.134	-0.262	-0.505	-0.42	-3.191	-1.577
IS	0.451***	2.358***	-0.093	-0.195	-0.286**	-0.003	0.158	3.469***
	-2.724	-4.941	-1.063	-0.836	-2.39	-0.025	-0.518	-4.333
EL	-0.421	-0.173	1.093***	-0.451	0.438**	-0.098	1.301***	0.634
	-1.336	-0.174	-4.115	-0.959	-2.033	-0.412	-4.006	-0.83

5. Conclusions and policy implications

The article used the panel data of 30 provinces and cities in China from 2005 to 2022 to measure, decompose and analyze regional differences in green technology R&D efficiency and transformation efficiency of industrial enterprises in China by using the super-efficiency EBM model, the ML index model and the Dagum Gini coefficient model, then the article analyzed the influencing factors of pure efficiency at each stage by using the spatial Durbin model, and robustness and heterogeneity analyses were also performed, the conclusions are as follows.

Through the efficiency measurement and analysis, it is found that:

(1) Technology R&D efficiency > technology transformation efficiency, and the level of efficiency at each stage is directly proportional to the level of economic development of the region; Scale efficiency stabilized above 0.9 at all stages, and low levels of pure efficiency contributed to low levels of total efficiency.

In view of the fact that the efficiency of technology transformation is much lower than the efficiency of technology research and development, and there are bottlenecks in technological progress at the transformation stage, it is necessary to strengthen the collaborative research and development and innovation of industry-university-research, and at the same time, to focus more on the breaking down of barriers to technological transformation. Through the establishment of “R&D-pilot-industrialization” whole chain docking mechanism, enterprises are encouraged to join colleges and universities, research institutes to form industrial innovation alliances, set up special funds for technology transformation, and focus on supporting the construction of pilot platforms in new quality productivity areas such as artificial intelligence, Internet of Things, and green manufacturing. Implementing the system of “revealing a list of commanders”, focusing on necklace technologies, such as high-end chips and industrial software, and improving the transformation efficiency through market-oriented projects. Optimize the allocation of resources at the transformation stage and use digital tools (e.g., industrial Internet) to monitor the process of technology transformation in real time, reduce the mismatch of resources, and improve the efficiency of pure technology (e.g., management efficiency);

(2) The level of efficiency in all phases tends to increase from 2005–2022, with the Eastern region having a higher level of efficiency in all phases than the other regions; China’s overall stage and R&D stage efficiency levels show good development, but there is insufficient coordination between technical efficiency and technological progress at the transformation stage, and there are significant bottlenecks in technological progress. Differences in the level of efficiency at each stage come mainly from differences in the level of efficiency between regions, with more pronounced differences between the eastern region and the other regions.

Based on the fact that the efficiency level in the eastern region is much higher than that in other regions, i.e., the problem of imbalance in efficiency levels among regions, efforts should be made to promote the balanced development of regions. In the eastern region, relying on the advantages of R&D and transformation, focusing on the development of the “R&D headquarters + transformation base” model, exporting technological achievements to the central and western regions, and establishing a cross-regional benefit-sharing mechanism (e.g., technology shareholding, tax revenue sharing). Central, western and northeastern regions, undertake the transfer of technology from the east, build regional technology trading markets, and reduce the cost of transformation. Establishing an “Eastern-Western and Northeastern China Technology Transfer Fund” to support the transformation of research and development results from the east in the central, western, northern and eastern China; and establishing an “enclave economy” model, for example, by constructing industrial parks in the East in the Central and Western China, so as to achieve complementarity of resources. Promoting the twinning of city clusters such as Beijing-

Tianjin-Hebei, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area with central and western provinces to reduce regional disparities through the division of labor in industrial chains and the sharing of innovation resources.

Through analysis of influencing factors, it was found that at the national level, the degree of nationalization and industrial structure contribute significantly to the level of efficiency, environmental regulation plays a significant inhibitory role in the level of efficiency, and human resource investment, R&D competitiveness, and market competitiveness have a significant role in the efficiency of the R&D stage only, and the former two play a significant contributing role, while the latter plays an inhibitory role. The level of education plays a significant role in promoting the efficiency of the R&D stage and a significant inhibiting role in the efficiency of the transformation stage.

Based on the results of the regression analysis, it is necessary to promote the transformation of state-owned enterprises into innovative subjects, encourage central enterprises and state-owned enterprises to take the lead in forming innovation consortiums, and give play to the positive effect of the degree of nationalization on efficiency through the introduction of market-based assessment mechanisms, such as the proportion of R&D investment and the effectiveness of the transformation of the linkage between the salary. We also need to pull industrial structural adjustment with new quality productivity, accelerate the deep integration of “intelligent manufacturing + industrial Internet”, such as guiding enterprises to use cloud computing and empowering them with intelligence, relying on low-cost SaaS platforms and intelligent decision-making systems to improve production and management efficiency, building a national industrial big data platform, promoting cross-regional and cross-industry data sharing, and narrowing the regional efficiency gap and reshape the pattern of industrial development with new quality productivity. Besides, formulating “industrial green technology innovation roadmap”, such as giving low-carbon technology research and development tax breaks, improving the carbon emissions trading market mechanism, turning environmental regulatory pressure into innovation momentum, forcing enterprises to upgrade technology is still an urgent task. In addition, Through the “New Quality Productivity Talent Special Program”, focusing on cultivating “R&D + Transformation” composite interdisciplinary talents, as well as lowering the threshold of entry, strengthening intellectual property protection and other ways to consolidate the foundation of applied talents and amplify the degree of competition in the market to promote efficiency is also very important.

At the level of regional heterogeneity, each influencing factor has a different effect on the level of efficiency at each stage in the East-Central-West and Northeast regions. Based on the results of the analysis of regional heterogeneity, it is necessary to optimize the allocation of regional resources and unleash new quality productivity dynamics. In the eastern region, we will continue to consolidate our advantages in human resources and industrial structure, and attract global innovation factors through the “talent + capital + technology” integration model.

In the central region, direct government intervention should be reduced, and market vitality should be stimulated through the liberalization of industry access, the cultivation of specialized small and medium-sized enterprises, and other competitive policies that expand the autonomous decision-making power of enterprises. In response to problems such as inefficient utilization of R&D funds, a digital platform is used to fine-tune the management of funds and to regularly track the effectiveness of the use of funds. The western region should balance environmental regulation and efficiency improvement, develop green technologies such as photovoltaic, wind power and energy storage, and turn environmental pressure into low-carbon industrial advantages. The government can strengthen special subsidies and green finance to guide enterprises to adopt cleaner production technologies. Strengthening human resources development, implementing the “Western Talent Return Program”,

and relying on the Chengdu-Chongqing, Xi'an and other urban agglomerations to create a regional talent plateau. In the Northeast, foreign investment and cooperation should be expanded by taking advantage of geographic location, introducing advanced technology and management experience, and activating the dynamics of market competition. Optimizing the talent policy to curb the problem of “manpower loss”, such as through school-enterprise cooperation to train industrial workers, relying on the transformation of old industrial bases demonstration zones, to promote the deep integration of traditional industries and digital technology, such as steel, equipment manufacturing intelligent transformation.

Funding

The National Social Science Fund Project of China (Project No.: 21BJL098)

Disclosure statement

The author declares no conflict of interest.

References

- [1] Liu J, Zhang Y, Li J, et al., 2024, A Study on the Improvement of Innovation Efficiency of National High-Tech Industrial Development Zones in Sichuan and Chongqing. *Journal of Chongqing College of Arts and Sciences (Social Science Edition)*, 43(6): 80–95.
- [2] Liang W, Wang W, Liu Z, 2022, Analysis of Coupling and Coordination of New Urbanization and Logistics Industry in Yangtze River Delta. *Journal of Chongqing College of Arts and Sciences (Social Science Edition)*, 41(3): 54–69.
- [3] Tang Q, 2020, Measurement and Empirical Research on the Efficiency of Circulation Industry. *Journal of Chongqing College of Arts and Sciences (Social Science Edition)*, 39(4): 50–59.
- [4] Liu D, 2019, Research on Financing Efficiency of Listed Companies in Textile Industry based on SBM-Malmquist-Tobit Model. *Journal of Chongqing College of Arts and Sciences (Social Science Edition)*, 38(5): 24–36.
- [5] Lin S, Wang Q, Guan H, 2023, Dynamic Evaluation of Green Technology Innovation Efficiency of Chinese Industrial Enterprises. *Statistics and Decision Making*, 39(16): 163–1.
- [6] Fan D, Wu X, 2022, A Study on the Spatio-Temporal Evolution Characteristics and Coordination of Green Technology Innovation Efficiency in Chinese Industry. *Exploration of Economic Issues*, 2022(12): 1–15.
- [7] Wu K, Qu H, Pan L, et al., 2023, Evaluation of Green Technology Innovation Efficiency of Chinese Industrial Enterprises based on Malmquist Index. *Journal of Heilongjiang Engineering Institute*, 37(3): 35–39.
- [8] Wang S, Lin X, Zhang W, et al., 2023, Research on the Impact of Green Credit on the Efficiency of Green Technology Innovation in Chinese Industry. *Statistics and Information Forum*, 38(4): 88–102.
- [9] Yuan P, Dong X, 2023, A Study on Spatio-Temporal Differences and Identification of Causes of Industrial Green Technology Innovation Efficiency in the Yellow River Basin. *Journal of Jinan University (Social Science Edition)*, 33(5): 93–105.
- [10] Huang J, Ma C, Zeng G, 2025, Environmental Regulation and the Efficiency of Agricultural Green Technology Innovation: Based on a Two-Stage Perspective of Innovation. *Journal of China Agricultural University*, 30(5): 230–247.
- [11] Cao Z, Su J, 2025, Research on the Spatio-Temporal Evolution Pattern and Influencing Factors of Green Technology

- Innovation Efficiency. *Journal of Tongling College*, 24(1): 42–47.
- [12] Hou X, 2024, Spatio-Temporal Evolution of Green Transportation Technology Innovation Efficiency and Influencing Factors in Chengdu-Chongqing City Cluster. *Science and Industry*, 24(24): 61–70.
 - [13] Yu S, Wang Y, Zeng J, et al., 2021, Research on Technological Innovation Efficiency and Driving Factors of High-Tech Industries in Beijing-Tianjin-Hebei under Innovation Value Chain. *Science Decision*, 2021(7): 77–90.
 - [14] Chen A, 2023, Evaluation of Green Technology Innovation Efficiency in Chinese Manufacturing Industry under the Background of “Double Carbon”. *Modern Industrial Economy and Informatization*, 13(11): 293–296.
 - [15] Lv T, Ma C, Tang T, et al., 2023, Environmental Regulation, Technological Innovation and Energy Intensity of Industrial Enterprises. *Statistics and Decision Making*, 39(10): 59–64.
 - [16] Wang H, Ding C, Ren Z, 2025, Research on the Factors Influencing Green Technology Innovation Efficiency of Enterprises Empowered by New Quality Productivity and the Improvement Path. *Research on Coal Economy*, 45(3): 140–148.
 - [17] Zou X, 2024, The Impact of Green Financial Policy on the Efficiency of Green Technology Innovation in Industrial Enterprises. *Times Economy and Trade*, 21(12): 125–128.
 - [18] Fang Z, Bai H, Bilan Y, 2020, Evaluation Research of Green Innovation Efficiency in China’s Heavy Polluting Industries. *Sustainability*, 12(1): 146.
 - [19] He Y, Cai D, 2021, Analysis of Green Technology Innovation Efficiency and its Influencing Factors of Industrial Enterprises in Yangtze River Delta. *Chongqing Social Science*, 2021(1): 49–63.
 - [20] Yan H, Xiao J, Feng B, 2022, Evaluation of Industrial Green Technology Innovation Efficiency and Analysis of its Influencing Factors in the Yangtze River Economic Belt. *Statistics and Decision Making*, 38(12): 96–101.
 - [21] Dagum C, 1997, A New Approach to the Decomposition of the Gini Income Inequality Ratio. *Empirical Economics*, 22(4): 515–531.
 - [22] Chung Y, Färe R, Grosskopf S, 1997, Productivity and Undesirable Outputs: A Directional Distance Function Approach. *Journal of Environmental Management*, 51(3): 229–240.
 - [23] Hou J, Wang G, Chen J, 2020, External Knowledge Sourcing, Knowledge Accumulation and Green Growth of Chinese Industry: A Study of Dynamic Heterogeneous Threshold Effects. *Research Management*, 41(3): 91–100.
 - [24] Sun F, Jiang Y, 2018, Measurement of Regional R&D Capital Stock in China: 1978–2015. *Statistical Research*, 35(2): 99–108.
 - [25] Jiang Y, Sun F, 2016, Measurement of R&D Capital Stock in China: 1952–2014. *Research on Quantitative and Technical Economics*, 33(7): 112–129.
 - [26] Zhang J, Wu G, Zhang J, 2004, Estimation of Interprovincial Physical Capital Stock in China: 1952–2000. *Economic Research*, 2004(10): 35–44.

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Research on Two-Stage Capacity Configuration Optimization of Internet Dispatching Systems: From the Perspective of AI Empowerment and User Behavior

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Abstract: Against the backdrop of the rapid development of the digital economy, internet dispatching platforms such as food delivery and ride-hailing services have become key urban infrastructure. However, they generally face the core contradiction between dynamic demand fluctuations and rigid service capacity constraints. This paper decomposes the dispatching system into a two-stage closed-loop structure of “waiting and service”. Combining queuing theory principles, AI empowerment characteristics, and introducing user loss aversion psychology and reference utility features, a configuration model covering basic capacity and safety capacity is constructed to explore optimal capacity strategies under profit-oriented and welfare-oriented orientations. Numerical examples verify the model’s effectiveness. Results show that the optimal capacity consists of basic capacity and safety capacity, with the two-stage safety capacity maintaining a specific matching ratio. Moreover, AI empowerment reduces the basic capacity demand in the waiting stage but requires simultaneous optimization of service stage capacity to avoid new bottlenecks. Consequently, platform positioning and user behavior characteristics significantly affect capacity configuration efficiency. The research conclusions provide theoretical support and practical guidance for dispatching platforms to achieve refined operations and balance efficiency with user experience.

Keywords: Internet dispatching system; Capacity configuration; AI empowerment; User behavior; Queuing theory

Online publication: February 10, 2026

1. Introduction

With the deep integration of digital technology and lifestyle service scenarios, internet dispatching platforms have become the core hub connecting supply and demand sides. The market scale in fields such as food delivery, ride-hailing, and same-city instant services continues to expand. According to iResearch data, China’s

instant delivery market transaction volume exceeded 500 billion Chinese Yuan in 2023, and the daily average number of ride-hailing orders exceeded 300 million. The service capacity of dispatching platforms directly affects urban operational efficiency and residents' quality of life.

However, such platforms have always faced prominent operational pain points. For instance, the demand side exhibits significant time-period fluctuations (e.g., morning peak, dinner time), weather sensitivity (e.g., rainfall, high temperature), and sudden scenario characteristics (e.g., large-scale events, holidays). In contrast, the supply-side service capacity (service personnel, equipment resources) has rigid constraints, leading to frequent supply-demand imbalances, such as order backlogs and excessively long user waiting times during peak hours, and service personnel idleness and high operational costs during off-peak hours.

Based on this, this paper divides the internet dispatching system into two stages, "waiting-service", constructs a theoretical model of capacity configuration by combining AI technology empowerment characteristics and user loss aversion psychology, clarifies the optimal ratio of basic capacity to safety capacity, and reveals the law of coordinated matching of two-stage capacity. It provides a new solution for platforms to improve operational efficiency and optimize user experience, while supplementing empirical support for theoretical research in related fields.

2. System model and problem description

2.1. System structure

The service process of an internet dispatching system can be clearly divided into a coupled two-stage closed-loop structure as follows:

- (1) Waiting stage: From the moment a user places an order on the platform to when the order enters the system, waits to be assigned to a suitable service personnel (e.g., rider, driver), and is successfully dispatched. The core of this stage is the "queuing" and "matching" of orders;
- (2) Service stage: From the moment service personnel accept the order to completing pickup, delivery or service, and finally ending the order. The core of this stage is the "execution" and "completion" of services, which directly determines the actual throughput capacity of the system.

There is a significant interactive effect between the two stages, where the matching quality in the waiting stage affects the route efficiency in the service stage, while the capacity redundancy in the service stage determines the order backlog threshold in the waiting stage, forming a dynamic cycle of "matching-execution-feedback".

2.2. Core problems

The core goal of capacity configuration is to achieve optimal overall system efficiency through resource investment and rule design. Specifically, it is necessary to solve three types of key problems as outlined:

- (1) Proportion division between basic capacity and safety capacity: How to set the basic capacity to meet daily demand and the safety capacity to cope with peak fluctuations, balancing operational costs and service stability;
- (2) Coordinated matching of two-stage capacity: How to avoid system bottlenecks caused by excess or insufficient capacity in a single stage, and achieve dynamic adaptation between matching efficiency in the waiting stage and execution efficiency in the service stage;

- (3) Capacity reconstruction under AI empowerment: How does the efficiency improvement of AI technology in a single stage (e.g., intelligent matching, route optimization) affect the overall capacity configuration, and how to avoid new contradictions arising from technological empowerment.

3. Theoretical model construction

3.1. Basic assumptions

Based on queuing theory principles and the actual operational characteristics of dispatching systems, the following core assumptions are made:

- (1) Order arrival distribution: The effective order arrival process follows a Poisson distribution with an arrival rate λ , which is consistent with the order generation rules in scenarios such as food delivery and ride-hailing;
- (2) Service rate distribution: The matching rate μ_1 in the waiting stage and the execution rate μ_2 in the service stage both follow exponential distributions, satisfying the memoryless property;
- (3) System steady-state assumption: The service rates of both stages are greater than the order arrival rate ($\mu_1 > \lambda, \mu_2 > \lambda$) to avoid infinite order backlogs;
- (4) AI empowerment assumption: AI technology acts on the waiting stage, increasing the matching rate to $(1 + kAI) \mu_1$ ($kAI \geq 0$ is the empowerment level), while generating additional costs CAI positively correlated with the empowerment level.

3.2. Parameter definition

The definition of parameters is as listed:

- (1) Demand-side parameters: λ is the effective order arrival rate; h is the user's unit time waiting cost; V is the upper limit of the user's reservation value; p is the service price;
- (2) Supply-side parameters: μ_1 is the initial matching rate in the waiting stage; μ_2 is the execution rate in the service stage; c_1 and c_2 are the unit capacity maintenance costs of the two stages, respectively;
- (3) AI empowerment parameters: kAI is the AI empowerment level; CAI is the additional cost of AI application;
- (4) User behavior parameters: r is the user expectation coefficient; η is the user reference sensitivity, reflecting loss aversion psychology (the degree of aversion to overtime is higher than the satisfaction with early completion).

3.3. Objective function construction

3.3.1. User utility function

User utility is a core indicator of user experience, determined by the reservation value of the service, payment price, waiting cost, and the deviation between actual waiting time and expected waiting time. Considering users' loss aversion characteristics and reference utility features for waiting time, this paper constructs the following user utility function:

$$T(W_1, W_2) = V - p - h(W_1 + W_2) + \eta \left(\frac{r}{\mu_1 - \lambda} - \frac{1}{\mu_2 - \lambda} \right)$$

Where W_1 is the actual time consumed in the waiting stage, W_2 is the actual time consumed in the service stage, and the total waiting time $W = W_1 + W_2$

According to the M/M/1 model of queuing theory, the average time consumed in the waiting stage under steady state is $W_1=1/(\mu_1-\lambda)$, and the average time consumed in the service stage is $W_2=1/(\mu_2-\lambda)$. This utility function includes four core parts: the first part $V-p$ is the user's basic utility, i.e., the value obtained by the user from the service minus the paid price; the second part $h(W_1 + W_2)$ is the user's waiting cost, the longer the waiting time, the lower the user utility; the third part is the user's reference utility, reflecting the impact of the deviation between actual waiting time and expected waiting time on user utility. When the actual total waiting time is less than or equal to the expected waiting time, the user obtains positive reference utility; when the actual total waiting time is greater than the expected waiting time, the user obtains negative reference utility, and the absolute value of the negative utility is larger, reflecting the user's loss aversion psychology.

3.3.2. Platform objective function

Internet dispatching platforms have diverse operational objectives, and different platform positions and market strategies lead to different goal orientations. This paper mainly considers two typical platform objectives: profit orientation and welfare orientation, and constructs corresponding objective functions respectively as follows:

(1) Profit-oriented platforms: Taking profit maximization as the core objective, their profit comes from order revenue. Costs include waiting stage capacity maintenance costs, service stage capacity maintenance costs, and additional AI technology application costs. The profit function is:

$$\Pi = p\lambda - (c_1\mu_1 + c_2\mu_2 + CAIkAI)$$

Under profit orientation, the platform's capacity configuration strategy will give priority to balancing costs and benefits, and achieve profit maximization by reasonably adjusting the two-stage capacity and AI empowerment level.

(2) Welfare-oriented platforms: Taking social welfare maximization as the core objective, social welfare includes total user utility and platform net profit. The welfare function is:

$$SW = T(W_1, W_2)\lambda + p\lambda - (c_1\mu_1 + c_2\mu_2 + CAIkAI)$$

Welfare-oriented platforms pay more attention to user experience and overall system efficiency. Their capacity configuration strategy will seek a balance between user utility and platform costs, appropriately sacrificing part of the profit to improve user experience and social welfare.

3.4. Derivation of optimal capacity configuration

To solve the optimal capacity configuration strategy under different goal orientations, this paper uses the Lagrange multiplier method to solve the extreme value of the objective function. In the solving process, the waiting time in the user utility function is replaced by the average time under the steady state of queuing theory, and the matching rate of the waiting stage after AI empowerment is substituted into the objective function to construct the Lagrange function. The partial derivatives of μ_1 and μ_2 are calculated and set to zero to obtain the first-order optimal condition, and then the two-stage optimal capacity configuration formula is derived. Through solving, this paper obtains the following core conclusions.

3.4.1. Law of capacity structure division

Regardless of whether the platform is profit-oriented or welfare-oriented, its optimal capacity consists of two parts: basic capacity and safety capacity. The basic capacity is used to meet the order arrival demand under

steady state, and its size is equal to the effective order arrival rate λ ; the safety capacity is used to cope with demand fluctuations, and its size is related to factors such as user waiting cost, user reference sensitivity, service price, and capacity maintenance cost. The optimal capacity configuration formulas for the two stages are:

$$\begin{aligned}\mu_1^* &= \lambda^* + \sqrt{\frac{\lambda(h-\eta r)(p-c_1-c_2)}{vc_1}}; \\ \mu_2^* &= \lambda^* + \sqrt{\frac{\lambda(h+\eta)(p-c_1-c_2)}{\bar{v}c_2}}\end{aligned}$$

Where the part inside the square root is the safety capacity, and μ_1^* , μ_2^* are the optimal capacities of the two stages, respectively. The optimal matching ratio of the two-stage safety capacity is:

$$\mu_1^s : \mu_2^s = \sqrt{\frac{h-\eta r}{c_1}} : \sqrt{\frac{h+\eta}{c_2}}$$

After AI empowerment, the basic capacity of the waiting stage decreases to $\lambda/(1 + k_{AI})$, and the safety capacity matching ratio is adjusted to:

$$\mu_1^{s'} : \mu_2^{s'} = \sqrt{\frac{h-\eta r}{c_1(1+k_{AI})}} : \sqrt{\frac{h+\eta}{c_2}}$$

This conclusion indicates that AI empowerment not only improves the efficiency of the waiting stage but also changes the matching ratio of the two-stage safety capacity. If the platform only improves the AI empowerment level of the waiting stage without synchronously optimizing the capacity of the service stage, the service stage will become a new system bottleneck. Therefore, when applying AI technology, the platform must synchronously adjust the two-stage capacity ratio to achieve the coordinated advancement of technological empowerment and capacity optimization.

4. Key strategies for two-stage capacity configuration

4.1. Capacity configuration strategy for the waiting stage

4.1.1. Dynamic demand response mechanism

The order arrival rate is predicted using historical data and real-time contextual features, including weather conditions, time periods, and special events, and is used to determine dynamic system thresholds. When the number of pending orders exceeds the threshold, a coordinated control strategy is triggered: price incentives are adjusted (e.g., increasing delivery fees), cross-regional scheduling is activated to dispatch nearby idle personnel, and demand guidance is provided by informing customers of expected waiting times. Together, these measures rapidly rebalance supply and demand.

4.1.2. AI-empowered intelligent matching optimization

Order characteristics, including pick-up and delivery locations and time-limit requirements, and service personnel characteristics, such as current location and historical efficiency, are integrated through machine learning algorithms to achieve globally optimal matching. This approach reduces empty driving rates while

enabling differentiated matching priorities for urgent and member orders, thereby improving service quality and the satisfaction of high-value users.

4.1.3. Elastic combination of basic-safety capacity

A fixed base capacity is configured to meet routine daily demand, while a hybrid “full-time + crowdsourcing” model is adopted to provide flexible safety capacity. Crowdsourcing personnel are activated to supplement capacity during peak periods and scaled down during off-peak periods to control costs, thereby maintaining optimal capacity utilization.

4.2. Capacity configuration strategy for the service stage

4.2.1. Route optimization and regional scheduling

Real-time route planning algorithms are used to optimize “one-pickup and multiple-delivery” routes, thereby reducing service time per order. Demand hotspots are predicted using heat-map analysis, enabling advance personnel positioning and a shift from passive order acceptance to active standby, which improves the service rate μ_2 .

4.2.2. Service personnel capacity management

Standardized service processes and systematic training programs are established to enhance operational proficiency. Subjective initiative is encouraged through incentive mechanisms, such as efficiency scores and positive review rates. Following AI-enabled efficiency improvements in the waiting stage, it is necessary to synchronously expand safety capacity in the service stage to absorb the increased service pressure generated by higher throughput.

4.2.3. Balance control of cost and efficiency

Safety capacity is adjusted based on the trade-off between unit capacity cost c_2 and user waiting cost h . When h is high, indicating strong user sensitivity to waiting, safety capacity is appropriately increased. Conversely, when c_2 is high, a portion of human capacity is substituted with technical optimization, such as intelligent route planning, to reduce overall costs.

4.3. Two-stage coordinated optimization strategy

A linked monitoring system is established for key indicators across the two stages, including waiting time, order acceptance rate, delivery time limits, and personnel idle rates, to prevent system imbalance arising from single-stage optimization. For example, when AI-driven matching efficiency in the waiting stage is improved, service-stage capacity must be synchronously expanded to eliminate the emerging bottleneck of “fast matching but slow execution.” Capacity configuration ratios are then dynamically adjusted through real-time data feedback to achieve global system optimization.

5. Numerical examples and management implications

5.1. Numerical example verification

Parameters are set based on the actual operational data of the dispatching system: $h = 1.6$, $\alpha = 0.6$, $r = 1.1$, $c_1 = 0.3$, $c_2 = 0.5$, $V = 6$, $\lambda = 10$, $CAI = 1$. The following key conclusions are obtained through numerical simulation:

- (1) When the AI empowerment level k_{AI} increases to 1, the basic capacity of the waiting stage decreases by more than 30%, and the safety capacity is saved by 25%, but the safety capacity of the service stage needs to be increased by 15% to match the efficiency;
- (2) Profit-oriented platforms are more inclined to control safety capacity investment, while welfare-oriented platforms will configure more safety capacity to reduce user waiting time;
- (3) When the user expectation coefficient r is in the interval $[0.8, 1.3]$, it is difficult for the platform to accurately judge user sensitivity, which is prone to capacity configuration deviations, and strategies need to be adjusted through dynamic monitoring.

5.2. Management implications

AI empowerment needs to consider the whole-process optimization. Only improving the matching efficiency of the waiting stage may trigger bottlenecks in the service stage. The platform should synchronously adjust the two-stage capacity ratio according to the k_{AI} value to avoid “one-sided optimization” of technological empowerment. Capacity configuration should be in line with user psychology. Based on users’ reference sensitivity and loss aversion characteristics for waiting time, prioritize configuring safety capacity in the service stage to reduce the risk of waiting overtime. Profit-oriented platforms can dynamically adjust safety capacity according to the cost-benefit ratio; welfare-oriented platforms need to seek a balance between capacity investment and user experience, and appropriately increase the proportion of basic capacity.

6. Conclusion

This paper divides the internet dispatching system into two stages, “waiting-service”, constructs a theoretical model of capacity configuration by combining queuing theory, AI empowerment characteristics, and user behavior psychology, and reveals the optimal configuration law of basic capacity and safety capacity and the two-stage coordination mechanism. Research shows that the optimal capacity configuration needs to comprehensively consider the platform’s operational objectives, user behavior characteristics, and technological empowerment level, and achieve supply-demand balance and efficiency improvement through strategies such as dynamic demand response, AI intelligent matching, route optimization, and coordinated scheduling. Future research can further expand the scenario boundaries, incorporate factors such as multi-regional coordinated scheduling and service personnel heterogeneity (efficiency differences, preference differences), and construct a multi-objective capacity configuration model closer to reality. Meanwhile, conduct A/B testing combined with empirical data to verify the applicability of the model in different dispatching scenarios, providing more accurate decision support for the refined operation of platforms.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Hong W, 2024, Research on the Business Model of Steel Business of Fujian SG Company Based on the IoT Cloud Commerce Platform, 32–38.

- [2] Zhou Y, Li F, 2022, Problems and Challenges Faced by New Retail Operation Management. *Journal of Systems & Management*, 31(5): 12–13.
- [3] Liu S, 2023, Optimization of Unmanned Vehicle Delivery Operation Strategy for Online Retailers, thesis, Beijing Jiaotong University, 78–89.
- [4] Gu Y, 2024, Research on the Dispatching Mode of Residential Decoration Trades Based on BIM+AR, China Architecture & Building Press, Beijing, 45–68.
- [5] Yang J, 2021, Design and Implementation of Fresh E-commerce Order Fulfillment System, Publishing House of Electronics Industry, Beijing, 20–21.
- [6] Yao Y, Xia B, 2014, Application of Phase Frequency Feature Group Delay Algorithm in Database Differential Access. *Computer Simulation*, 31(12): 238–241.
- [7] Gamelin F, Baquet G, Berthoin S, et al., 2009, Effect of Low-Intensity Training on the Triacylglycerol Oxidation Rate During Exercise. *Journal of Applied Physiology*, 2009(105): 731–738.
- [8] Jackson D, Firtko A, Edenborough M, 2009, Personal Resilience as a Strategy for Surviving and Thriving in the Face of Workplace Adversity: A Literature Review. *Journal of Advanced Nursing*, 60(1): 1–9.
- [9] Hargreve M, Jensen A, Nielsen T, et al., 2015, Maternal Use of Fertility Drugs and Risk of Childhood Acute Lymphoblastic Leukemia. *International Journal of Cancer*, 136(8): 1931–1939.
- [10] Schneider Z, Whitehead D, Elliott D, 2009, Nursing and Midwifery Research: Methods and Appraisal for Evidence-Based Practice, 3rd edn, Elsevier Australia, Marrickville, NSW.
- [11] Davis M, Charles L, Curry M, et al., 2013, Challenging Spatial Norms, Routledge, London.
- [12] Knowles M, 1986, Independent Study, In *Using Learning Contracts*, Jossey-Bass, San Francisco: 89–96.
- [13] Zhang S, Liaw L, Ruppenicker J, 1999, Proceedings of the Twenty-Fifth Annual Meeting of the Berkeley Linguistics Society, February 12-15, 1999: General Session and Parasession on Loan Word Phenomena. 2000, Berkeley Linguistics Society, Berkeley.
- [14] Bukowski R, 2008, Prognostic Factors for Survival in Metastatic Renal Cell Carcinoma: Update 2008. *Innovations and Challenges in Renal Cancer: Proceedings of the Third Cambridge Conference*. *Cancer*, 115(10): 2273.
- [15] Este J, Warren C, Connor L, et al., 2009, Life in the Clickstream: The Future of Journalism. Media, Entertainment and Arts Alliance, 2009.
- [16] Developing an Argument, 2025, <https://writing.princeton.edu/resources/academic-writing/constructing-arguments>.
- [17] Gale L, 2000, The Relationship Between Leadership and Employee Empowerment for Successful Total Quality Management, thesis, University of Western Sydney.

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Innoscience Research (Malaysia), which is global market oriented, was founded in 2016. Innoscience Research focuses on services based on scientific research. By cooperating with universities and scientific institutes all over the world, it performs medical researches to benefit human beings and promotes the interdisciplinary and international exchanges among researchers.

Innoscience Research covers biology, chemistry, physics and many other disciplines. It mainly focuses on the improvement of human health. It aims to promote the cooperation, exploration and exchange among researchers from different countries. By establishing platforms, Innoscience integrates the demands from different fields to realize the combination of clinical research and basic research and to accelerate and deepen the international scientific cooperation.

Cooperation Mode



Clinical Workers



In-service Doctors



Foreign Researchers



Hospital



University



Scientific institutions

OUR JOURNALS



The *Journal of Architectural Research and Development* is an international peer-reviewed and open access journal which is devoted to establish a bridge between theory and practice in the fields of architectural and design research, urban planning and built environment research.

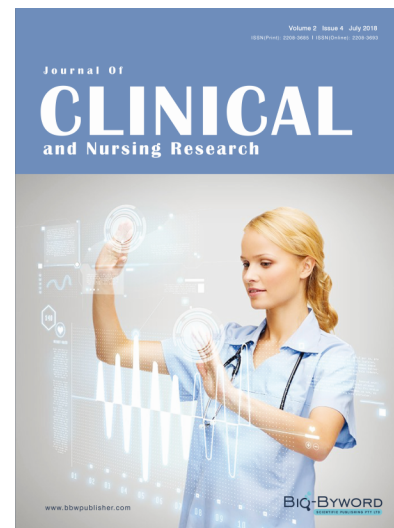
Topics covered but not limited to:

- Architectural design
- Architectural technology, including new technologies and energy saving technologies
- Architectural practice
- Urban planning
- Impacts of architecture on environment

Journal of Clinical and Nursing Research (JCNR) is an international, peer reviewed and open access journal that seeks to promote the development and exchange of knowledge which is directly relevant to all clinical and nursing research and practice. Articles which explore the meaning, prevention, treatment, outcome and impact of a high standard clinical and nursing practice and discipline are encouraged to be submitted as original article, review, case report, short communication and letters.

Topics covered by not limited to:

- Development of clinical and nursing research, evaluation, evidence-based practice and scientific enquiry
- Patients and family experiences of health care
- Clinical and nursing research to enhance patient safety and reduce harm to patients
- Ethics
- Clinical and Nursing history
- Medicine



Journal of Electronic Research and Application is an international, peer-reviewed and open access journal which publishes original articles, reviews, short communications, case studies and letters in the field of electronic research and application.

Topics covered but not limited to:

- Automation
- Circuit Analysis and Application
- Electric and Electronic Measurement Systems
- Electrical Engineering
- Electronic Materials
- Electronics and Communications Engineering
- Power Systems and Power Electronics
- Signal Processing
- Telecommunications Engineering
- Wireless and Mobile Communication

