ISSN 2959-6149

Research on the Development Status, Influencing Factors, and Countermeasures of Digital Transformation of China's Manufacturing Enterprises

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Abstract:

The manufacturing enterprises' digital transformation is a complex and long-term process that requires the joint efforts of the government, enterprises, and society. By strengthening digital technology capacity building, promoting business model innovation, optimizing supply chain management, strengthening data sharing and circulation, strengthening policy support, and promoting industry-university-research cooperation, manufacturing enterprises can effectively adapt to the opportunities and challenges of the digital economy era and attain sustainable growth. This paper seeks to investigate the development status, key influencing factors, and corresponding countermeasures of manufacturing enterprise's digital transformation. With the rapid growth of the digital economy, the manufacturing enterprise's digital transformation has become a prominent way to enhance competitiveness, optimize production processes, and promote product innovation.

Keywords: manufacturing enterprises; digital transformation; influencing factors; countermeasure analysis.

1 Introduction

The digital economy is prevailing currently. The increasing maturity of information technologies such as big data, blockchain, and 5G communications has led to a digital economy's new economic form. Cultivating and strengthening the digital economy is not only a practical need to comply with the current digital development trend and consumption upgrading but also a decisive direction for advancing economic transformation and the development of society in the future. Developing the digital economy and promoting the construction of a more diverse, efficient, and convenient digital consumption ecosystem is an inevitable option to keep up with the changes of the times and seize development opportunities (Liu and Zhang, 2021). The report on the 14th Five-Year Plan of the Party proposed that we have to "accelerate digital development, build a digital China to welcome the digital age and activate the potential of data elements. Accelerate the construction of digital economy, society, and government, and use digital transformation to drive the overall transformation of production methods, lifestyles, and governance methods." At the forefront of the industrial transformation, Numerous new technologies, formats, and applications can emerge from the digital economy, producing new opportunities for economic growth. (Xiong, 2024).

Manufacturing, a key pillar of the national economy, is not only the ballast of the Chinese economy but also the core part of the contemporary industrial system. Therefore, manufacturing development is particularly critical to my country's economic growth. The 13th Plenary Session of the 11th Central Committee of the Communist Party of China pointed out that "a sound system will be established to promote the deep integration of the real economy and the digital economy. We will accelerate the promotion of new industrialization, cultivate and expand advanced manufacturing clusters, and promote the high-end, intelligent, and green development of manufacturing." To transform from a manufacturing power to a manufacturing power, we ought to prioritize our manufacturing industry's high-quality development, strive to maintain a stable proportion of manufacturing, implement actions to improve the manufacturing industry's core competitiveness, and let traditional industries glow with new vitality.

Firstly, promote the manufacturing industry's transition and technical development. Our country has deeply implemented the industrial base reconstruction project, supported the growth of specialized businesses and new start-up enterprises, and promoted a new round of large-scale equipment updates. These are all essential and crucial measures in advancing the high-end growth of the manu-

facturing sector. For example, encouraging the transition and modernization of food processing technology or equipment has effectively promoted the elegant development of the food processing sector, better satisfied the diversified food consumption needs of both populations in the urban and rural, and increased the competitiveness of the food processing industry. The advanced and useful technologies' development and application have expedited the traditional manufacturing industry's transition and upgrading, promoted the traditional manufacturing sector to meet the residents' consumption structure better, and continuously opened up international markets.

Secondly, since the manufacturing industry has completed technological upgrading, it is pivotal for us to encourage the intelligent transition and digital transformation of enterprises. Many typical manufacturing enterprises have realized customized production, automated production, precision manufacturing, and low-energy manufacturing by implementing intelligent manufacturing projects and promoting the application of intelligent manufacturing technologies. This has not only greatly improved production efficiency and expanded the path of technological innovation and upgrading, but also played an important role in promoting enterprises to increase varieties, improve quality, create brands, and thus improve efficiency and competitiveness. In a word, encouraging the manufacturing industry's upscale, intelligent, and environmentally friendly development has not only effectively promoted the transition of traditional industries, but also driven the demand expansion for critical emerging and future industries. Looking to the future, we have to continue to pay close attention to the real economy, deepen the new paradigm of industrialization, and quicken the manufacturing industry's growth.

In short, we have to bring about digital transformation and revolution in the manufacturing industry and inject a steady stream of power to guarantee China's economic growth consistently over the long run. The State Council Executive Meeting examined and adopted the Action Plan for Digital Transformation of the Manufacturing Industry, pointing out that "digital transformation of the manufacturing industry is an important measure to promote new industrialization and build a modern industrial system". The integrated growth of the digital economy and traditional manufacturing industry is bound to be a strong engine for our country's economy's high-quality development. Traditional manufacturing enterprises and the digital economy complement each other: The only way for the manufacturing industry to transform and upgrade is to further promote integration with the digital economy. If traditional enterprises face the future and do not carry out digital transformation, they will face elimination; on the contrary, the digital economy can drive the all-round and full-chain traditional manufacturing industry's transition. A digital economy without the support of a real economy is a "castle in the air". To encourage digital technology and the traditional manufacturing industry's deep integration, we can consider the following several aspects: Firstly, fully leverage the innovative engine role of data elements, accelerate the pace of data sharing, openness, circulation, and application, and improve transformation efficiency. Secondly, enhances the dual and complementary forces of industrial digitization and digital industrialization. The core part of the digital economy is the digital industrialization sector, which provides industries with digital development measures. In addition, the process of upgrading, transforming, and rebuilding all factor digitization is known as industrial digitization (Jin, 2023). Therefore, only by promoting the synergy and integrated development of these two points can we better promote the joint release of the potential of manufacturing and the real economy.

Whether from a theoretical perspective or a case analysis perspective, the majority of existing research focuses on how digital technology and the economy influence existing enterprises. However, there is a Darth of topics relevant to the digital transition in traditional manufacturing organizations, and there is a lack of investigation and analysis of typical transformation solutions of such enterprises. Therefore, it is theoretically and practically significant to explore the development status, influencing factors, and countermeasures of digital transition in Chinese manufacturing businesses.

2 Analysis Oo The Current Status of Digital Transformation of Manufacturing Enterprises

2.1 Analysis of regional characteristics of digital transition of manufacturing enterprises

2.1.1 Overall development shows strong east and weak west

The level of manufacturing digitalization and manufacturing standardization is positively correlated with the regional economic foundation. China's manufacturing sector is primarily concentrated in the eastern and coastal economically developed regions and is generally distributed in a stepped manner. The first gradient is the Yangtze River Delta (including Shandong, the Pan-Pearl River Delta is the second gradient, the third gradient is the Beijing-Tianjin-Hebei region, the fourth gradient is the central region, the fifth gradient is the western region, and the sixth gradient is the northeast region. According to kernel density analysis, from 2015 to 2020, the integration level

between the digital economy and manufacturing in the eastern region was consistent with global development, and showed an overall upward trend; the development gap between provinces with extremely high integration levels and the tail provinces was not large. The distribution of integration levels in the central region shows a concentrated trend, and the absolute difference is narrowing, but in terms of distribution ductility, the number of low-integration provinces has increased, and the gap is obvious relative to high-integration provinces.

The integration level in the western region continues to improve, but it is generally dispersed, with poor integration. The gap is widening. As for the Northeast region, the integration level between the digital economy and manufacturing has not been significantly improved, and polarization is serious. The lifeblood of China's economy is manufacturing. To optimize the spatial pattern of the digital revolution and the growth of my country's manufacturing industry, promote regional coordinated development, and avoid the intensification of polarization, we should fully strengthen the development momentum of the eastern region, release potential, play a leading role, and propel the coordinated growth of other regions; strengthen the construction of digital transformation in the central and western regions, promote the transformation and upgrading of backward areas, and direct the penetration of development factors into these two regions; Prioritize efforts to enhance the integration of the digital economy with traditional manufacturing in the underdeveloped areas of Northeast China, implement digital infrastructure's construction, and introduce supportive policies and financial assistance (Zheng, 2023).

2.1.2 Digitalization of manufacturing boosts the "Rise of Central China"

The digital revolution in the central region's manufacturing sector has reached a full burst state owing to the extensive spread of digital technology. In 2023, Henan proposed to promote green development with digital transformation, and it is expected that in about three years, all industrial businesses above a specific scale in the province would achieve full coverage of digital transformation; in April 2024, the "Pangu Model" was proposed at the Hunan Advanced Manufacturing Application Scenario Matchmaking Conference, which solved the "difficulty of implementation" regard to artificial intelligence in the smelting industry, led the AI development model of smelting enterprises to change from workshop-style to factory-style, and laid a strong basis for the large-scale use of AI in steel manufacturing scenarios (Ju Helin, 2024).

2.1.3 Guangdong, Hong Kong, and Macao Digitalization Crosshairs Regulatory Docking

Currently, one of China's most transparent and economically dynamic areas is The Greater Bay Area. The digital economy has an increasingly strong power to reshape the Greater Bay Area's manufacturing businesses. Through the reshaping of production processes, production models, and collaboration across the entire industrial chain, an open and integrated industrial ecological pattern has been formed. The value chain model of the entire ecosystem is gradually becoming a new path for the manufacturing industry's transformation. Simultaneously, rich data resources and broad application scenarios are important elements of this value chain model, making the Greater Bay Area's development prospects of the digital economy better than other regions (Zhang, 2023).

At the end of 2023, Guangdong Province issued the "Three-Year Action Plan for the Construction of the "Digital Bay Area" to deepen the regulatory docking of digital cooperation rules among Guangdong, Macao, and Hong Kong, and promote the market integration of the Guangdong-Hong Kong-Macao Greater Bay Area. Guangdong will continue to support the construction of Guangzhou and Shenzhen data exchanges, promote the docking of cross-border data rules, fully release the value of data elements through cross-border data circulation transactions, and continue to explore rules for cross-border secure flow of data.

The proposal and suggestion reply proposed that Guangdong will also build the Guangdong-Hong Kong-Macao "Data Special Zone" based on major platforms such as Hengqin, Qianhai, Nansha, and Hetao, build cross-border software and hardware infrastructure, trusted storage space and circulation platform for data elements, strive for national pilot support, make breakthroughs in key areas such as data infrastructure and data basic system, explore and promote cross-border data sharing and circulation, and create a "Bay Area model" for the data element market (Li, 2024).

At present, humanoid robots in the Guangdong-Hong Kong-Macao Greater Bay Area have entered the fast lane of development. Including humanoid robots, new quality productivity anchored by technological innovation-driven productivity is becoming the key driving force for the future of the Guangdong-Hong Kong-Macao Greater Bay Area. The Guangdong-Hong Kong-Macao Greater Bay Area is an important base for the world's manufacturing industry, with a solid industrial foundation and a complete system. Here, the output of 5G mobile phones, air conditioners, refrigerators, rice cookers, microwave ovens, etc. ranks first in the world. At present, there are 8 trillion-yuan industrial clusters mainly located in the Greater Bay Area.

"Lighthouse Factory" is also known as the "world's most

advanced factory", representing the top intelligent manufacturing capabilities in the industrial field. There are eight "lighthouse factories" like this in the Greater Bay Area, in Guangzhou, Shenzhen, Foshan, and other cities. For example, in the Shunde factory of Midea's hot-water dishwasher, various screens can be seen everywhere in the production workshop, which displays all the operating parameters of the production process in real time. In the equipment inspection link, this factory also realizes the combination of virtual and reality (Huang, 2024).

2.2 Analysis of the results of the digital transformation of manufacturing enterprises

First, there is a period of rapid development entering the digital economy industry. Speeding up the manufacturing sector's digital revolution is a significant breakthrough in promoting China's economy's high-quality development. China's digital economy industry has advanced rapidly in recent years, and the manufacturing industry's digital transition has made remarkable progress. Data show that China's digital economy will exceed 55 trillion yuan in 2023, and the core industries' added value will be worth more than 12 trillion yuan, or around about 10% of the country's GDP. Empowering the transformation and upgrading of traditional manufacturing with digital technology will inject a strong impetus into building a contemporary industrial system.

Secondly, the level of digital technology application of enterprises has been effectively improved. The Ministry of Industry and Information Technology indicated that 421 national demonstration factories and tens of thousands of provincial digital workshops and smart factories have been put into operation as of the end of 2023, of which "5G+Industrial Internet" construction projects have reached 7,000, and there are over 340 industrial Internet platforms with industry competitiveness and regional influence in the world, and over 100 million sets of industrial equipment are connected to major platforms. The utilization of advanced digital technology has effectively promoted industrial automation's development and production efficiency, among which the industry's growth statistics in the production of electronic and communication equipment are particularly obvious (Wang, 2024).

Thirdly, the digital transformation of the manufacturing industry has achieved remarkable results. As a forward-looking and strategic technology leading the future, artificial intelligence has provided a vital impetus for a new round of scientific and technological revolution and industrial transformation. With the accelerated iteration and upgrading of artificial intelligence big model technology, the general and special intelligence levels of big models have made important progress. The manufacturing industry with a high degree of dependence on mental labor has become the main battlefield for the application of big models, and "artificial intelligence +" has become the most active field for digital technology to empower new industrialization (Huang, 2024).

Artificial intelligence has injected new momentum into productivity and improved the production efficiency of the manufacturing industry, while the manufacturing industry has created a huge market space for the development of the artificial intelligence industry. Artificial intelligence + manufacturing has promoted intelligent manufacturing, predictive maintenance, and automated production, making manufacturing companies more competitive and flexible (Ye, 2024).

Finally, digital trade promotes the quality and efficiency of manufacturing exports. Digital trade has a driving effect on the transformation and upgrading of traditional trade. Attaching importance to the high-quality development of digital trade is an important driving force for the continuous optimization of the trade system. In June 2024, the Ministry of Commerce issued the "Three-Year Action Plan for Digital Commerce (2024-2026)", focusing on the implementation of the "Digital Commerce to Promote Trade" action, proposing four measures to improve the level of trade digitalization, promote cross-border e-commerce exports, expand the digital content of service trade, and vigorously develop digital trade to accelerate the cultivation of new advantages in foreign trade (Wang et al., 2024). Since the 18th National Congress of the Communist Party of China, China's digital trade has maintained a good development trend. In 2023, the scale of China's digitally deliverable service imports and exports reached 2719.37 billion yuan, an increase of 8.5% year-on-year. Among them, exports were 1543.52 billion yuan, an increase of 9.0%; imports were 1175.85 billion yuan, an increase of 7.8%.

2.3 Analysis of current problems in the digital transformation of manufacturing enterprises

2.3.1 Lack of authoritative data standards

There is a lack of unified and credible data system standards, data specification definitions, and high-quality data foundations. The data language within manufacturing enterprises is not unified, the data is scattered and fragmented, and the introduction of internal information systems in enterprises is in a liberalized state; various data resources generated by key businesses in various links lack unified processing standards, thus forming data islands, making data integration difficult and unable to integrate applications, limiting the scenarios and scope of digital business applications in the manufacturing industry (Xu, 2024).

Enterprises usually need to integrate data from different

departments, different systems, and different data sources, but these data may have problems such as incompatible formats, data duplication, or missing data. Ensuring data accuracy and consistency, as well as data integrity is an important technical challenge. With the large-scale collection and processing of data, security and privacy protection have become important issues in digital transformation (Kong, 2024).

My country has promulgated standardized documents such as the "Industrial Internet Standard System Framework", "National Intelligent Manufacturing Standard System Construction Guidelines", and "Industrial Internet Comprehensive Standardization System Construction Guidelines", but there are still inconsistent data standards among regions, industries, and even departments within enterprises, and the barriers to data flow have not been completely broken (Chen and Zhang, 2023).

2.3.2 The "bottleneck problem" of key core technologies needs to be broken through

China's manufacturing industry digital transformation faces a "high wall" in the core digital technology market. Although China has built a technical foundation for participating in the global value chain, the increasingly high core technology barriers built by Western companies in recent years have made it more difficult to obtain digital information technology (Wang and Si, 2023).

2.3.3 The level of data openness and sharing needs to be improved

There is a digital divide in the industrial chain and supply chain of some manufacturing enterprises, and the level of data openness and sharing is relatively weak, which is mainly affected by the following three factors. First, different equipment from different well-known companies is equipped with different external communication interfaces or industrial field bus protocols, which makes it difficult to integrate and interconnect heterogeneous networks, affecting the integrated access and interconnection of products. Second, some digital equipment systems are strictly closed, lacking external communication connections and data sharing standard interface design, or the design interface is non-standardized, making it difficult to open the system for transformation and data sharing. Third, a large number of traditional mechanized and automated equipment did not consider the needs of data collection, digital control, network control, etc. at the beginning of the design, making it extremely difficult to carry out digital secondary transformation and upgrading, which affects the network access and interconnection of equipment (Defense, 2023).

2.3.4 Some enterprises are in the dilemma of "not being able to turn"

First, the financing cost of enterprises is high, the capital pressure is great, and there is a lack of external capital support. Due to the problem of digital transition of traditional equipment, high investment cost, long payback period, and the need for continuous investment of a large number of funds, a large number of small and medium-sized enterprises can hardly continue to promote digital transformation by relying on their income without using special support or capital leverage (Lu, 2024).

Under the premise of controlling risks and pursuing profits, financial institutions generally treat corporate credit business with a very cautious attitude, which makes it difficult for many traditional manufacturing companies to obtain sufficient funds through external channels; at the same time, because different companies are in different economic environments, some companies have incomplete and inaccurate financing information, and thus cannot find effective financing methods (Shi et al., 2024).

Second, lack of technology. Enterprises need to master various cutting-edge digital technologies, like big data, and cloud computing, to achieve digital transformation. However, the rapid update and replacement of digital technology and the wide range of technical fields involved have put forward higher requirements on the professional knowledge and capabilities of the enterprise's technical team. Enterprises have numerous technical challenges in digital transformation in the context of the digital economy, such as how to react quickly to shifts in the market changes and customer needs and adopt agile open, and innovative methods for rapid iteration and trial and error (Kong, 2024).

Third, lack of resources. The traditional enterprises' digital transformation requires the convergence and coordination of various resources, and the small and medium-sized enterprises' resource supply capacity is limited. As for human resources, the in-depth promotion of digital transformation requires plenty of employees who have digital skills and innovation capabilities while replacing some traditional jobs, and the current labor market makes it hard to satisfy the needs of enterprises for high-quality talents. In terms of training, many companies ignore the quality of employee training and fail to ensure the effectiveness of digital integration (Zhao, 2024).

3 Six Major Factors Affecting The Digital Transformation of Manufacturing Enterprises

3.1 Industrial software is the sole pillar for promoting the digital transformation of the manufacturing industry

Industrial software is the core element and important sup-

port for promoting the high-quality growth of intelligent manufacturing in China and is an important foundation for enterprises to carry out intelligent, networked, and digital transformation. This statement aptly summarizes the important role of industrial software in the modernization process of the manufacturing industry (Cao, 2022). It can not only help enterprises realize the automation and intelligent management of production processes, and improve production efficiency and product quality, but also support enterprises in decision-making by using data analysis, prediction optimization, and other measures, and encourage sustainable growth of businesses. Specifically, the following aspects show how industrial software is contributing to the digital transformation of the manufacturing industry:

3.1.1 Production control

Industrial software can encourage the automation of intelligent equipment in the manufacturing industry and the lean production process, and reduce manual intervention by integrating automation equipment and control systems; with the aid of cutting-edge technologies like big data and cloud computing, it can analyze and process production data in real-time to assist in making scientific decisions (Jiang, 2022).

3.1.2 R&D Design

With the help of industrial software such as CAD and CAE, enterprises can carry out design drawings and multiple rounds of simulation tests in the early stages of product design, discover and solve potential problems in advance, shorten the product development cycle, and reduce costs (Wang et al., 2024).

3.1.3 Industrial Chain Management

Industrial chain collaboration is one of the ultimate goals of enterprise digital transformation. Through industrial software such as SCM (supply chain management), enterprises can achieve information sharing and collaborative operations with suppliers, customers, and other partners (Wang et al., 2022).

Therefore, it can be said that industrial software is an indispensable key element in encouraging manufacturing's digital transformation. In the future, industrial software will play a vital role in the manufacturing industry, helping enterprises to achieve a higher level of digital transition and intelligent upgrading.

3.2 Industrial Internet is the key force in promoting the digital transformation of the manufacturing industry

The industrial Internet, a product of the deep integration of new-generation information technology and the manufacturing industry, is the critical force in promoting the digital transformation of the manufacturing industry (Yang, 2024). It provides a strong driving force for the transformation and upgrading of the manufacturing industry by building a basic functional system to form a new production system of intelligence, networking, and service.

3.2.1 Breaking the Data Information Island

The industrial Internet is formed under the closed loop of data, computing power, models, and applications. Therefore, it can break the information island of traditional the manufacturing industry, realize the comprehensive collection, real-time transmission, and intelligent analysis of production data, and improve the sharing of public data (Zhang and Zhang, 2024). This enables enterprises to grasp the production status more accurately and discover and solve problems in time. At the same time, through the in-depth mining of production data, enterprises can also discover new market opportunities and growth points, and promote the innovation of products and services.

3.2.2 Provide strong background support

As the core of the industrial Internet, the industrial Internet platform provides powerful digital, networked, and intelligent services for the manufacturing industry. These platforms bring together rich industrial knowledge, algorithm models, and microservice components, and can provide enterprises with intelligent solutions for the entire life cycle of design, simulation, manufacturing, and services. Through "platformization" and colocalization, enterprises can more conveniently obtain the required resources and capabilities, accurately match demand and supply, and accelerate the process of digital transformation (Yu, 2024).

3.2.3 Promote service-oriented transformation

The Industrial Internet has promoted the service-oriented transformation of the manufacturing industry. Relying on the Industrial Internet, enterprises can realize the interconnection and multi-dimensional visualization of manufacturing data, and create multi-dimensional customization centered on the personalized needs of users. With its powerful connectivity, data processing, and service capabilities, the Industrial Internet has become a key force in promoting the digital transformation of the manufacturing industry.

3.3 Large model application is a new option to promote the digital transformation of the manufacturing industry

With the rise of artificial intelligence, large models have become a vital driving force from informatization to digital intelligence. The application of large models is a new

option to promote the digital transformation of the manufacturing industry, and this view has been verified and supported in many aspects.

3.3.1 Technology integration and innovation

Big model technology, through its huge parameters and powerful data processing capabilities, can actively output innovative results and deeply integrate into all aspects of the manufacturing industry, promoting technological innovation and production model changes in the manufacturing industry (Wu et al., 2023). For example, engineers can automatically generate code instructions through big models to complete the development and debugging of robot functions, and even create new functions for robots, thereby improving production efficiency and flexibility.

3.3.2 Improve production efficiency

The application of big models can optimize production processes, reduce manual intervention, and reduce production costs. Through real-time data collection and analysis, production needs can be accurately predicted, resource allocation can be optimized, and production efficiency and product quality can be improved. For example, the application of AI big models by industrial manufacturing enterprises can promote the high intelligence of production lines, improve the operating efficiency and flexibility of production lines, and realize flexible control (Ding, 2024).

3.3.3 Promote intelligent upgrading

Big models are important tools for intelligent upgrading, which can help the manufacturing industry achieve the transformation from traditional production mode to intelligent production mode. For example, manufacturing enterprises can combine basic big models with enterprise industry knowledge to form exclusive big models and apply them to intelligent collaboration in various links to achieve intelligent upgrading (Luo et al., 2023). Therefore, through the intelligent analysis and decision support of big models, manufacturing enterprises can better respond to market changes and improve their competitiveness.

3.4 Digital infrastructure is a solid foundation for promoting the digital transformation of the manufacturing industry

Digital infrastructure is the hard power of digital manufacturing power and a solid foundation for promoting the digital transformation of the manufacturing industry. It mainly involves new-generation information and communication technologies such as 5G, data centers, the Internet of Things, and various digital platforms formed based on such technologies. These technologies and services together constitute the technical foundation required for the digital transformation of the manufacturing industry.

3.4.1 Promote integrated development

Digital infrastructure can bridge the digital divide, promote data flow and resource sharing, break down data barriers, and give play to the synergy of data by building an intensive and comprehensive data platform (Pang and Zhu, 2023).

The digital platform coordinates the construction of digital infrastructure, promotes interconnection and interoperability among different regions, different entities, and different levels, eliminates barriers, and realizes coordinated and integrated development across departments through the connection computing skills of digital technology (Fang et al., 2023).

3.4.2 Provide technical support

The digital technology's development has provided strong technical support for the digital transition of my country's manufacturing sector and injected new vitality into the rapid economic development. For example, cloud computing and edge computing provide more optimized technical conditions for new models and new formats such as digital management, intelligent production, and personalized customization of enterprises. The application of new-generation technologies in digital infrastructure enables manufacturing enterprises to realize intelligent monitoring and management of production processes, optimal allocation, and flexible scheduling of production resources.

3.4.3 Promoting Supply Chain Collaboration

The supply chain's role characteristics in enterprise digital investment are not single. It may promote or hinder the digital transformation of enterprises.

Digital infrastructure enables manufacturing enterprises to share information and collaborate with other supply chain partners, improving the transparency and responsiveness of the supply chain (Zhang and Xiao, 2024). Through technologies such as blockchain, asymmetric information can be corrected, production processes can be optimized, data can be recorded in real time, and the reliability of the supply chain can be improved, thereby improving resource allocation efficiency and strengthening the digital empowerment effect.

However, many enterprises still encounter obstacles in utilizing supply chain digitalization. Research data show that supplier concentration and customer concentration reduce the level of digital investment of enterprises (Zhai and Zhang, 2021). In addition, the loopholes of enterprises in handling supply chain data management and coordination, security, and privacy protection also slow down the promotion of the supply chain and reduce the digitalization process of enterprises (Lin and Guo, 2023).

3.5 Policy environment is an important guarantee for promoting the digital transformation of the manufacturing industry

With the release of policy documents such as "Guiding Opinions on Deepening the Integration and Development of New Generation Information Technology and Manufacturing Industry" and "The 14th Five-Year Plan for the Deep Integration and Development of Informatization and Industrialization", the top-level design of the digital transformation of manufacturing industry has been continuously improved, providing clear guidance for industrial practice. Improving the policy system is an important engine for promoting the digital transformation of traditional manufacturing enterprises in China, and provides strategic guidance for China's goal of becoming a strong manufacturing country.

3.5.1 Support key industries and fields

Policy documents often formulate specific digital transformation action plans for key industries and key fields, and provide clear transformation directions and paths for enterprises in these industries and fields by building a forward-looking and systematic policy system. The "Three-Year Action Plan for Data Elements × (2024-2026)" issued by the National Data Bureau and other departments adheres to the principle of "pilot first, key breakthroughs", selects 12 industries and fields such as commercial circulation, scientific and technological innovation, and industrial manufacturing, focuses on the digital transformation of all factors and processes, and gives full play to the multiplier effect of data elements (Wu and Tao, 2024).

3.5.2 Promote the development of small and medium-sized enterprises

Small and medium-sized enterprises are an important part of the manufacturing industry, and the policy environment has also played an important role in promoting the digital transformation of small and medium-sized enterprises. The support of industrial policies, on the one hand, can enable enterprises to better deal with the complexity and uncertainty of the external environment, and on the other hand, can offer impetus for enterprises to integrate internal resources and achieve cost reduction and efficiency improvement. Through such favorable measures at the national level as "Special Action for Digital Empowerment of Small and Medium-sized Enterprises" and "Selection of Pilot Cities for Digital Transformation", small and medium-sized organizations can not only enjoy policy dividends but also gain the guidance of the top-level design of digital transformation (Liu and Zhang, 2021).

3.5.3 Encourage technological innovation and application

The policy environment has increased the supply of common technologies through a series of policies that encourage innovation, encourage enterprises to increase R&D investment in digital technology, intelligent manufacturing, and other fields, promote technological innovation and application, and provide solid technical support for the digital transformation of the manufacturing industry.

3.6 Digital talents are the driving force for building the digital competitive advantage of the manufacturing industry

Digital talents are the driving force for enhancing the manufacturing industry's core competitiveness and an important starting point for realizing digital transformation. In the era of the digital economy, the integration of the traditional manufacturing industry and digital technology is accelerating, and compound talents with both manufacturing professional knowledge and digital information technology are needed to speed up the process of digital empowerment.

Digital talents master digital technology and can provide solid technical support for enterprises. They optimize production processes, improve the quality of the product, reduce operating costs, and help enterprises realize intelligent production through data analysis, machine learning, artificial intelligence, and other means. In addition, digital talents are also an important source of innovation. Technological innovation is no longer only achieved by large digital enterprises, but a new situation of mass innovation (Shi, 2022). Traditional manufacturing enterprises still need a large and professional technical research and development team to promote innovation in the manufacturing industry in products, services, business models, etc. by introducing new technologies and new methods, to bring competitive advantages to enterprises.

Digital talents can keenly perceive market changes, grasp digital trends, and expand new market areas and customer resources for enterprises. They use digital means to achieve precision marketing, customer relationship management, etc., and improve the market competitiveness of enterprises. Not only do they have high-level skills and knowledge, but they can also drive other employees in the company to improve their digital literacy and capabilities through training and guidance and cultivate more digital talents for the long-term development of the company. In addition, the talent resource-sharing mechanism is also the source of vitality for the transformation of today's manufacturing industry. Talent sharing can break rigid barriers and encourage a flexible flow of talents. Through various forms such as the joint construction of new R&D institutions, joint laboratories, and contract development projects by scientific research institutes and corporate talent R&D

teams, technology sharing can be achieved, and various forms of technological achievements can be encouraged to be transformed, promote industry-university-research cooperation, and further promote the digitalization process of enterprises (Liu and Zhang, 2021).

In summary, enterprises should attach importance to the introduction and training of digital talents, and build a high-quality digital talent team by creating a digital transformation atmosphere and promoting the deep integration of technology and business, to provide strong support for the long-term development of enterprises.

4 Motivations and Paths For The Digital Transformation of Manufacturing Enterprises

4.1 Motivations for the digital transition of manufacturing enterprises

4.1.1 External motivations

The literature related to the motivations for the digital transformation of enterprises can be separated into four aspects, including political factors, economic factors, social factors, and technological factors.

From the perspective of political factors, the digital transformation of enterprises is an inevitable trend. It can be roughly divided into international political influence and domestic policy promotion. After the financial crisis, many European and American countries regarded digital technology as a vital way to achieve the revitalization of their industries and successively launched digital strategies, which accelerated the development of the digital economy and promoted the digital transformation of the manufacturing industry (Chen and Zhang, 2023). In addition, unilateral protectionism in international trade is rampant. In addition to making full use of international trade rules to resolve disputes, Chinese enterprises also need to carry out digital transformation and improve their operational capabilities to gain advantages in international competition. In terms of domestic policies, local governments have launched a series of digital economic development strategies to cultivate a new digital economy ecology. For example, the "2022 Government Work Report" mentions encouraging the digital economy's development and coordinating the promotion of industrial digitalization and digital industrialization. It can be seen that digital transformation has become an important means to transform and enhance traditional momentum and cultivate new development momentum (Yuan et al., 2021).

From the perspective of economic factors, external economic and industrial economic conditions will drive the digital transformation of enterprises. External economic factors will affect organizational structure and organizational behavior, and further affect the tendency of enterprises to apply digital technology for digital transformation (Quinton, 2018). In addition, the changes in the competitive environment, the formation and evolution of the value chain system, and the changes in the business ecosystem brought about by the industry's economic situation have become important factors for enterprises to shift from single information technology applications to comprehensive digitalization (Chen et al., 2020). At the industrial chain level, digital development will strengthen exchanges and collaboration between enterprises and accelerate the integration of the industrial chain.

From the perspective of social factors, changes in consumer demand drive enterprises to undergo digital transformation. With the development of digital technology and the advent of the artificial intelligence era, consumers' habits have shown more personalized characteristics, traditional design and production models are difficult to adapt to, and online consumption behaviors have become increasingly frequent (Chen et al., 2022). This requires companies to continuously update and upgrade their products, adapt to changes in consumer demand and consumer behavior, and launch digital business models to obtain new ways of value acquisition (Li Sijia, 2022).

At the technical level, the in-depth application of a new generation of digital technology has become a key driving factor for economic growth in all walks of life. The replacement of digital technology will promote changes in corporate strategic management and innovative thinking, and promote digital transformation of enterprises. The application of digital technology by enterprises has reconstructed the competitive model of industrial organizations, promoted integration between industries, enabled industrial upgrading, and profoundly changed the original business logic, thereby further promoting the digital transformation of enterprises (Xiao et al., 2019).4.1.2 Internal motivations

The internal motivations for enterprise digital transformation mainly include the internal strategic needs of the organization and the degree of digital awareness of enterprise managers.

Organizational strategy can drive enterprise digital transformation. The strategic starting point of enterprise digital transformation is to adapt to changes in the external environment so that enterprises can achieve sustainable development. In the process of implementing development strategies, enterprises often need digital transformation to support and adapt to the strategic needs of enterprises through digital transformation (Liu et al., 2020). At the same time, when facing the uncertainty of both technology and market environment, enterprises will produce a group effect and actively adjust their strategies according

to the decisions of competitors. When industry competitors generally carry out digital transformation, they will seek strategic convergence to maintain the balance of competition (Chen et al., 2021). In addition, during the crisis, because the business model and development path that the enterprise relies on are affected, the enterprise will generate organizational resilience, promote reflection and improvement in unfavorable situations, and thus drive the enterprise to transform. Among them, the use of digital technology for empowerment will enable organizational capabilities to achieve a leap from low-level to high-level (Shan et al., 2021).

The digital transformation awareness of enterprises can promote the digital transformation of enterprises. In most enterprises, the level of managers' understanding of digitalization will have an impact on the enterprise's exploration of digital transformation. Moreover, executives with strong digital transformation thinking and high sensitivity to future market development trends play a key role in promoting digital transformation (Zheng et al., 2020). The same is true for enterprise employees. As the main force of digital transformation, employees' digital literacy is also a key dynamic ability to promote the digital transformation of enterprises. At the same time, the construction of survival and development pressure and absorptive capacity within the enterprise will improve the enterprise's awareness of digital transformation, thereby promoting the digital transformation of the enterprise (Wang and Chen, 2023).

4.2 Path of digital transformation of manufacturing enterprises

4.2.1 Organizational change

Organizational change is the basic path for enterprises to carry out digital transformation. First, manufacturing enterprises reconstruct organizational boundaries through three knowledge coupling mechanisms: knowledge reorganization, knowledge integration, and knowledge decoupling. Reshaping organizational boundaries through knowledge interaction can promote digital transformation (Wang et al., 2022); second, some scholars have proposed that building a flexible organization and constructing a dual-circulation open innovation network can promote the improvement of corporate innovation capabilities, thereby promoting digital transformation (Yang, 2021); third, building an adaptive learning organization is the key to the formation of a digital system for enterprises, which can drive enterprises to make adaptive changes in management and thus break through the industrialization system (Xiao, 2020); enterprises can also promote digital transformation and form organizational guarantees by setting up transformation offices, digital departments, embedded digital business groups, etc. in their organizations according to their conditions (Zhang, 2020). In summary, through the organizational strategic layout and transformation of enterprises, new growth poles can be brought to enterprises and the digitalization process of enterprises can be promoted (Tang et al., 2024).

4.2.2 Financial digitalization

Financial digitalization is an important path for the overall digital transformation of the enterprise. In practice, it mainly includes two paths: financial sharing and data middle platform construction. Financial sharing is to intensively process financial data through the reshaping of organizational methods and operating methods. Through the application of new technologies, the financial digitalization of enterprises is promoted in an interconnected, shared, and intelligent way. It can further support the flexible and scalable work transformation of enterprises and adapt to the flexible processes formulated by enterprises to satisfy the customers' personalized needs (Zhang, 2020). The data middle platform is different from financial sharing. It builds a digital platform based on the Internet and big data architecture to help enterprises realize data businessization and business dataization. The construction of a service-oriented data middle platform will help enterprises become the best path for traditional large enterprise groups to carry out comprehensive digital transformation (Yi, 2022).

4.2.3 Intelligent production and operation

Informatization of operation management and intelligent production and manufacturing are the implementation paths of digital transformation. First, using information systems can help enterprises learn digital knowledge. Information systems play a major role in knowledge acquisition, knowledge interpretation, and knowledge sharing. The mechanism is that the knowledge obtained through exploratory learning can be converted into fixed processes and stored in the system, offering a foundation for the digital transformation of enterprises (Barros, 2015); second, using digital technology to improve the level of digital operations and achieve intelligent decision-making. The mechanism is to use technologies such as simulation experiments to reasonably allocate resources, improve production quality, change the cost structure of revenue, and ultimately improve user experience, achieve a closed loop of digital operations, drive the evolution of digital transformation and improve operating efficiency (Majchrzak, 2016); through business system integration and cloud transformation, a complete business process system is built to achieve integrated operation of key businesses. Third, the transformation of intelligent manufacturing will improve the original management level and business

foundation of enterprises. The mechanism is that lean and intelligent production digitalization can affect the entire process of product manufacturing, improve the dramatization and standardization of manufacturing resources, improve the interconnection between manufacturing processes, improve the intelligence of manufacturing equipment, and achieve interconnection (Yang, 2022); Fourth, from the perspective of reshaping the production process, it can be used as a method to assist digital transformation and improve performance. The main mechanism is that the controllability of the enterprise's production process and the modularization of the production model under digitalization will enable the enterprise to configure production factors according to market information, flexibly release production capacity, and thus reduce the production cost of the enterprise (Bai, 2022).

4.2.4 Ecological synergy

Building an ecosystem to achieve resource and technology synergy and complementarity is a win-win path for digital transformation. First, enterprises use the industrial Internet platform to carry out digital transformation through knowledge transactions and knowledge reuse in the industrial Internet platform. The mechanism of action is to use knowledge transactions to help enterprises obtain systematic digital knowledge, and use knowledge reuse to replicate and imitate the digital transformation experience of similar enterprises, to carry out digital transformation at low cost and high efficiency (Lu et al., 2022); second, when the digitalization and R&D level of the enterprise itself is insufficient and it is difficult to support the digital transformation of the enterprise, it becomes a better way to achieve digital transformation through cooperation with platform enterprises. Rococo Group joined DingTalk, an ecological participant, and promoted the digital transformation of enterprises with the help of platform enterprises, realizing collaborative upgrading and forming a transformation path of "mutual integration, symbiosis, and autonomy". Its mechanism of action is to achieve resource complementarity, feedback to the enterprise itself with platform resources, and achieve efficiency improvement, business growth, and ecological construction (Chen, 2021); third, from the perspective of ecological empowerment, building an enterprise ecological network can be used as one of the transformation paths. Its mechanism is complementary advantages and resource sharing. Through the equity and contractual connection between core nodes and non-core nodes in the enterprise network, and the dynamic adjustment of the connection objects, the boundaries of enterprise digital transformation are made more open and flexible (Sun, 2021). By building a shared digital network platform, the interests of various digital economic entities are tied together to form a digital ecological community of co-construction and sharing, thereby promoting digital transformation (Shi, 2022).

5 Main conclusions

5.1 Management inspiration

For enterprises, digital transition is a gradual process, which requires enterprises to reflect and summarize. Firstly, enterprises need to establish organizational guarantees during the digital transformation process. Promoting the enterprise's digital transformation inevitably requires streamlining the organizational structure. The more complex the organizational structure is, the greater the resistance to change. Through the change of the organizational structure, the enterprise's digital transformation will be better achieved, and the improvement of enterprise performance will be more obvious. Second, enterprises can coordinate strategies based on the external environment and their situation during digital transformation. Third, before digital transformation, enterprises need to improve their digital transformation awareness and improve the awareness of enterprise personnel transformation through senior executives visiting other enterprises and organizing collective learning of enterprise employees. Fourth, financial digital transformation and promotion of financial shared centers are not only simple financial centralized processing, but also should establish a matching data middle platform to support the financial shared center to process finance more efficiently, improve financial management efficiency, and ensure the cash flow of organizations.

For the industry, if the manufacturing industry wants to achieve high-quality development and long-term sustainable development, it must undergo digital transformation. However, the maturity of digital transformation of enterprises in the industry is not enough, and digital technology has not been deeply applied in the entire industry chain, so it is difficult to cope with changes in the industry environment. Enterprises in the industry should actively promote digital transformation, actively use the industrial Internet platform to provide digital transformation solutions for upstream and downstream enterprises in the industry, promote the entire industry chain's digital empowerment, and enable the industry to achieve high-quality growth.

For the government, it has to be recognized that the enterprises' digital transformation is a thorough change and often faces failure. In addition to encouraging enterprises to transform digitally through various policies, the government should also provide support and guarantees for enterprises that fail in transformation. First, it can connect with university teachers and digital transformation experts to provide advice for the digital transformation of enter-

prises and accept transition consultations from enterprises. Second, provide certain financial and policy assistance to enterprises that fail in transformation, so that they can reduce the negative impact brought about by the pain period of digital revolution and continue to increase the depth of digital transformation.

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