Research on Digital Maturity Measurement Index System of Small and Medium-Sized Manufacturing Enterprises Digital Innovation

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Objectives: Facing the tidal wave of the global digital, taking advantage of the trend to carry out digital transformation is an inevitable choice for the development of small and medium-sized manufacturing enterprises. Based on the analysis of digitalization, digital transformation and digital maturity and other related documents, the paper developed a digital maturity model for small and medium-sized manufacturing enterprises (Digital maturity model, DMM), and designed a rule-based digital maturity level identification method. The literature method and expert review method are used to refine the digital maturity index system of small and medium-sized manufacturing enterprises, and the specific weight of the evaluation index is calculated by the analytic hierarchy process. The model includes 4 first-level indicators, 14 second-level indicators, and 36 third-level indicators for digital infrastructure, core business digitalization level, digital human resource level, and digital transformation management. Using the proposed index system and the corresponding digital maturity level identification method, the digital level of small and medium-sized manufacturing enterprises and their value chains can be evaluated, which helps enterprises to achieve strategic goals of digital transformation in a targeted manner, and provides effective solutions for the development of digital transformation of enterprises. The evaluation methods and tools also provide useful reference and guidance for the theoretical community.

Key words: small and medium manufacturing enterprises; digitalization; digital maturity; evaluation index system
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RESEARCH BACKGROUND

With the rapid development of digital technologies represented by the Internet, big data, and artificial intelligence, digitization has become one of the main trends that change society and business models, bringing unprecedented opportunities and challenges to the development of the industry. All industries are faced with the

opportunity to use advanced information technology and the challenge of avoiding technology-induced business risks. Under the wave of the digital economy, it is not a panacea for companies to take advantage of the trend to carry out digital transformation, but if they do not carry out digital transformation, they may be abandoned by the market. The high-quality development of the manufacturing industry is an important prerequisite and guarantee for the high-quality development of China's economy. In the era of Industry 4.0, how to use the digitalization to empower the transformation and upgrading of the manufacturing industry is a problem that SMEs must face. The current research on digital transformation focuses on the necessity and importance of digital transformation, ignoring the evaluation of enterprise digital maturity and digital transformation capability. The failure rate of digital transformation projects of small and medium-sized manufacturing enterprises is as high as 66%-84% due to the lack of capital volume, digital level of production equipment, business process, organizational structure and digital talents, etc. Considering the capital and other costs of these projects, this is a considerable proportion. [1]Therefore, in order to explore a more appropriate method and path to realize the digital transformation of an enterprise, fully understand the digital resources and capabilities of the enterprise, and scientifically analyze and evaluate the digital level of the enterprise itself becomes crucial, and the digital maturity model can usually be used as an in-depth study. An important prerequisite for enterprise digital transformation.

China is in a critical period of industrial digitization and digital industrialization transformation. How to use digital technology to empower small and medium-sized manufacturing enterprises is the key to enterprises gaining competitive advantage. As experts and scholars have significant differences in their understanding of the indicators for measuring the maturity of digital transformation, a unified evaluation dimension and indicator has not yet been formed, and it is not feasible to directly apply the indicator system of the existing foreign digital transformation maturity model. In order to help small and medium manufacturing enterprises to better measure their own digital level, formulate specific areas of improvement and achieve effective transformation, a scientific and systematic maturity model and indicator system suitable for small and medium manufacturing enterprises is urgently needed. This paper intends to design a digital transformation maturity model for small and medium-sized manufacturing enterprises, using a rule-based evaluation method to evaluate the digital maturity level of the company, and on this basis, to evaluate the overall potential of the company's digital transformation status.

THEORETICAL SUMMARY

Digitization and Digital Transformation

The early definition of digitization focused on computer technology, which was defined as "the conversion of analog information to digital form" (i. e. binary format). Wilhelm first explained the concept of digitization, which referred to the binary system represented by 1 or 0. [2]Boole believed that digitization represented signals, images, sounds, and objects by generating a series of numbers. In recent years, scholars have gradually studied the concept of digitization from a theoretical perspective.[3]Sjodin et al believe that digitization has given birth to digital technologies such as the Internet of Things, Industrial Internet, Industry 4.0, big data, and blockchain, which is the process of using advanced digital technologies to trigger changes in the industry.[4] Manyika et al believe that digitization includes the direct process of converting analog information into digital pages as a unit, the use of digital technology or digitized information, and create and obtain value through new methods.[5] Kirsi believes that digitalization is to re-adjust or invest in digital technologies, business models and processes, to create value for customers and employees, and to compete more effectively in the ever-changing digital economy.[6] Chen Jian and others believe that "digitalization" refers to the technology transfer of information (processes) and tasks to computers, and the use and integration of digital technology for reorganizing the company's work

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process and changing the organization's business model to achieve business process upgrades.[7] Digitization plays an important role in the development of the economy now and in the future. It can not only effectively improve the production efficiency and quality of the enterprise, but also may subvert the old operation management process of the enterprise, and realize the innovation of operation management model, business model and competition paradigm.

The initial digital transformation only used IT for basic management tasks. Later, integrated solutions were introduced on the basis of improved connectivity and a new database system. The concept of digital transformation became broader and richer. Chanias, et al believe that digital transformation is a process in which companies increase the use of IT to affect the main activities and support activities (such as production, marketing and sales, control or human resources).[8] Wuman believes that digital transformation is a process of using digital transformation technology to change the enterprise's R&D, manufacturing, sales, service and product use and the entire value chain process.[9] Xiao, et al believe that digital transformation is a process of improving the quantity and efficiency of industrial production.[10] Wang, et al believe that digital transformation involves the application of digital technology, cultural and organizational changes, and is the interaction between artificial intelligence, big data, cloud computing and other IT technologies and specific businesses of enterprises.[11] Zeng, et al believes that digital technology is the prerequisite and basis for digital transformation.[12] The future development of digital transformation is networking with other companies and private customers based on Internet infrastructure. Currently, the new generation of systems for data processing and analysis, the integration of different (user) devices, and the further expansion of Internet-based connections provide new opportunities once again.

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Digital Maturity Model

Digital maturity can usually be used as the first step to further study the company's digital transformation. From a technical point of view, digital maturity describes the degree to which the company's tasks are performed, and the extent to which information (flow) is processed by IT. From a management perspective, digital maturity describes the state of the company's digital transformation and the company's achievements in implementing transformation efforts. Chanias and Hess believe that the digital maturity is the degree of completion of digital transformation of an enterprise and the status of digital transformation of enterprises. They analyzed 20 models based on the summary of 36 internationally published models related to digital maturity. Related models.[13] Kane et al believe that the analysis of digital maturity is to guide organizations to systematically prepare to adapt to continuous digital changes.[14] Wang et al optimized the digital maturity evaluation index system based on the 20 models selected by Chanias and Hess, and proposed that digital maturity includes three aspects: digital readiness, digital intensity, and digital contribution. It is divided into five levels: initial level, growth stage, promotion level, comprehensive integration level and continuous improvement level.[15]

The maturity model is a common tool in the fields of software engineering, project management, and quality management. In order to assess the ability of government contractors to deliver software projects, Humphrey et al proposed a maturity framework at the request of the Software Engineering Institute of the US Department of Defense,[16] and the framework was later extended,[17] and finally evolved into a capability maturity model (CMM).[18] The model is mainly used in developing products, establishing services, managing and acquiring products and services, etc. Digital maturity related models generally adhere to the basic principles and framework of CMM, but differ in the description of the ability level that reflects the digital level. The global major consulting companies first began to study the key factors of enterprise digital transformation and digital maturity models, such as IBM and Accenture Consulting proposed the strategy and dimensions of enterprise digital transformation, and LEYHC et al proposed the SIMMI 4.0 model, [19] German National Academy of Sciences and Engineering proposed the Industry 4.0 Maturity Index to manage the digital transformation

of enterprises.[20] In recent years, domestic scholars have also begun to study related content such as "digital empowerment", "digital capability", and "digital maturity". Zhou et al believe that the digital empowerment of employees and customers can improve the digital capabilities of enterprises.[21] Wang Rui constructed a manufacturing enterprise digital maturity evaluation model that includes four dimensions: strategy, operation technology, cultural organization capabilities, and ecosystem, and use the analytic hierarchy process and evaluation laboratory method to conduct an empirical analysis of the digital maturity of a commercial vehicle company.[22]

DIGITAL MATURITY MODEL CONSTRUCTION

Digital Maturity Model Index System Construction

Digital maturity model dimensions

There are many indicators for evaluating the dimensions of digital maturity, such as digital competitiveness, digital innovation capability, innovation performance, and digital transformation level. Some indicators focus on measuring the level of digitalization of the entire country or region, while others focus more on identifying indicators and dimensions that are more relevant to individual SMEs. The European Commission uses a set of pre-defined indicators to measure the digital competitiveness of each country, monitors the country's digital performance and digital competitiveness,[23] and developed a digital economy and social index covering five dimensions including connectivity, human capital, Internet service use, digital technology integration, and digital public services. In addition, the European Commission also monitors the digital transformation effects of existing industries and companies from both driving force and output. The driving factors include the supply and demand of digital infrastructure, investment, financing channels, digital skills, e-leadership, and entrepreneurial culture, which use the digital transformation enabler index to measure. The output is expressed as the integration of digital technology and changes in the ICT entrepreneurial environment, which are measured by the Digital Technology Integration Index and the ICT Entrepreneurship Evolution Index, respectively.[24] The regional innovation scoreboard uses 18 of the 27 indicators of the European innovation scoreboard, including 10 dimensions of human resources, attractive research systems, an environment conducive to innovation, funding and support, company investment, innovators, connections, intellectual assets , Employment impact, and sales impact.[25] The German Federal Ministry of Economic Affairs and Energy uses the Digital Economy Index to assess the degree of digitalization of the German economy.[26] The index focuses on the three themes of the use of digital equipment and infrastructure, the digital development of enterprises, and commercial success through digitalization. The Digital Maturity Index is published by the Politecnico di Milano. It analyzes the business processes of small and medium-sized enterprises in design, engineering and maintenance, and provide them with digital maturity assessment in human resources, production, supply chain, quality, logistics, marketing, sales, customer service, and monitoring.

Rauch developed an evaluation model and tool with 4 dimensions including technical dimensions and 42 concepts to promote the adoption of Industry 4.0 concepts by small and medium-sized manufacturing enterprises.[27] Bogovac designed a digital index IDSME that includes four dimensions: Internet connection, digital skills, digital technology integration, and Internet use to examine the digital status of small and medium-sized enterprises. [28] Pham (2010) proposed a four-factor model that includes ICT infrastructure, ICT applications, human resources, and ICT policies to measure the ICT maturity of SMEs.[29] Ramantoko et al developed a capability model of digital transformation maturity of SMEs with 9 dimensions including organization or company presence, store presence, support, knowledge management and decision-making, marketing and sales, customer relations, internal communication, ecosystem management, and digital revenue.[30] Aida took natural fibers as an example to study the value chain of SMEs under digitalization, and constructed an evaluation system for the digitalization level of SMEs including 8 dimensions (connectivity, online presence, online activities, ICT infrastructure, policies, ICT use, human resources and R&D infrastructure) and 54 indicators.[31] Institute of The University of St Gallen and Swiss management consulting firm

Crosswalk proposed a "digital maturity model" based on literature reviews, expert interviews and focus groups, and revised it regularly to keep updated best practice indicators. The model mainly includes 9 dimensions including customer experience, product innovation, strategy, organization, process digitization, collaboration, ICT operation and development, culture and expertise, and transformation management.[32,33]

Drawing on the relevant theories about digital transformation maturity models at home and abroad, we use the Delphi method and invite 6 experts from academia and business circles to refine and screen the index system of the digital transformation maturity evaluation model. This index system aims to cover SMEs as comprehensively as possible. This indicator system is prepared in accordance with the principle of covering all areas of digitalization of small and medium-sized manufacturing enterprises as comprehensively as possible, which includes 4 dimensions (digital infrastructure, core business digitalization level, digital human resource level, and digital transformation management), 14 second-level indicators, and 36 third-level indicators, as shown in Table 1.

Explanation of specific indicators

(1) Digital infrastructure. Digital infrastructure is the basis for manufacturing enterprises to realize digital transformation, and IT basic capabilities and equipment network interconnection level are selected as the main evaluation indicators. Among them, the basic IT capability is the basic carrier to realize the digital transformation of the enterprise, which can reflect the internal network connection of the enterprise and realize the digital connection of the core business links of the enterprise that include the utilization level of fixed-line broadband, mobile broadband and enterprise ERP system. The level of equipment network interconnection includes the digitization level of equipment and the level of equipment networking, which can transmit production, R & D and other data to the data center in real time to achieve accurate and efficient production management.

(2) The digital level of core business. The digital level of core business is the most important factor that affects the digital level of an enterprise, and it is also the most important part of the evaluation model of enterprise digital transformation maturity. It is necessary to ensure that the applications of the core business of the enterprise can provide services quickly, efficiently, and smoothly on various channels such as mobile, Web, Internet of Things, and API, and monitor and analyze the data and customer behaviors on each application in real time, and continuously to improve customer satisfaction. The core business process of an enterprise includes multiple links such as procurement, production, logistics, and marketing. It is not only necessary to achieve digitalization through technical production, but also to achieve digital collaboration and integration of business processes, to open up the data chain of the whole process of management such as procurement, R&D, production, marketing, logistics, and finance, etc, and realize the transformation of core business processes and efficient human and financial management. Thereby, the enterprise could promote the optimal allocation of factors such as technology, business, talents, capital, etc., and improve product quality and production efficiency. The digitization level of core business mainly includes six second-level indicators: procurement digitization level, R&D digitization level, production digitization level, marketing digitization level, logistics digitization level, and financial digitization level. Procurement digitization is further divided into three third-level indicators: supplier digitization, procurement process digitization, and procurement process control digitization. The digitization level of supplier is the key to the digitization of the procurement process. The digitization of the procurement process enables companies to instantly obtain information such as procurement completion, procurement channels and procurement quantities. R & D digitization is an important driving force for the digital transformation of the enterprise, including the networking of R & D platforms and the digitization of R & D management processes. Only the interconnection of various R & D platforms within the enterprise to form a harmonious innovation network and innovation ecosystem can stimulate the emergence of innovation. The digitalization of the R & D management process is the key to realize the digital interconnection of various R & D platforms. The level of production digitization is the key to the digital transformation of an enterprise,

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including the digitization of products or services, the digital management of the production process, and the degree of customer participation in product customization. The level of marketing digitalization mainly includes the construction of e-commerce platform, digital management of online sales and digitalization of customer experience. The level of logistics digitization includes digitization of warehousing and digitization of logistics distribution, which can reflect the digital capabilities and processes of logistics. The level of financial digitalization can provide an effective guarantee for the digital transformation of the enterprise, which select indicators that reflect the level of digital financial management of the enterprise, such as the level of financial informatization, the internal financial and business integration capabilities of the enterprise, and the degree of financial data sharing.

(3) The digital level of human resources. Enterprise transformation requires talents first. The essence of enterprise digital transformation is to change the mindset of human resources. Professional digital human resources support is a prerequisite for digital transformation. They must understand business, products and technology as well as digitalization. The level of digital human resources includes three first-level indicators: digital operation skills of employees, digital communication skills of employees, and the employment of ICT experts. The digital operation skills of employees are mainly improved through employees' ICT training and their independent learning ability. The digital communication ability of employees is mainly reflected in the ability of employees to use email or instant messaging tools and standard applications or office software. Employees who have mastered the ability to operate and communicate with digital equipment can improve the utilization of digital equipment. The recruitment of ICT experts is measured by two third-level indicators: the number of ICT experts and the degree of reuse of professional knowledge. The number of ICT experts reflects the soft power of the company's digital transformation and the potential for future digital development, while the degree of reuse of professional knowledge determines the speed and future development trend of enterprise digital transformation.

(4) Digital transformation management. The wave of digital economy and digital transformation has brought huge challenges to the transformation of senior managers and organizational management structure. The understanding and attitude of senior managers on digital transformation determines the upper limit of enterprise digital transformation. The failure of many enterprises' digital transformation is due to the lack of understanding of digital transformation by senior managers or the inability of the enterprise's internal organization and management structure to support the needs of digital transformation of enterprises. Digital transformation management mainly selects senior managers' attitudes towards digital transformation, the company's ICT policies, and the organization's ability to adapt to digitalization as evaluation indicators. The key to digital transformation is the attitude of corporate senior managers towards digital transformation. Whether top managers formulate a digital transformation strategy, whether they actively invest in digital construction, and whether they participate in digital transformation decisions all determine the speed and quality of a company's digital transformation. The corporate ICT policy takes the establishment of corporate ICT departments and the upgrade of ICT software or hardware as the main evaluation indicators. The ability of an organization to adapt to digitalization includes three third-level indicators: the degree of organizational matching to adapt to digital transformation, the improvement of management systems, and the culture of innovation and change.

Determination of Index Weight of Digital Maturity Model

Analytic hierarchy process (AHP) is a decision-making method that combines qualitative and quantitative methods to decompose factors related to decision-making into multi-level single-objective problems such as goals, criteria, and plans.[34] This method constructs a comparison matrix and uses mathematical operations to obtain the weight relationship of each indicator in this dimension compared to the upper level dimension. The principle and calculation are simple and the results are simple and clear. This paper conducted interviews and surveys with 6 experts from small and medium-sized manufacturing enterprises, governments, and

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universities, and combined with the AHP method to determine the weights of various indicators of the digital maturity model, as shown in Table 1.

Design Idea of Digital Maturity Level Identification Method Based on Rules

Due to insufficient research and literature on the degree and level of development of enterprise digital transformation, we use the rule-based identification method of high-tech products by Wang Hongqi's team.[34] This method can not only realize the quantification of qualitative indicators, but also reduce the subjective arbitrariness of experts, improve the accuracy of expert judgment and the standardization of scoring. In addition, it is easy to operate, and has good judgment and practical effects. According to the specific evaluation index system for judging the development level of the digital transformation maturity of the enterprise, the development of each index is designed to be excellent, good, medium, and poor, of which each single indicator has 20 points. The quantitative rules and standards for the third-level indicators of digital maturity judgment for small and medium-sized manufacturing enterprises are shown in Table 2.

Classification of Maturity Levels

There are currently a large number of qualitative and quantitative methods to determine digital maturity. For example, qualitative models can be based on semi-structured management interviews and evaluated on the basis of interpretation. Quantitative models mostly use structured questionnaires of the Likert scale, which could be very simple, such as using aggregate scores for each dimension, or very complex, such as combining various mathematical statistical score calculation procedures. Some models also rely on (dynamic) dimensions and weighting of related indicators. Most models are evaluated based on 4-5 levels of evolutionary maturity. This paper draws on relevant literature[35-37] and combines the opinions of relevant experts to divide the digital maturity model into four levels: starting level, growth level, mature level, and optimization level. The details are shown in Table 3.

Starting level: In the early stages of digital transformation, they have almost no advanced digital capabilities. Most of them use traditional methods to implement production and management in accordance with industry norms. They have a weak sense of digital transformation and are skeptical of the value of new digital trends. They are not affected by digital benefits, have not formulated strategic goals for digital transformation, and have no relevant digital transformation. planning.

Growth level: Various digital technologies have been tested and started to be implemented. Some of these initiatives may have created value, but most of them have not yet achieved value. The management skills to create a successful and sustainable digital transformation strategy are lacking. Although these applications look great, they did not produce the expected synergies.

Mature level: The enterprises really understand how to create value through digital transformation. Digital and mobile channels have been integrated into the core business process of the enterprise. The management clarified the strategic goals of digital transformation and promoted digital transformation as a strategic change project. They realized the latest digital trends and coordinated them with a strong vision and digital culture, resulting in effective value creation. Therefore, they have a competitive advantage and surpass other companies in their industry.

Optimization level: Digital transformation is a business goal predetermined by management and has been transformed into a measurable and actionable goal. The digital potential in core activities and processes is fully utilized, and the qualitative leap of corporate development and the path to sustainable development after the digital transformation are explored.

CONCLUSION AND OUTLOOK

The improvement of digitalization of small and medium-sized manufacturing enterprises will help low-digitized small and medium-sized enterprises to successfully integrate into the digital value chain and realize technological progress and digital transformation. By improving the digital level of individual SME and the entire value chain, it will help SMEs and their value chains to transform to a more competitive and sustainable direction, thereby

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significantly promoting the development of circular economy. China is currently in a critical period of digital transformation. The digital transformation of industry is a hot topic discussed by academia and industry. The digital transformation of manufacturing is a complex system engineering involving multiple levels and multiple aspects, and a scientific and reasonable reference architecture and evaluation index system is of great significance for guiding the digital transformation and development of the manufacturing industry. Studying the maturity of digitalization is the primary prerequisite for exploring the feasibility of digital transformation of enterprises, which helps enterprises obtain comparable evaluation conclusions and strategic enlightenments in the process of digitalization. Based on the research and reference of relevant domestic and foreign documents, this paper deeply analyzes the core business activities of small and medium-sized manufacturing enterprises in the digital transformation process, refines and screens out the evaluation indicators of the digital maturity of enterprises and their specific weights, divides the digital maturity, and designed the specific rating method. However, due to the large number of small and medium-sized manufacturing enterprises in China, and the digital transformation of different types of small and medium-sized enterprises have different focuses, they must be adjusted and supplemented in accordance with the actual situation of the enterprise.

Table 1
Evaluation Index System and Weight of Digital Maturity Model for Small and Medium-Sized Manufacturing Enterprises

First-level indicator	Weight	Second-level indicator	Weight	Third-level indicator	Weight
Digital Infrastructure A	0.3	IT basic ability A_1	0.615	Fixed broadband A_{11}	0.29
				Mobile broadband A_{12}	0.38
				Enterprise ERP system utilization level A_{13}	0.33
		Equipment network interconnection level A_2	0.395	Digital level of equipment A_{21}	0.55
				Networking level of equipment A_{22}	0.45
Core business characterization level B	0.245	Procurement digitalization B_1	0.149	Digital level of internal supply chain B_{11}	0.34
				Digital level of supplier B_{12}	0.19
				Digital level of procurement process B_{13}	0.25

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				Digital level of procurement process control B_{14}	0.22
		R & D digitalization B_2	0.185	Networked degree of R&D platform B_{21}	0.54
				Digital level of R&D management process B_{22}	0.46
				Digital level of product or service B_{31}	0.35
		Production digitalization B_3	0.225	Digital management level of production process B_{32}	0.33
				Customization level of customer involvement in product B_{33}	0.32
				Construction level of E-commerce platform B_{41}	0.37
		Marketing digitalization B_4	0.195	Digital management level of online sales B_{42}	0.32
				Digital level of customer experience B_{43}	0.31
				Digital level of warehousing B_{51}	0.49
		Logistics digitalization B_5	0.146	Digital level of logistics distribution B_{52}	0.51
				Level of financial informationization B_{61}	0.38
		Financial digitalization B_6	0.1	Level of enterprise internal financial and business integration capability B_{62}	0.33
				Degree of financial data sharing B_{63}	0.29
Digital Level of Human Resource C	0.225	Digital operation skills of employee C_1	0.39	ICT training frequency C_{11}	0.40

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				Data analysis and visualization processing capability C_{12}	0.60
		Digital communication skills of employee C_2	0.39	Ability to use e-mail or instant messaging tools C_{21}	0.46
				Standard application or office software usage level C_{22}	0.54
		Hiring of ICT experts C_3	0.22	Number of ICT experts C_{31}	0.5
				Professional knowledge reuse level C_{32}	0.5
		Top management's attitude towards digital transformation D_1	0.42	Digital transformation strategy formulation D_{11}	0.37
				Digital construction capital investment level D_{12}	0.38
				Participate in digital transformation decision D_{13}	0.25
Digital transformation management D	0.23	ICT Policy D_2	0.34	Set up ICT department D_{21}	0.535
				Upgrade ICT software or hardware level D_{22}	0.465
		The organization's ability to adapt to digitalization D_3	0.24	The degree of organizational matching to adapt to digital transformation D_{31}	0.4
				Improvement level of management system D_{32}	0.32
				Innovation and change cultural atmosphere D_{33}	0.28

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Table 2
Quantitative Rules and Standards for Judging and Selecting Indicators of Digital Maturity Level of Small and Medium-Sized Manufacturing Enterprises

		Evaluation rules and standards				Note
Second-level indicator	**Third-level indicator**	**20-16 (excellent) (median 18)**	**15-11 (good) (median 13)**	**10-6 (medium) (median 8)**	**5-1 (poor) (median 3)**	
IT basic ability A_1	Fixed broadband A_{11}	Super fast	Fast	General	Not connected	
	Mobile broadband A_{12}	Connect to 5G	Connect to 4G	Connect to 3G	Not connected	
	Enterprise ERP system utilization level A_{13}	International advanced level	International general level	Domestic advanced level	Domestic general level	
Equipment network interconnection level A_2	Digital level of equipment A_{21}	International advanced level	International general level	Domestic advanced level	Domestic general level	Calculated based on the statistical data of the past 2 years
	Networking level of equipment A_{22}	International advanced level	International general level	Domestic advanced level	Domestic general level	
Procurement digitalization B_1	Digital level of internal supply chain B_{11}	Very perfect	Relatively perfect	General	Imperfect	Determined according to the average management level of the small and medium manufacturing industry
	Digital level of supplier B_{12}	Very high	Relatively high	General	Low	
	Digital level of procurement process B_{13}	Very high	Relatively high	General	Low	
	Digital level of procurement process control B_{14}	Very high	Relatively high	General	Low	

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R & D digitalization B_2	Networked degree of R & D platform B_{21}	Very advanced	Relatively advanced	General	Backward	
	Digital level of R&D management process B_{22}	Very high	Relatively high	General	Low	
Production digitalization B_3	Digital level of product or service B_{31}	Very high	Relatively high	General	Low	
	Digital management level of production process B_{32}	Very strong	Relatively strong	General	Insufficient	
	Customization level of customer involvement in product B_{33}	Often	Occasionally	Rarely	Never	
Marketing digitalization B_4	Construction level of E-commerce platform B_{41}	Very strong	Relatively strong	General	Insufficient	Calculated based on the statistical data and data of the past 2 years
	Digital management level of online sales B_{42}	Very strong	Relatively strong	General	Insufficient	
	Digital level of customer experience B_{43}	Very high	Relatively high	General	Low	
Logistics digitalization B_5	Digital level of warehousing B_{51}	Very high	Relatively high	General	Low	
	Digital level of logistics distribution B_{52}	Very high	Relatively high	General	Low	
Financial digitalization B_6	Level of financial informationization B_{61}	Very high	Relatively high	General	Low	
	Level of enterprise internal financial and business integration capability B_{62}	Very high	Relatively high	General	Low	
	Degree of financial data sharing B_{63}	Very high	Relatively high	General	Low	
Digital operation skills of employee C_1	ICT training frequency C_{11}	Once a month	Once every three months	Once every six months	Once a year	
	Data analysis and visualization processing capability C_{12}	Once a month	Once every three months	Once every six months	Once a year	

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Digital communication skills of employee C_2	Ability to use e-mail or instant messaging tools C_{21}	Every day	Every week	Every month	Every three months	
	Standard application or office software usage level C_{22}	≥ 80% employees will use	50%-80% employees will use	30%-50% employees will use	≤ 30%employees will use	
Hiring of ICT experts C_3	Number of ICT experts C_{31}	≥ 40%	30%-40%	15%-30%	≤ 15%	0.5
	Professional knowledge reuse level C_{32}	Appreciate	Relatively Appreciate	General	Indifference	0.5
Top management's attitude towards digital transformation D_1	Digital transformation strategy formulation D_{11}	Often	Occasionally	Rarely	Never	Take the latest R & D investment as a reference
	Digital construction capital investment level D_{12}	≥ 12% (sales income)	8%-12% (sales income)	5%-8% (sales income)	≤ 5% (sales income)	
	Participate in digital transformation decision D_{13}	Often	Occasionally	Rarely	Never	
ICT Policy D_2	Set up ICT department D_{21}	Set and important	Set and relatively important	Set and unimportant	Not set	
	Upgrade ICT software or hardware level D_{22}	Update every three months	Update every six months	Update every year	Update every two years	
The organization's ability to adapt to digitalization D_3	The degree of organizational matching to adapt to digital transformation D_{31}	Very high	Relatively high	General	Low	
	Improvement level of management system D_{32}	Continuous	Relatively continuous	General	Low	
	Innovation and change cultural atmosphere D_{33}	Dense	Relatively dense	General	Low	

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Table 3
The Maturity Level of the Digital Maturity Model

Maturity level	Features
Starting level (16 points-20 points)	In the early stages of digital transformation, the awareness of digital transformation was weak and the digitization capability was weak, and the traditional production and operation methods were still adhered to. It was urgent to change the attitude towards digitalization and plan digital transformation strategies and ideas.
Growth level (11points-15 points)	Various digital technologies have been tested and started, and some of the specific measures have already achieved results. It is necessary to continue to use digital technologies to deepen the level of digitalization, improve the quality and innovation capabilities of employees, and realize the success of digital transformation as soon as possible.
Mature level (6 points-10 points)	Enterprises truly understand how to create value through digital transformation. The digital infrastructure is relatively advanced, and the digital quality of employees is high. They can grasp the digital dividend and maximize the benefits of digital transformation.
Optimization level (1 points-5 points)	Enterprises have achieved considerable benefits through digital transformation, pay attention to the future development trend of digitalization, formulate corresponding optimization strategies, set measurable and actionable goals and continue to explore the qualitative leap in corporate development and the path to sustainable development after digital transformation.

Conflicts of Interest Disclosure Statement

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