Research on Construction of Evaluation System for Digital Transformation of Manufacturing Enterprises

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Abstract: With the goal of constructing an evaluation system for the digital transformation of manufacturing enterprises in line with the development of manufacturing industry and the realization of the new generation of network technology, this paper uses analytic hierarchy process (AHP) to construct an evaluation system for the digital transformation of manufacturing enterprises, including 16 elements from four dimensions. The results show that in the process of digital transformation, manufacturing enterprises should pay special attention to the cultivation of research and development ability, which mainly depends on the construction of research and development team, production integration ability, integration platform construction and management integration ability. Secondly, they should pay attention to their own strategic planning and organizational structure, which mainly depends on the capital supply ability, enterprise strategic planning and human resources guarantee.

Keywords: Digital transformation; Manufacturing enterprises; Hierarchical evaluation system.

1. INTRODUCTION

The high-end, intelligent and green manufacturing industry has become one of the main driving forces for the high-quality development of China's economy in the new era. On the basis of "vigorously developing digital economy" at the Central Economic Work Conference, the Ministry of Industry and Information Technology further proposed to deepen the industrial digital transformation and promote the deep integration of manufacturing industry and digital economy. As a major manufacturing country, China's manufacturing value-added accounts for nearly 30% of its GDP. In the past, China's manufacturing advantages were mainly reflected in low labor cost and advantages in processing and manufacturing links. However, there are still problems such as large but not strong, insufficient key technologies and low division of labor in the global value chain. In the new era, the transformation and upgrading of the manufacturing industry has accelerated, the quality of development has steadily improved, and technological innovation has become a new point of competition. Digital transformation and upgrading refers to the application of digital technology in the process of product research and development, product sales and internal management to improve purchasing capacity, production capacity, marketing capacity, product capacity, supply chain capacity and ecological construction capacity, mainly from the four aspects of data governance, system construction, personnel organization and process mechanism, so as to shorten product delivery

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time or realize mass production. So as to achieve the purpose of reducing production cost and improving production efficiency.

The deep integration of the new generation of information technology and manufacturing companies is helping to reshape their research and development design, production processes, business management and even user relationships. At present, the extensive application of advanced sensing technology, digital design and manufacturing, robotics, intelligent control system and other technologies provides the technical basis for the digital transformation of manufacturing enterprises. Building a group of high-standard enterprises for digital transformation of manufacturing enterprises, exploring the path of digital transformation of manufacturing enterprises, and applying the transformation experience to the scenario-based and standardized replication and promotion of small and medium-sized manufacturing enterprises will help promote the upgrading of the manufacturing industry. At the present stage, manufacturing enterprises are stepping into the digital transformation stage one after another, but limited by their own strategic organizational structure, digital application basis and business integration and other factors, in the process of digital transformation shows the characteristics of scale, stage by stage, there are problems such as unclear strategic planning, difficult to find the transformation entry point, and insufficient interaction with the enterprise ecology. Therefore, by constructing an evaluation system for the digital transformation of manufacturing enterprises, issues needing attention in the process of digital transformation of manufacturing enterprises are discussed, in order to provide guidance and help for the digital transformation and practice of enterprises.

Based on this, on the basis of summarizing the existing literature, this paper adopts the analytic hierarchy process (AHP) and YAAHP software, obtains first-hand data through expert investigation, compares and scores in pairs, calculates the weight of evaluation indicators, and builds the evaluation model of digital transformation of manufacturing enterprises.

2. RESEARCH STATUS

A large number of scholars have conducted relevant researches on how manufacturing enterprises carry out digital transformation, mainly focusing on the concept, essence, function and evaluation system construction of digital transformation. The digital transformation of manufacturing enterprises refers to the deep integration of digital economy and manufacturing industry, and the integration of digitalization into each link of production, sales and internal management of manufacturing enterprises, which is not only reflected in technology, but also in management. In terms of the nature of the digital transformation of manufacturing industry, Chen and Zhang (2023), based on Schumpeter's innovation theory and Porter's innovation-driven theory, and on the practice of the digital transformation of China's manufacturing industry, proposed that the digital upgrading of manufacturing industry is essentially a comprehensive innovation model that includes product innovation, technology innovation, market innovation, resource allocation innovation and organizational innovation[3].And the digital transformation promotes the industrial structure, value chain and processing degree to be advanced. In terms of the role of digital transformation, Liu , Dong et al.(2021), starting from the perspective of innovation management and summarizing existing literature, propose that digital transformation is conducive to enterprise innovation, which is reflected in

innovation support, innovation process, innovation output, innovation mechanism and innovation result[4]. Chen and Cao(2023) proposed a significant positive correlation between digital transformation of manufacturing enterprises and total factor productivity through empirical test[2]. Chen and Xu (2020) used analytic hierarchy process (AHP) to construct an evaluation system of manufacturing enterprises' digital transformation capability from three dimensions of technological change, organizational change and management change, and proposed that enterprises' digital transformation should increase R&D investment, strengthen the construction of talent team, and pay attention to the application in production management[1]. The research results on the construction of enterprise digital transformation evaluation system are more diverse. Wan, Wang et al.(2020) used analytic hierarchy process (AHP) and based on the concept of architecture to build evaluation models from three perspectives: strategy and foundation evaluation, level and capability evaluation, and efficiency and benefit evaluation[8]. Sun and Sun(2023)applied fuzzy analytic hierarchy process (AHP) and based on the maturity model, started from the perspective of data empowerment, and constructed an evaluation model from three aspects: depth, breadth and enhancement of data empowerment[6]. Wang , Liu et al.(2022) used analytic hierarchy process(AHP)to study the influencing factors for the transformation and upgrading of intelligent manufacturing enterprises in Jiangsu province, and constructed an evaluation index system from four indicators, including resource input, enterprise management, regional development and innovative service environment[7]. The influencing factors were successively as follows: market competition degree, enterprise organizational structure, regional economic structure, etc.Liu and Fu (2022) used analytic hierarchy process (AHP) to analyze the influencing factors of the digital transformation and upgrading of construction enterprises, and built an evaluation model from six perspectives: organizational system, digital foundation, digital research and development, digital application, innovation performance and efficiency and benefit[5].The influencing factors were organizational system, digital research and development, digital application, etc.

To sum up,this paper believes that the evaluation of the digital transformation of manufacturing enterprises should not only consider the enterprise's digital R&D investment and corresponding effects, but also consider the existing conditions such as the enterprise's own strategy and organization, and the digital foundation. In addition, to ensure the model refinement, the actual situation of the digital transformation of manufacturing enterprises should be taken into account: the digital application scenario is broad, and the digital application should be excluded from the evaluation index.

Table 1 Evaluation system of digital transformation of manufacturing enterprises

Manufacturing enterprise digital transformation evaluation system A		
Secondary index	Three-level index	Index interpretation
Strategy and organization B	Strategic planning B1	Data empowerment long-term strategic development planning, data empowerment overall establishment and construction mechanism
	Process and organization B2	The administrative status of leaders in digital departments, the degree of data productivity applicable to organizational structure, and the degree of enterprise management system adapting to digitalization

	Human resources B3	Construction of digital compound talent team, digital talent management and incentive
	Fund guarantee B4	Data infrastructure investment, digital system investment, digital talent cultivation investment, data security maintenance investment, data empowerment construction special funds
Digital Basics C	Infrastructure C1	Software and hardware configuration
	Data standardization C2	Form standardized documents and promote to production management
	R&d and design C3	Ability to manage product design, process design and test verification
	Information security C4	Data security protection software and hardware systems, network and data security regulatory standards, data rights confirmation and privacy protection
Digital research and development D	R&d team D1	Has a digital system development, maintenance, software design comprehensive capabilities of the core team
	Integrated platform D2	Integrate all production, operation and management functions of the enterprise based on the integrated platform
	Production integration D3	Develop and implement the production platform system of data integration on the integrated platform
	Manage integration D4	Develop and implement the data integration management platform system on the integrated platform
Digital benefit E	Economic benefit E1	Economic benefits from digital transformation
	Quality benefit E2	The increase in the quality of production results resulting from digital transformation
	Social benefit E3	The benefits of energy conservation, emission reduction, environmental protection and innovation brought by digital transformation
	Cost effective E4	Reduced production and management cost ratio due to digital transformation

3. MODEL CONSTRUCTION AND EMPIRICAL ANALYSIS

In order to construct the evaluation model of digital transformation of manufacturing enterprises, Delphi method and analytic hierarchy process were adopted, and first-hand data were obtained through expert scoring method to confirm the weight of the model components. With reference to the research of Liu , Fu (2022), Chen , Xu (2020) and other experts, this paper constructs the evaluation system of digital transformation of manufacturing enterprises through analytic hierarchy process. The target layer is the evaluation system of digital transformation of manufacturing enterprises A, and the secondary index layer is set as strategy and organization B, digitalization foundation C, digitalization research and development D, and digitalization benefit E. Strategy and organization B includes strategic planning B1,

process and organization B2, human resources B3, capital security B4; Digital infrastructure C includes infrastructure C1, data standardization C2, research and development C3, information security C4; Digital R&D D includes R&D team D1, integration platform D2, production integration D3, management integration D4; Digital benefit E includes economic benefit E1, quality benefit E2, social benefit E3 and cost benefit E4. Table 1 shows the three-level indicators and their explanations.

After building the evaluation system, the Delphi method method scored by experts is used to build the judgment matrix, conduct consistency test, and give weight to each index to form a comprehensive judgment matrix. To ensure the objectivity and authority of the expert results, this article visited three physical manufacturing industries during the collection of expert data, selected 9 manufacturing enterprise executives, and surveyed 6 economics professors from universities to form an expert investigation group. The scaling of the judgment matrix is scored using the 1-9 quantitative scaling method. If the indicator is assigned a value of 1, it indicates equal importance. The former has an extremely important score of 9 compared to the latter. The importance scale and the random consistency index RI scale are shown in Table 2-3.

Table 2 Importance Scale of Analytic Hierarchy Process

Scale aij	Factor i is more than factor j
1	Equally important
3	Slightly important
5	Strongly important
7	Strongly important
9	Extremely important
2、4、6、8	Intermediate value of two adjacent judgments
count backwards	If the importance ratio of element i to element j is aij, then the importance ratio of element j to element i is aji=1/aij

Table 3 Consistency Comparison Table of Judgment Matrix

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

By analogy, the judgment matrix for each level can be obtained. After calculating the ranking vectors of each expert through arithmetic mean, the group decision can be obtained: the ranking weight of the elements in the scheme layer to the decision objective and the ranking weight of the elements in the first intermediate layer to the decision objective, as shown in Table 4-5.

Table 4. Ranking weights of decision objectives at the scheme level.

Alternative plan	weight
Fund guarantee	0.0954
R&d team	0.0917
Production integration	0.0907
Integrated platform	0.0896
Strategic planning	0.0858

System integration	0.0833
Research and development design	0.0696
Human resources	0.0649
infrastructure	0.0618
Social benefit	0.053
Economic benefit	0.0468
Process and organization	0.0452
Information security	0.04
Data standardization	0.0291
cost-effectiveness	0.0276
Quality and benefit	0.0256

Table 5 Ranking weights of decision objectives in the middle layer.

Intermediate layer element	weight
Digital R & D	0.3553
Strategy and organization B	0.2913
Digital Basics C	0.2004
Digital benefit E	0.153

After consistency test of judgment matrices at all levels, it can be seen that the test results are consistent, and there is no inconsistent judgment matrix, as shown in Table 6:

Table 6 Consistency test of judgment matrix of elements at each level.

hierarchy	λmax	CR	Criterion	test results
A-B	4.2153	0.0806	0.1	consistent
B-Bi	4.2153	0.0806	0.1	
C-Ci	4.0813	0.0304	0.1	
D-Di	4.1431	0.0536	0.1	
E-Ei	4.1545	0.0579	0.1	

Through the analytic hierarchy process (AHP), the comprehensive weight results of the evaluation system for the digital transformation of the manufacturing industry were sorted out after the decision results of the expert group were obtained. In order to facilitate observation and comparison of the importance of various elements, the results were ranked, as shown in Table 5. Among all intermediate layer elements (secondary index), digital R&D has the highest weight (0.35), and experts more agree that digital R&D is the most important ability to master in the digital transformation of manufacturing industry. In the digital R&D ability, the comprehensive weight of R&D team ranks the first in the whole scheme layer, and the production integration ranks the second. The integrated platform and system integration rank third and fourth respectively, and the scheme layer elements of the whole digital research and development rank the top, which is the ability that the manufacturing industry transformation must pay priority attention to. Among the middle tier factors (secondary indicators), the weight of strategy and organization is second only to that of digital research and development (0.29). In strategic organization, corporate capital security and strategic planning are more

important, and the comprehensive weight ranks 5th and 6th respectively, which needs to be paid attention to. Human resources, process and organization also need to be paid attention to, and the comprehensive weight ranks 7th and 9th respectively. Among the intermediate layer elements (second-level indicators), the weight of digitalization foundation and digitalization benefit is lower than the other two second-level indicators, which are 0.20 and 0.15 respectively. In terms of digital foundation, the comprehensive weight of R&D design is higher than other scheme elements, ranking the 8th, followed by infrastructure, information security and data standardization. In terms of digital benefits, the comprehensive weight of social benefits is higher than other scheme elements, ranking the 11th place, followed by economic benefits, cost benefits and quality benefits. Enterprises need to pay attention to the two three-level indicators of research and development design and social benefits.

Table 7 Comprehensive weight and ranking of manufacturing digital transformation evaluation system.

Secondary index	weight	Three-level index	weight	Comprehensive weight	sort
Strategy and organization B	0.2913	B1	0.0858	0.0250	6
		B2	0.0452	0.0132	9
		B3	0.0649	0.0189	7
		B4	0.0954	0.0278	5
Digital Basics C	0.2004	C1	0.0618	0.0124	10
		C2	0.0291	0.0058	14
		C3	0.0696	0.0139	8
		C4	0.04	0.0080	12
Digital research and development D	0.3553	D1	0.0917	0.0326	1
		D2	0.0896	0.0318	3
		D3	0.0907	0.0322	2
		D4	0.0833	0.0296	4
Digital benefit E	0.153	E1	0.0468	0.0072	13
		E2	0.0256	0.0039	16
		E3	0.053	0.0081	11
		E4	0.0276	0.0042	15

4. CONCLUSION

Digital transformation is the only way for manufacturing enterprises to break through the bottleneck of industrial development in the new era. Due to the large number of personnel, business and information systems involved, the scope of change is large. At the same time, the new generation of information network technology develops rapidly and integrates with business widely, the digital transformation of manufacturing enterprises will be a comprehensive and multi-dimensional system engineering. An accurate, refined and comprehensive evaluation system is of great significance for the digital transformation of manufacturing enterprises. The conclusion is as follows: in the process of digital transformation, manufacturing enterprises should pay special attention to the cultivation of research and development ability, which mainly depends on the construction of research and development team, production integration ability, integration platform construction and management integration ability. Secondly, they should pay attention to their own strategic

planning and organizational structure, which mainly depends on the capital supply ability, enterprise strategic planning and human resources guarantee.

In order to ensure the smooth implementation of the digital transformation of manufacturing enterprises, based on the above research results, the following two suggestions are proposed:

(1) Strengthen the cultivation of digital research and development ability.

Under the new era, the original approach: Direct use of other enterprises ready-made digital system is not so effective, only to establish their own, professional, compound R & D team, according to the actual situation of the enterprise to develop digital system, build an integrated digital platform, adhere to the problem-oriented, production, operation, management and other functions together, especially pay attention to the construction of production integration capacity and management integration capacity. From raw material procurement, factory manufacturing, product research and development innovation, marketing digitization and supply chain, we can comprehensively improve the digital capability of all business lines, so as to stimulate the results of digital transformation with maximum validity and realize the dual-wheel drive of "digital technology + management innovation".

(2) Adjust the enterprise's own strategy and organization.

Because the digital transformation takes a long time, costs a large amount of capital and involves a wide range of personnel, the results can be seen in the short term are limited, and the main results can only play a role in the enterprise's strategic planning. Adjust enterprise strategic planning, make it more consistent with long-term development law, more conducive to digital transformation, and gradually disassemble and divide tasks, formulate corresponding business process, system mechanism, incentive and other implementation plans, to ensure its implementation effect, at the same time, increase human and capital guarantee support, conduct training based on digital ability supporting courses, Strengthen employees' recognition of digital capability and value, do a good job in financial budgeting, and use funds rationally to ensure the smooth implementation of digital transformation process.

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