Construction of Evaluation Index System of Development Level of Digital Transformation of Manufacturing Enterprises Based on Innovation-Driven

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Abstract. The evaluation index system of the development level of digital transformation of manufacturing enterprises based on innovation-driven is an important basis for the measurement and evaluation of the development level of digital transformation of manufacturing enterprises under the current environment. According to the "National informatization index construction scheme", referring to the existing measurement and evaluation system related to the development level of digital transformation of manufacturing enterprises, according to the characteristics of digital transformation development of manufacturing enterprises, this paper constructs an evaluation index system of digital transformation development level of manufacturing enterprises based on innovation-driven. Through questionnaire survey, expert consulting method and practice methods of inspection, The index system is mainly constructed from the four aspects of digital configuration, digital application, digital ecology and digital comprehensive benefits of manufacturing enterprises, combined with 9 secondary indicators such as digital operation and 27 tertiary indicators such as the proportion of digital investment, and uses entropy method to determine the weight of each index. Through verification it can objectively reflect the development level of digital transformation of manufacturing industry.

Keywords: Innovation-driven · Digital transformation development level · Evaluation index system

1 Introduction

The report of the 19th CPC National Congress pointed out that innovation-driven is the only way to realize China's industrial transformation and industrial structure upgrading. The key to realizing innovation-driven and building a new driving force for manufacturing enterprises is to create the word "new", the important connotation of the word "new" is digitization. Digitization is the basis and core connotation of networked and intelligent information. The digital transformation and development of manufacturing enterprises is that manufacturing enterprises use emerging information technology to

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digitally empower manufacturing enterprises, so as to bring new digital value to enterprises. The development level of digital transformation of manufacturing enterprises based on innovation-driven is an important symbol to measure the degree of modernization, economic growth ability and comprehensive competitiveness of a manufacturing enterprise. The strategy of "made in China 2025 + Internet" and the special plan of "deep integration of industrialization and industrialization" are important basis for promoting the digital transformation and development of manufacturing enterprises. Innovation-driven is an important driving force and main means for the digital transformation and development of manufacturing enterprises. This paper constructs an evaluation index system of the development level of digital transformation of manufacturing enterprises based on innovation-driven, from the four aspects of digital configuration, digital application, digital ecology and digital comprehensive benefits of manufacturing enterprises, and uses entropy method to determine the weight of each index. Through verification, it can objectively reflect the development level of digital transformation of manufacturing industry.

2 Necessity of Constructing Evaluation Indicators

The construction of the evaluation index system of the development level of digital transformation of manufacturing enterprises based on innovation-driven can be used as an important basis for calculating and evaluating the development level of digital transformation of manufacturing enterprises based on innovation-driven; Based on the objective calculation and comparison of the evaluation index system, it can relatively accurately grasp the current development level of digital transformation of manufacturing enterprises; It can provide quantitative and scientific basis for the research and formulation of digital transformation and development strategic planning of manufacturing enterprises; It can improve the scientificity and accuracy of the digital transformation and development decision-making of manufacturing enterprises, accelerate the development pace of digital transformation of manufacturing enterprises, and then improve the comprehensive strength of manufacturing enterprises. Therefore, it is necessary to build an evaluation index system of the development level of digital transformation of manufacturing enterprises based on innovation-driven, analyzing the characteristics of the development of digital transformation of manufacturing enterprises according to the current development of digital transformation of manufacturing enterprises, formulating scientific evaluation standards based on the idea of innovation-driven, quantifying evaluation indicators.

The innovation-driven model with digital transformation as the core content has attracted extensive attention under the context of innovation-driven, and providing a new direction for the digital transformation and upgrading of entity enterprises [1]. Yang Tao and Wang Qiuyue analyzed the digital transformation cooperation needs of manufacturing enterprises from six aspects: Digital talents, digital consciousness, digital knowledge, digital technology, digital methods and digital environment [2]. Wang Keyi et al. established the basic framework for the evaluation of digital transformation capability of manufacturing enterprises from five aspects: basic support, data aggregation, new model application, service innovation and sustainable development [3]. Wang

Rui et al. constructed the digital maturity evaluation model of manufacturing enterprises from four dimensions: strategy, operation technology, cultural organization ability and ecosystem [4]. Yang Wenpu evaluated the industrial digital transformation from four aspects: Digital talents, industrial digital investment, industrial digital income and digital infrastructure [5]. However, there is no corresponding evaluation index system for the development level of digital transformation of manufacturing enterprises based on innovation-driven theory.

To sum up, the existing evaluation methods and index systems related to the development of enterprise digital transformation can not fully adapt to the objective evaluation of the development level of manufacturing enterprise digital transformation under the background of innovation-driven. Based on the existing similar research results, combined with the innovation-driven background and the characteristics of digital transformation and development of manufacturing enterprises, this paper formulates a set of scientific evaluation system based on innovation-driven digital transformation and development of manufacturing enterprises, which provides strong support for realizing digital management of manufacturing enterprises and scientifically evaluating the development level of digital transformation of manufacturing enterprises.

3 Construction of Evaluation Index System

3.1 Evaluation Index System

The design of the evaluation index system for the development level of digital transformation of manufacturing enterprises is a complex systematic project. Scientific and reasonable selection of evaluation indicators which can deeply reflect the development level of digital transformation of manufacturing enterprises is an important basis for evaluating the development level of digital transformation of manufacturing enterprises based on innovation-driven under the background of innovation-driven. Based on the design principles of evaluation indicators - scientific, systematic, feasible and the combination of qualitative and quantitative, and according to the specific characteristics of the development of digital transformation of China's manufacturing enterprises under the background of innovation-driven, and referencing to "the report on the digital transformation index of Chinese enterprises "and "the construction scheme of national informatization indicators", and combining with the existing measurement and evaluation index system with similar development level of digital transformation of manufacturing enterprises in the current literature, through expert consultation and practical test, this paper constructs an evaluation index system for the development level of digital transformation of manufacturing enterprises based on innovation-driven, which takes the digital configuration of manufacturing enterprises as the basis, digital application as the core, digital ecology as the driving force and digital comprehensive benefits as the foundation. The evaluation index system includes 4 first-level indicators, 9 s-level indicators and 27 third-level indicators (Table 1).

Table 1. Evaluation index system of digital transformation development level of manufacturing enterprises based on innovation-driven

Evaluation objectives	*First-level indicators*	*Second-level indicators*	*Third-level indicators*
Development level of digital transformation of manufacturing enterprises based on innovation-driven	Digital configuration index	Infrastructure construction	Proportion of digital investment
			Equipment layer digital resources
			Network layer digital resources
			Networking rate of CNC equipment
		Digital organization and management	Digital strategic planning
			Digital performance appraisal reform
			Digital integrated management and decision-making
		Digital talent allocation	Proportion of employees with bachelor degree or above
			Introduction and renewal rate of digital talents
			Digital talent training rate
	Digital application index	Digital production and operation	Digital R & D rate
			Digital procurement rate
			Digital manufacturing rate
			Digital marketing rate
			Digital operation and maintenance rate
		Digital transformation and innovation	Digital business and product innovation

(*continued*)

Table 1. (*continued*)

Evaluation objectives	*First-level indicators*	*Second-level indicators*	*Third-level indicators*
			Digital service innovation
			Digital mode innovation
	Digital ecological index	Internal collaboration	Collaborative optimization degree of key manufacturing links
			Flexible allocation of resources and services
		External collaboration	Sharing degree of upstream and downstream resources in supply chain
			Degree of interaction with end users
	Digital comprehensive benefit index	Digital social benefits	Employee satisfaction
			Completion degree of social benefit objectives
		Digital economic benefits	Return on investment
			Growth rate of digital business in total revenue
			Completion degree of economic benefit objectives

3.2 Main Contents of Evaluation Index System

The Evaluation index system of digital transformation development level of manufacturing enterprises based on innovation-driven, which takes digital configuration as the foundation, digital application as the core, digital ecology as the foundation, and digital comprehensive benefits as the foundation. The development degree of these 4 primary indicators determines the level of digital transformation and development of manufacturing enterprises under the background of innovation-driven.

3.2.1 Digital Configuration Index

Digital configuration index refers to the basic configuration of digital transformation construction of manufacturing enterprises, including infrastructure construction, digital organization and management and digital talent allocation. The digital infrastructure construction of manufacturing enterprises mainly includes the proportion of digital investment, network layer digital resources, equipment layer digital resources and NC

equipment networking rate. In the aspect of digital organization and management, it mainly includes three aspects: digital strategic planning, digital performance appraisal reform, digital comprehensive management and decision-making. It is necessary to realize intelligent decision-making through digital comprehensive management of all links, so as to promote the digital transformation and development of manufacturing enterprises, based on the digital transformation and development of all links of manufacturing enterprises and innovation-driven. In terms of digital talent allocation, the professional and business skills possessed by digital talents are very important for manufacturing enterprises to implement digital transformation and development, mainly including the proportion of employees with bachelor degree or above, the introduction and renewal rate of digital talents, and the training and further study rate of digital talents.

3.2.2 Digital Application Indicators

The digital application based on innovation-driven is the key index to determine the development level of digital transformation of manufacturing enterprises based on innovation-driven. According to the idea of innovation-driven, digital application indicators are divided into digital production and operation indicators and digital transformation innovation indicators. In terms of digital application of production and operation activities, it is mainly reflected in the digitization of R & D, procurement, manufacturing, marketing, operation and maintenance and other aspects. In terms of digital transformation and innovation, including digital business and product innovation, digital service innovation and digital mode innovation. Through digital comprehensive management and decision-making to achieve or realize the digital transformation and development of manufacturing enterprises driven by innovation, based on the digitization of all links of production and operation activities and the digitization of transformation and innovation.

3.2.3 Digital Ecological Indicators

Digital ecology includes internal cooperation and external cooperation. Internal collaboration includes collaborative optimization of key manufacturing links and flexible allocation of resources and services. Collaborative optimization of key manufacturing links mainly refers to the collaboration of internal R & D and design, material procurement and supply, production and manufacturing, marketing, operation and maintenance, as well as the traceability of the whole process within the enterprise. The flexible allocation of resources and services mainly refers to the dynamic analysis and flexible allocation of internal production resources and manufacturing services. External cooperation includes the sharing degree of upstream and downstream resources in the supply chain and the interaction degree of end users. The way and degree of resource information sharing between upstream and downstream enterprises in the supply chain refers to the way and degree to which upstream and downstream enterprises in the supply chain establish or adopt unified information interaction standards and norms to realize timely resource information interaction and sharing among enterprises, so as to realize the sharing of innovation resources, design ability, manufacturing ability, marketing ability and operation and maintenance ability among enterprises. The degree of interaction with end users

refers to the degree of interaction between manufacturing enterprises and their end users, so as to better carry out information feedback and further improve user satisfaction.

3.2.4 Digital Comprehensive Benefit Index

Digital comprehensive benefit refers to the output of digital transformation and development of manufacturing enterprises driven by innovation. The digitalization of manufacturing enterprises was first applied in the production and manufacturing links to improve product R & D capacity, production efficiency and product quality, so as to achieve the purpose of reducing cost and increasing efficiency. This paper holds that digital comprehensive benefits mainly include digital social benefits and digital economic benefits. Digital social benefits include employee satisfaction and completion of social benefit objectives brought by the digitization of manufacturing enterprises. Digital economic benefits include the return on investment brought by the digitization of manufacturing enterprises, the growth rate of digital business in the total income of enterprises, and the completion degree of economic benefit objectives. The return on investment refers to the rate of return and input / output ratio of the total investment in the digital construction of manufacturing enterprises in the corresponding accounting year [6].

4 Evaluation Method of Digital Development Level of Manufacturing Enterprises

This paper obtains the relevant data of the evaluation index of the development level of digital transformation of manufacturing enterprises based on innovation-driven, according to statistical literature, field research and network query. Firstly, the data obtained should be standardized; Secondly, the weight of each evaluation index is determined by entropy method; Thirdly, the comprehensive score of the digital transformation development level of each manufacturing enterprise based on innovation-driven is obtained, and the digital transformation development level of manufacturing enterprises is evaluated according to the comprehensive score by using the linear weighted summation method and the standardized matrix; Finally, the scientificity and practicability of the index system are verified. The specific steps are as follows:

4.1 Standardize the Obtained Data

The original data of various evaluation indicators are collected by means of field investigation and data access. These data need to be standardized before calculation [7], to eliminate the impact of different dimensions on the evaluation results.

The data standardization process is as follows:

$$r_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \tag{1}$$

Of which, x_{ij} represents the original data of the j-th index of the i-th manufacturing enterprise.

The standardization matrix is obtained, after standardizing the original data of the development level of digital transformation of manufacturing enterprises driven by innovation:

$$R = (r_{ij})_{m\times n} \tag{2}$$

And find out: $P = (P_{ij})_{m\times n}$

Of which:

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} (1 \le i \le m, 1 \le j \le n) \tag{3}$$

4.2 Determine the Weight of Each Index According to Entropy Method

Calculate and determine the weight of each index in the evaluation index system through information entropy value and information utility value. The quantitative relationship between information entropy and information utility is: information entropy + information utility = 1.

Information entropy of index J:

$$E_j = -k \sum_{j=1}^{m} p_{ij} \ln p_{ij} \quad \text{Of which:}$$

$$k = \frac{1}{\ln m}, 0 \le E_j \le 1 \tag{4}$$

According to the relationship between information entropy and information utility value, the information utility value of the j-th evaluation index is:

$$D_j = 1 - E_j \tag{5}$$

Then, the weight of the j-th index determined according to the information utility value is:

$$w_j = \frac{D_j}{\sum_{i=1}^{m} D_j} \ (1 \le j \le n) \tag{6}$$

The weight vector is $W = (w_1, w_2 ... w_n)^T$, Of which:

$$(w_1 + w_2 + ... w_n) = 1 \tag{7}$$

Using entropy method to determine the weight of each index of the development level of digital transformation of manufacturing enterprises can avoid the subjective randomness of weight assignment to a certain extent.

Table 2. Criteria for determining the development level of digital transformation of manufacturing enterprises based on innovation-driven

Comprehensive score	≤40	41–60	61–75	76–85	≥86
Grade evaluation	Poor	Qualified	Medium	Good	Excellent

4.3 Calculate the Comprehensive Score of Digital Development Level of Each Manufacturing Enterprise

Using the linear weighted summation method, combined with the standardized matrix $R = (r_{ij})_{m\times n}$, the comprehensive score of digital development level of each manufacturing enterprise based on innovation-driven is obtained.

$$U = \max_{1\le i\le m} \sum_{j=1}^{n} (w_j \cdot r_{ij})$$

Of which:

$$(1 \le i \le m, 1 \le j \le n). \tag{8}$$

Finally, the level of digital transformation and development of manufacturing enterprises is determined according to the comprehensive score. Combined with my own research results and experience, and referring to the research methods of relevant scholars, the judgment criteria for the development level of digital transformation of manufacturing enterprises based on innovation-driven are shown in Table 2.

5 Conclusion

The digital transformation of manufacturing enterprises driven by innovation is ultimately for the comprehensive development of manufacturing enterprises and building a modern enterprise with strong comprehensive competitiveness. Its transformation and development level is an important symbol to measure the modernization degree, economic growth ability and comprehensive competitiveness of a manufacturing enterprise. The evaluation index system of digital development level of manufacturing enterprises based on innovation-driven is composed of 4 first-level indicators, 9 s-level indicators and 27 third-level indicators. The selection of indicators is mainly based on the expert consultation method; The determination of weight is mainly based on entropy method. There are many factors that affect the development level of digital transformation of manufacturing enterprises based on innovation-driven, and the weight of each factor will also change. This paper selects the more important factors in the current environment. With the continuous development of economic situation, the evaluation index system and weight of the development level of digital transformation of manufacturing enterprises based on innovation-driven need to be constantly revised and improved.

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