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Digital Maturity Evaluation Study of Manufacturing Companies

Yifan Liu, Hui Li

College of Management, Shandong University of Technology, Zibo, Shandong, 255000, China

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Abstract: In recent years most manufacturing enterprises are trying their best to develop enterprise digital transformation, and it is important to evaluate the current situation of enterprise digital transformation to analyze the stage of enterprise digital transformation and formulate the enterprise digital transformation policy. Therefore, combined with the current situation of industry development, this paper constructs a digital maturity evaluation system suitable for domestic manufacturing industry, determines the index weights with hierarchical analysis method, and finally evaluates the digital maturity of specific manufacturing enterprises with fuzzy comprehensive evaluation method.

1. Introduction

As the key to China's economic development for a long time, the manufacturing industry has always maintained a strong vitality, and since the 14th Five-Year Plan, the digital transformation of the manufacturing industry has become an imminent "test". Digital transformation is a necessary path from industrial economy to digital economy, the main core driving factor is data, and the application of information technology in the new era is used to promote profound changes in the way of resource allocation, business organization, business operation logic and value creation value, forming an important historical process of digital economic system [1].Based on this, this paper systematically establishes the evaluation system of digital maturity of manufacturing industry, quantitatively describes the maturity process of digital transformation development in manufacturing industry, and evaluates digital maturity by combining with enterprise examples to help enterprises understand their own digital level, continuously improve their shortcomings, and optimize the problems arising in digital transformation.

2. Digital Maturity and Evaluation

2.1 Meaning of Digital Maturity

Maturity is the state of being complete, perfect or ready. Maturity can be captured qualitatively or quantitatively in a discrete or continuous manner. Maturity, i.e., the relative value of the object of study to its perfect state, serves two main purposes: first, to determine the relative perfect state of the object based on current knowledge; and second, to identify the gap to the perfect state based on

the object's current state. Maturity can be measured in terms of levels, each of which consists of a number of related criteria and generic practices predefined from different dimensions, and the dimensions describe a specific, relatively independent component that reflects the main, fundamental and unique aspects of maturity or a field of action.

2.2 Maturity Model

The development of existing literature based on digital maturity was all started by the software capability maturity model (CMM) [2], and after continuous development and evolution, integrated versions of maturity models emerged [3], after which Bai Jing proposed a maturity model that fits the national context [4].In contrast, Liu Chengming established a corresponding organizational maturity evaluation system based on the current status of organizational change in enterprises [5].After this experts have extended the application of maturity models to major industries one after another. For the digital maturity model in the manufacturing industry, in 2015 LICHTBLAU K proposed the IMPLUS-Industrie 4.0 Readiness 2015 model [6], which evaluates six dimensions, respectively: strategy and organization, smart factory, efficient operations, smart products, data-driven services, and employees. The maturity stage is divided into five levels: layman, beginner, intermediate level, experienced, expert, and top player. Immediately after that, in 2016, the Chinese Institute of Electronics Technology Standardization proposed a maturity model of intelligent manufacturing capability under the study of the characteristics of Chinese manufacturers.8 Ten evaluation dimensions of design, production, logistics, sales, service, resource elements, interconnection, system integration, information fusion, and emerging industry were constructed to have five maturity stages of planning level, specification level, integration level, optimization level, and leading level [7].In 2017, the German National Academy of Science and Engineering constructed a digital maturity model in four dimensions: resources, information systems, organizational structure, and culture, and classified the maturity stages into six levels: computerization, connectivity, visibility, transparency, predictive capability, and adaptive [8].

2.3 Digital Maturity Evaluation of Manufacturing Companies

Lerch et al. (2016) proposed to construct a digital maturity evaluation model from six dimensions, including strategy and organization, and divided the maturity level into five stages [9]. Gill and VanBoskirk (2016) published the Digital Maturity Model 4.0 report, which measured the digital maturity of enterprises in four dimensions, including organization, culture, technology, and insight, and divided the the level of digital maturity of enterprises into four levels [10]. And Schumacher et al. (2016) proposed to construct a digital evaluation model from nine dimensions such as strategy, culture, leadership, and operations, and the importance level of indicators was evaluated by a Likert scale, and then a weighted average method was used to calculate the evaluation results, and the maturity level was divided into five levels, with 1-5 representing Industry 4.0 from unrealized to fully realized, respectively [11].In the same year, Leyh et al. (2016) constructed the evaluation theory of digital maturity from 4 dimensions, such as horizontal integration, vertical integration, cross-sectional technical standards, and digital product development, while dividing the maturity level into 5 stages. China Electronics Technology Standardization Research Institute (CETRI) constructs the evaluation model of digitalization from 10 dimensions such as design, production, and sales, respectively, while dividing the maturity level into 5 stages such as self-planning level, specification level, integration level, optimization level, and leading level [12]. In addition, Schuh et al. (2017) constructed evaluation models from four dimensions, such as organizational structure, culture, resources, and information systems, respectively, and used radar diagrams to analyze each module accordingly, while classifying

maturity levels into six stages, such as computerization, connectivity, visibility, transparency, predictive capability, and self-adaptation [13].Wang Rui (2019) proposed to construct a digital maturity evaluation model from four dimensions, namely: strategy, ecosystem, operational technology, and cultural and organizational capabilities, through a study related to various digital activities of manufacturing enterprises, and then the AHP and DEMATEL methods were used to evaluate the actual digital maturity level of a commercial vehicle enterprise [14]. Li Min et al. (2020) argued that the division of the maturity of the digital transformation process of an enterprise helps to understand the stage of digital transformation that the enterprise is in and provides guidance for the next digital transformation practice, and divided the main evaluation indicators of digital transformation maturity into technology application, strategy, organizational structure, management, team and leadership [15]. From the aforementioned studies of domestic and foreign scholars, it can be found that there are many studies on digital maturity models, and the selection of evaluation dimensions has its own focus with the different industries of the research subjects. Some scholars study the macro dimensions such as corporate strategy and organizational culture, while some scholars analyze the business activity level of enterprises.

3. Digital Maturity Model Construction Principles

In order to ensure that the evaluation system indicators are more compatible with the manufacturing industry, the following three principles will be used in constructing the digital maturity model in this paper:①objectivity, the evaluation system of digital transformation of manufacturing industry needs to be based on the actual industry and make an objective and fair evaluation;②comprehensiveness, comprehensiveness means to pay attention to every aspect when constructing indicators, and not to overlap or omit every indicator as much as possible; ③scientific, scientific is the basic principle of constructing this model, and following the principle of scientific should pay attention to theoretical facts and objective facts to make the evaluation results more credible.

4. Establishment of Digital Maturity Evaluation Indexes and Determination of Weights

On the basis of following the principles of digital maturity model construction, this paper summarizes the digital maturity dimensions proposed by major scholars and forms the evaluation index system used in this paper on this basis, including four primary indicators: strategy, product, logistics, and service, as well as the corresponding 17 secondary indicators. Strategy includes digital management, digital strategy, human resource reserve, and digital adaptability of corporate culture; products include digital R&D, digital production, digital procurement and digital marketing; logistics includes order management, intelligent warehousing, intelligent logistics, intelligent logistics equipment, and logistics path optimization; and services include intelligent after-sales service, personalized service, product service, and network service. The determination of subjective weights is the basic of evaluating the digital maturity of manufacturing enterprises. In this paper, we use hierarchical analysis to calculate the weights of each index, and the basic steps are to invite experts to judge the importance of the indexes, construct a judgment matrix and then calculate the index weights. Based on a series of calculations to organize the digital maturity index weights of manufacturing enterprises, at the same time for convenience we also calculated the weights of secondary indicators to the total evaluation system, as shown in Table 1.

Table 1: Weighting table of digital maturity evaluation indicators

Target layer	Guideline layer	Indicator layer	The weight of secondary indicators in the total system
Digital Maturity	Strategy (0.560)	digital management (0.258)	0.144
		digital strategy (0.181)	0.101
		human resource pool (0.467)	0.262
		digital adaptability of corporate culture (0.094)	0.053
	Product (0.280)	digitalization of R&D (0.157)	0.044
		digitalization of production (0.219)	0.061
		digitalization of procurement (0.378)	0.106
		digitalization of marketing (0.246)	0.069
	Logistics (0.068)	order management (0.225)	0.015
		smart warehousing (0.310)	0.021
		smart logistics (0.125)	0.009
		smart logistics equipment (0.095)	0.006
		logistics path optimization (0.245)	0.017
	Service (0.092)	smart after-sales service (0.120)	0.011
		personalized service (0.372)	0.034
		product service (0.295)	0.027
		network service (0.213)	0.020

5. Comprehensive Evaluation and Example Application

After all the preparations are completed, the most important thing is to choose the method that can evaluate the digital maturity of the enterprise, and the fuzzy comprehensive evaluation can make an overall judgment of things affected by many factors, and the results are clear and systematic, which can better solve the problem of the existence of cognitive uncertainty and the difficulty of quantification [16], so this paper chooses the fuzzy comprehensive evaluation method to do the final index evaluation. The general process of the fuzzy comprehensive evaluation method is: establishing the set of evaluation factors; establishing the set of rubrics; determining the weights of evaluation factors as well as constructing the fuzzy judgment matrix [17].

(1) Case selection

In this paper, a manufacturing enterprise in Qingdao, Shandong Province is selected for digital maturity evaluation, and several experts are invited to score the digital maturity of the company to obtain the evaluation matrix of each criterion layer, and finally the final fuzzy matrix of the target layer is collated to obtain the final evaluation of the digital maturity of the manufacturing enterprise.

(2) Establishing a collection of rubrics and a set of judging factors

Rubric Set Y= {digital start-up, digital upswing, digital transformation, digital maturity, digital benchmark};

Judgment factor set target layer X= {strategy, product, logistics, service};

Criteria level X_1= {digital management, digital strategy, human resource pool, digital adaptability of corporate culture};

Guideline layer X_2= {digitalization of R&D, digitalization of production, digitalization of procurement, digitalization of marketing};

Criteria layer X_3= {order management, smart warehousing, smart logistics, smart logistics equipment, logistics path optimization};

Guideline layer X_4= {smart after-sales service, personalized service, product service, network service}.

(3) Calculation of results

The single-factor judgment matrix of the criterion layer was obtained based on the weights and expert scores obtained above, and the single-factor judgment matrix of the four criterion layers was calculated and organized to obtain the judgment matrix of the target layer as follows:

$$R = \begin{bmatrix} 0.150 & 0.166 & 0.387 & 0.214 & 0.083 \\ 0.152 & 0.290 & 0.365 & 0.097 & 0.097 \\ 0.264 & 0.198 & 0.273 & 0.176 & 0.088 \\ 0.193 & 0.337 & 0.271 & 0.109 & 0.090 \end{bmatrix} \tag{1}$$

From the above, the target layer weight A = [0.560 0.280 0.068 0.092]; according to the algorithm, we can get the target layer evaluation result B = [0.135 0.248 0.342 0.189 0.086], through the above calculation results, we can know that this manufacturing enterprise belongs to the digital transformation period, and it needs more in-depth digital reform in the future.

6. Conclusion and Recommendations

The successful digital transformation of manufacturing enterprises under the new development opportunities is a must for enterprises. This paper constructs a digital maturity evaluation model for manufacturing enterprises, covering four aspects: strategy, product, logistics, and service. And using hierarchical analysis and fuzzy comprehensive evaluation method, the digital maturity evaluation process of a manufacturing enterprise is elaborated in depth, and the result obtained is that the enterprise belongs to the digital transformation period, so several suggestions are made for the digital transformation of the enterprise:

First, after the completion of the digital maturity evaluation, enterprises need to recognize the status of their own digital level, benchmark with the leading enterprises in the industry, clarify the gaps in each dimension, sort out what they need to improve, and improve the problems that exist in the enterprise. Second, we improve the digital transformation strategy of enterprises, focusing on strengthening the training of new talents as well as the improvement of digital strategy, developing the planning of transformation and upgrading, and promoting the strategic management of enterprises. Third, focus on the digital transformation of the company's product supporting development, and increase the digitalization of the research and development and production of the product itself, as well as the digitalization of procurement and marketing with other departments. Fourth, the company's necessary digital equipment to upgrade, so that the digital transformation of the road to go faster.

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