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Research on the Maturity Evaluation and Application of Digital Transformation in Engineering Enterprises

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Abstract: For engineering enterprises to achieve leapfrog development, digital transformation has become an urgent task, and establishing a scientific digital evaluation model is the key to realizing this transformation. In response to the maturity evaluation issue during the digital transformation process of engineering enterprises, this paper, taking the digital transformation of engineering enterprises in China as the background and referring to the research theories of different scholars at home and abroad, constructs a framework for the digital transformation of engineering enterprises, conducts a quantitative assessment of it, and builds a digital transformation maturity assessment model centered on this. This model aims to accurately measure the progress and effectiveness of digital transformation in engineering enterprises. Through quantitative analysis, it provides insights into the connection between the whole and the part, identifies weak links, formulates improvement strategies, and promotes the enhancement of digital capabilities.

Keywords: Engineering enterprises; Digital transformation; Quantitative analysis

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1. Introduction

In the current era of rapid development of information technology, big data has become a new driving force for economic growth. With the rise of the new round of technological revolution, the digital economy has become a new hot spot in global competition. China has successively introduced important strategies such as "Digital China", "Energy Revolution", "Digital Transformation of Central Enterprises", and "Carbon Peak and Carbon Neutrality". Against this backdrop, large engineering enterprises, leveraging the vast amount of core data resources they possess, have decided to advance digital transformation. However, at present, the digital construction of engineering enterprises in our country is relatively backward. Many enterprises lack a clear understanding of their own digital level and future development direction. Meanwhile, most previous studies have focused on the development of engineering enterprises themselves, while the exploration of digital maturity has been relatively insufficient. Therefore, in order to deeply analyze the digital maturity of engineering enterprises, it is currently urgent to build an assessment model that can combine digital transformation practice with theory.

When discussing the core characteristics of digital transformation, this process of change is based on digital technology innovation, deeply covering the comprehensive reshaping of enterprise business processes, operational standards, operational frameworks and organizational capabilities, and may even drive enterprises to achieve strategic migration or exit in the market field [1]. From the perspective of data interconnection that digital transformation, through the collaborative integration of information technology, computing power, communication networks and connection technologies, not only essentially changes the attributes of entities, but also significantly optimizes the operational efficiency of entities [2]. Unlike the perspective that focuses on digital technology, Vial emphasizes that the core of digital transformation lies in the interaction of data and the convenience it brings to enterprises and customers [3]. Digital transformation is manifested as a comprehensive system of emerging organizational forms, architectures, practice models, and values, with a particular emphasis on the role of elements such as organizational structure and corporate culture, advocating that enterprises promote the digitalization process from these aspects [4]. Subsequently, the implementation of digital transformation not only relies on the back-end support of traditional Internet technologies, but also lies in how it redefines and constructs key areas such as strategy, innovation and entrepreneurship through organizational change. The practical paths of digital transformation based on two major dimensions: the degree of digital resource integration and functional characteristics [5].

By establishing a complete theoretical framework for digital transformation, he integrated strategic design at the organizational management level and formulated a standard system for monitoring and evaluating the digital process, laying a theoretical foundation for enterprises to establish a scientific management supervision mechanism, and thereby ensuring the steady implementation of digital reform and the achievement of expected goals. The dimensions of evaluating the maturity of enterprise digital transformation. Starting from four perspectives: strategy, operational technology, cultural organizational capabilities, and ecosystem, he constructed a comprehensive enterprise evaluation model by applying the Analytic Hierarchy Process (AHP) and the evaluation laboratory method [6]. This not only provides enterprises with a tool for self-assessment It also provides strong support for enterprises to identify their strengths and make up for their weaknesses.

The existing enterprise digital transformation maturity assessment models generally face a common problem that cannot be ignored in practical applications: the determination method of indicator weight values lacks sufficient flexibility and dynamic adaptability, and fails to make corresponding adjustments closely in line with the changes in the enterprise's phased development goals. This limitation largely restricts the long-term applicability and practicality of the evaluation model, making it difficult to comprehensively and accurately reflect the real situation and actual needs of enterprises during the digital transformation process. To address this issue, research needs to delve deeper into the dynamic adjustment methods of indicator weight values and construct more flexible and adaptable evaluation models. This not only enhances the accuracy and practicality of the assessment model, but also provides enterprises with more precise guidance and suggestions, helping them better cope with challenges and seize opportunities during the digital transformation process.

2. Construction of a maturity evaluation model for digital transformation of engineering enterprises

Through the analysis of the maturity development degree of digital transformation in engineering enterprises, the basic principles, steps and formulas of the G1 method and the COWA operator method are introduced. The G1 method, with its intuitiveness and simplicity, determines the relative importance of each evaluation index through expert scoring. The COWA operator rule can effectively handle the fuzziness and uncertainty in the evaluation process, providing strong support for the precise quantification of maturity. Secondly, the principle, steps and formula for calculating the combined weight based on the G1-COWA combined weighting combined with the idea of game theory are introduced. This method not only integrates the advantages of the G1 method and the COWA operator method, but also ensures the rationality and fairness of the weight through the idea of game theory. Finally, the cloud model theory was introduced to conduct an in-depth analysis of the maturity levels in each dimension. The cloud model theory, with its unique ability to handle randomness and fuzziness, accurately classifies and assesses maturity levels, thus successfully constructing a maturity evaluation model for the digital transformation of engineering enterprises and thereby obtaining the maturity levels of enterprises.

By ranking the weights of the evaluation indicators, the priority order among each indicator can be revealed. Inviting authoritative experts in the field to select the initial key indicators based on subjective judgment, and then picking relatively important indicators from the updated indicator set. This process is carried out continuously until the importance order of all indicators in the set is established, and finally a ranking sequence is constructed.

Judgment of the relative importance of two adjacent evaluation indicators. Based on **Equation (2)**, the weights of the first-level indicators, second-level indicators and third-level indicators are calculated respectively. The weights of the first-level indicators, second-level indicators and third-level indicators are calculated respectively. After determining the weight of a single indicator, the weights of other indicators within the same indicator set can be calculated according to **Equation (3)**. Finally, the comprehensive weights of the design indicators are obtained based on **Equation (4)**.

$$\mathrm{r_n}=\mathrm{w_{n-1}}/\mathrm{w_n},\ \mathrm{n}=2,3,4,\cdots \quad (1)$$

$$w_m=(1+\sum_{n=2}^{m}\prod_{i=n}^{m} r_i)^{-1} \quad (2)$$

$$\mathrm{w_{n-1}}=\mathrm{r_n}\mathrm{w_n} \quad (3)$$

$$w=\alpha_1^{*}\ w_1^{T}+\alpha_2^{*}\ w_2^{T} \quad (4)$$

The cloud model is a mathematical model used to handle uncertain problems. It was innovatively proposed by the renowned scholar, on the basis of deeply integrating the essence of probability theory and fuzzy mathematics. This theory innovatively reveals the two core uncertainty characteristics inherent in things–fuzziness and randomness, and ingeniously builds a bridge to achieve seamless connection and mutual conversion between qualitative description and quantitative measurement, thus pioneering the unification of these two long-regarded independent categories of uncertainty expressions. Based on the scoring results of the experts on the actual situation of the project, the mean, variance and cloud parameters of each indicator score are obtained through the reverse cloud model. The cloud parameters of the indicators are processed by weighting and summarized to obtain the comprehensive cloud parameters.

$$\begin{cases} \overline{X}_j = \frac{1}{k}\sum_{i=1}^{k} x_{ij} \\ S_j^2 = \frac{1}{k-1}\sum_{i=1}^{k}\left(x_{ij} - \overline{X}\right)^2 \\ Ex_j = \overline{X}_j \\ En_j = \sqrt{\frac{\pi}{2}}\frac{1}{k}\sum_{i=1}^{k}\left|x_{ij} - \overline{X}_j\right| \\ He_j = \sqrt{\left|S_j^2 - En_j^2\right|} \end{cases} \tag{5}$$

$$\begin{cases} Ex = \sum_{j=1}^{n} Ex_j z_j \\ En = \sqrt{\sum_{j=1}^{n} En_j^2 Z_j} \\ He = \sum_{j=1}^{n} He_j Z_j \end{cases} \tag{6}$$

3. Examples and analysis of results

This article takes Z Engineering Enterprise as an example and conducts an evaluation using the theories and methods proposed in this paper. In this evaluation, eight industry assessment experts are invited. Firstly, they anonymously score it based on the evaluation indicators for the digital transformation of engineering enterprises. Then, using the theories and methods proposed in the previous chapters, they conduct a maturity assessment to determine the level of maturity of the digital transformation of engineering enterprises. This verified the rationality and effectiveness of the proposed evaluation method, providing improvement and optimization measures for the problems existing in the digital transformation process of enterprises.

This article invited six experts from the research group to fill it out. To make the results more objective, two relevant experts from the research institute were contacted through the experts of the research group and the survey forms were distributed to them. Eight experts respectively made judgments on the index relationships and assigned importance values to the assessment indicators for the digital transformation maturity of engineering enterprises. Based on the information fed back by the experts, the weights of the indicators were determined through the G1 method. The indicator system selected in this article consists of 4 first-level indicators, under which there are 9 second-level indicators, and under which there are 24 third-level indicators. When determining the index weights of the digital transformation maturity index system for engineering enterprises using the G1 method, it is necessary to calculate the index weights layer by layer.

Based on the results of the survey form fed back by A certain expert, the importance ranking of the first-level indicators was determined as: A > C > B > D, and the weights of each level of indicators were obtained according to Equations (1), (2), (3), and (4), as shown in **Table 1**.

Table 1. The weights of the indicators were determined through the G1 method

Indicator number	Weights
Device networking rate (A11)	0.3024
Intelligence level (A12)	0.3954
The coding rate of the physical "ID" of the main equipment (A13)	0.3022
Total factor productivity (A21)	0.4819
The contribution rate of comprehensive benefits of digitalization (A22)	0.3016
The industrial digitalization rate (A23)	0.2165
Online service rate (A31)	0.2019
The online business conversion rate (A32)	0.297
Digital Risk Prevention and Control (B11)	0.5002
Data Security (B12)	0.4998
Digital Strategy Formulation (C11)	0.583
The digital strategy matches (C12)	0.417
The cloudification rate of IT basic resource systems (C21)	0.2017
Data Management Capability Maturity (C22)	0.2968
The number of cybersecurity responsibility incidents affecting power grid safety (C23)	0.2991
Management decision-making efficiency (D11)	0.5231
Market response efficiency (D12)	0.4769

Through expert consultation and in combination with language expression habits, this paper uses the language values "poor", "poor", "average", "good" and "excellent" to describe the security level. The corresponding score value range is set as [0,100]. The higher the score, the more mature the digital transformation of enterprise Z, and a reasonable set of comments is obtained. Among them, [0.0, 25.0] indicates that the enterprise's digital transformation is very immature, (25.0, 50.0] indicates that the enterprise's digital transformation is relatively immature, (50.0, 75.0] indicates that the enterprise's digital transformation is generally mature, (75.0, 90.0] indicates that the enterprise's digital transformation is relatively mature, (90.0) 100] indicates that the digital transformation of the enterprise is very mature.

Based on the intervals, the parameters of the cloud model are obtained through the forward cloud generator, and thus the evaluation standard cloud model can be obtained. Based on **Equation (5)**, the cloud model of the five comments was calculated to obtain the standard cloud, and the value of b in this paper is 0.5. The calculation results are as follows (**Table 2**).

Table 2. The calculation results of the indicators

Evaluation grade	Grade range	Ex	En	He
Bad	[0.0,25.0]	12.5	4.17	0.5
Poor	(25.0,50.0]	37.5	4.17	0.5
General	(50.0,75.0]	62.5	4.17	0.5
Good	(75.0,90.0]	82.5	2.5	0.5
Optimal	(90.0,100.0]	95.0	1.67	0.5

After calculating the digital characteristic values of the secondary indicators, the comprehensive weight values of the indicators and the corresponding cloud characteristic parameters are combined to obtain the comprehensive evaluation cloud of the entire evaluation object, and it is compared with the standard evaluation cloud to obtain the final comprehensive evaluation value (**Table 3**).

Table 3. The final comprehensive evaluation value

Aspect	Ex	En	He
The final comprehensive evaluation value	80.36	3.22	0.93

A case analysis was conducted on the comprehensive evaluation model of the digital transformation maturity of this enterprise. The scores of 10 experts were selected as samples. The comprehensive evaluation model of digital transformation of engineering enterprises was used to evaluate the maturity of Enterprise Z. The evaluation results showed that the digital transformation maturity level of this enterprise was “good”, and the evaluation results were consistent with the actual situation. It is concluded that the maturity evaluation model has certain practicality and provides a scientific method for the maturity evaluation of digital transformation in engineering enterprises.

4. Conclusion

Based on domestic and international research and in accordance with the actual situation of engineering enterprises in China, this paper analyzes the main influencing factors of digital transformation of engineering enterprises, constructs an evaluation index system for the maturity of digital transformation of engineering enterprises from four aspects, uses the G1 method to obtain the index weights, and finally uses the cloud model to evaluate the maturity of digital transformation of engineering enterprises. Based on current standards and norms, this paper analyzes the influencing factors of digital transformation in engineering enterprises by establishing index principles and bases, and uses principal component analysis to screen the influencing factors of digital transformation in engineering enterprises, eliminating secondary indicators An evaluation index system for the maturity of digital transformation of engineering enterprises has been established, which includes four first-level indicators: digital operation technology, digital system guarantee and digital foundation, and digital performance, nine second-level indicators, and 24 third-level indicators. By using G1 to calculate the weights of the evaluation indicators for the digital transformation maturity of engineering enterprises, corresponding measures can be taken during the digital transformation process. Accelerate the digital transformation of engineering enterprises. This paper employs a cloud model to evaluate the maturity level of digital transformation in engineering enterprises, which can effectively address the ambiguity and randomness of the evaluation, complete the conversion between qualitative expression and quantitative values of maturity evaluation, and make the evaluation more objective and reasonable.

Disclosure statement

The authors declare no conflict of interest.

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