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The idea of establishing a digital level measurement model in the construction machinery industry

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Abstract: *At present, industrial digitalization has attracted extensive attention from the industry and academia, digital level measurement and improvement path research is an important field.The establishment of a model that can measure the digital level of the industry in real time is particularly important.This paper takes the construction machinery industry as an example, puts forward the idea of building a digital level measurement model, and puts forward a general framework for building a measurement model based on the digital level of the construction machinery industry, and it will provide certain guiding significance for future research.*

Keywords: *Construction machinery, Digitization, Measure the model*

1. Introduction

Industrial digitalization stems from "Industry 4.0", which first appeared at the Hannover Fair in 2011 and was driven by German academia and industry, and is now Germany's national strategy, with the goal of establishing a highly flexible production model for personalized and digital products and services. Therefore, industrial digitalization has also aroused the interest of the industry and academia. Among them, the research on digital level measurement and improvement path is an important field.

In China's digital transformation began from the manufacturing industry, the initial understanding of the digitalization of manufacturing enterprises in academia and the industry stemmed from the application of CNC technology in the production and manufacturing process, and regarded digitalization as a technical means or tool to assist enterprise management, focusing on improving product research and development capabilities, production efficiency and quality through digital applications, thereby reducing costs and increasing benefits. Industrial digitalization is the use of digital technology to promote industrial upgrading and transformation, 2015 "Made in China 2025", pointed out that digital manufacturing is one of the important directions of China's manufacturing transformation and upgrading. The 2017 "Chinese Intelligent Development Plan" pointed out that intelligent manufacturing is one of the important areas of artificial intelligence application. The 2018 National Industrial Internet Development Plan puts forward the goals and tasks of the technical architecture, development path, key areas and policy support of the Industrial Internet. The "Digital China Construction Development Strategy" released in the same year pointed out that industrial digitalization is one of the important contents of digital China construction.

2. A brief review of the measurement and improvement of industrial digitalization

Raul Katz, et al.[1]argues that measurement digitization should cover intensive societies that transition to digital across multiple sets of indicators, not just capturing technology penetration. To understand the full impact of digitalization, it is also necessary to capture its use. To this end, a composite index based on six main components: affordability, infrastructure investment, network access, capacity, use and human capital is proposed, which is subdivided into several sub-indicators to measure the level of digitalization; The Industry 4.0 maturity index proposed by the Acatech study [2]helps companies identify the stage of transformation they are currently in and guide them to become a learning, agile company. It evaluates it from a technical, organizational, and cultural perspective, with a focus on the business processes of manufacturing companies. It is pointed out that each company path is different, it must start with an analysis of the company's current situation and goals, successful

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transformation must be carried out in stages, and a digital roadmap must be specified, and a step-by-step benefit approach must be achieved to reduce investment and implementation risks. Although this is a relatively macroscopic measure, it obviously has reference value for the measurement and improvement of industrial digitalization. The construction industry is one of the least developed sectors in digital technology, and its projects lack digital evaluation.Ahmet Anil Sezer, et al. [3]proposed a digital index to measure construction projects. Based on four activities: ①visual drawings and 3D models of the site; ②Updated drawings, models and system documents; ③ Develop and update the work disposal plan, ④select the updated time resource plan, and evaluate the process involved in these four activities by achieving a simple, data-based digitization level construction project digitization level. The disadvantage is that there is insufficient research on the accurate and simple evaluation of the degree of digitalization of the project, as well as the opportunities for studying the relationship between digitalization degree and project performance. However, through vertical measurement, it is possible to report the digitalization trend in the construction industry; Literature proposes the so-called SIRI framework, LEAD framework, and evaluation matrix tools. Among them, the SIRI framework consists of three layers. The top layer consists of three basic layers of Industry 4.0: process, technology, and organization. The intermediate support building blocks are the eight pillars that represent the company's need to focus on preparing the organization for the future. The final layer includes 16 dimensions, which should be referenced when evaluating the current maturity level of its loans; The Evaluation Matrix is the world's first Industry 4.0 self diagnostic tool aimed at helping companies around the world evaluate the current status of their factories; The renovation and upgrading of manufacturing facilities is not a one-time process, on the contrary, it is a continuous iterative process encapsulated in the LEAD framework: a cyclic and continuous four step process that all manufacturers can adopt in achieving Industry 4.0 transformation; To measure the level of digital maturity and obtain the company's digital status, Tristan Thordsen et al[4] reviewed 17 existing digital maturity models, determined the effectiveness of their measurement through a systematic literature search (2011-2019),based on established academic standards, such as generalizability or theoretical explanations, applied qualitative content analysis to these models, and the results show that most of the identified models do not meet the established evaluation criteria. Godfrey Mugurusi et al [5]propose a detailed research agenda, propose their own research questions and strategies and explore how to perceive and measure digitalization in supply chain management (SCM) literature. A systematic review was conducted on scientific articles extracted from SCM literature from 2012 to 2017. It shows that digitalization and supply chain digitalization are popular concepts in theory and have high potential in practice. "Digitization" and "Digital transformation" run through the existing literature. The indicators for measuring the degree of digitalization are not different in enterprises and supply chains, but may vary in different industries; F. Martell et al. [6] considered the relationship between Industry 3.0 and Industry 4.0, constructed a measure based on the improvement of some key behavioral indicators in the past, used it to measure the company's level of automation and digitization, and used it as a diagnostic tool to measure the degree of implementation of Industry 4.0. Empirical analysis of metal machinery industry companies using diagnostic tools has proposed methods for implementing Industry 4.0 primarily in small and medium-sized enterprises.

In terms of constructing a digital indicator system for the manufacturing industry, different scholars have constructed different indicator systems based on different integration paths. Hongxiang Tang[7] and Renfa Yang [8]et al. (2020) measured the quality, efficiency, and power of the manufacturing industry from three dimensions. Yunsheng Gao[9]constructed an evaluation system that includes four primary indicators of innovation, economy, society, and environmental effects. Xubin Luo[10] constructed an evaluation index system for high-quality transformation and upgrading of the manufacturing industry from four perspectives: digitization, networking, intelligence, and greening. Lun Wan[11]selected evaluation indicators for Digital transformation of manufacturing enterprises from five aspects: strategy and organization, digital infrastructure construction, digital technology application, business integration and industrial collaborative innovation based on value creation, enterprise elements and capability dimensions; Aiqi Wu [12] built a measurement index system for the level of Digital transformation of manufacturing enterprises from the aspects of updating the organizational structure to adapt to digital technology, adjusting management thinking to promote digital technology, and linking customer groups to use digital technology.

In terms of industrial digitalization measurement methods and empirical research, the following scholars have conducted the following research. Jie Li[13]constructed an evaluation index system for manufacturing enterprise digitalization from three aspects: digital investment, digital application, and digital benefits. He used a combination evaluation method combining Analytic Hierarchy Process and Factor Analysis to evaluate and study 120 manufacturing enterprises in Guangdong Province, in order

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to test the effectiveness of the evaluation system. Weizhong Fu [14],Wenpu Yang [15]built an indicator system for statistical measurement, and conducted a study on the measurement of industrial Digital transformation and regional convergence, and showed a clear spatial agglomeration feature. Hejun Fan [16]constructed a conceptual model of regional digital capability and ultimately obtained regional digital capability indices for 30 provincial-level administrative regions in China (excluding Tibet, Hong Kong, Macau, and Taiwan).Aiqin Zhang[17] used a combination of CRITIC entropy method and TOPS1S evaluation method to measure and analyze the high-quality development level of the manufacturing industry in 30 provinces and cities in China from 2013 to 2018. Wang Nijuan evaluated the digital capabilities of small and micro enterprises in Guizhou based on the AHP fuzzy comprehensive evaluation method. Heyong Wang [18]constructed an evaluation index system for Digital transformation of regional manufacturing industry from three dimensions of benefit enhancement, innovation driven and green development, and evaluated the comprehensive level of Digital transformation of manufacturing industry in 30 provinces. Xiaowen Tang [19] analyzed the key factors affecting the digital maturity of enterprises from the perspective of "input-output", constructed an indicator system using fuzzy rough set method and random frontier method, and applied "VHSD_ EM "model weighting indicators. Based on the annual report data of 49 high-end equipment manufacturing listed companies from 2015 to 2020, the digital maturity of enterprises is calculated, and maturity levels are divided using K-means clustering. On this basis, the Tobit model is used to examine external factors that affect digital maturity.Xiaohua Li[20] used the entropy weight TOPSIS method to calculate the comparative advantage index of industrial digitization in the eight major economic regions of China from 2007 to 2020 as the research sample. It was found that the overall comparative advantage of industrial digitization in the eight major economic regions is weak, and the comprehensive indicator gap of industrial digitization comparative advantage in the economic regions is large, showing obvious gradient characteristics.

From the above research results, the measurement of industrial Digital transformation is still insufficient in the four dimensions of "perspective, object, content and method". In terms of research perspective, maturity evaluation is mainly based on business integration, technology driven, and transformation capabilities, lacking systematic and rigorous theoretical support. In terms of research objects, although the Digital transformation of manufacturing enterprises has attracted extensive attention, no research has been conducted on a specific industry. In terms of research content, most of the existing digital maturity studies are based on the perspective of capability maturity to develop maturity models, or to conduct some enterprise maturity assessments, without conducting in-depth research based on a certain industry. Especially, there is limited research on digital measurement in the construction machinery industry. In terms of research methods, literature analysis, expert review, semi-structured interviews, etc. are commonly used in the process of determining indicator systems. The development and qualitative evaluation of digital maturity models for enterprises, such as questionnaire surveys, are subjective. Therefore, currently exploring the measurement and improvement path of industrial digitalization level has significant theoretical and practical significance.

3. The Construction ideas of Industrial Digitalization Measurement Model

At present, the research on industry digitalization is relatively slow, mostly from industries or enterprises, and the scope of research is easy to be too large or too small. Therefore, we might as well determine the scope of research in a certain industry, such as the construction machinery industry. First, we can study the existing indicator system through the literature metrology method, and then adjust the indicator system. In previous studies. We often use some qualitative methods to determine the indicator system, which inevitably leads to some subjectivity. So in the process of determining the indicator system, we can try to use quantitative methods such as python data collection, data mining, text mining to eliminate the uncertainty of qualitative methods. (1) For example, we can use python data collection methods to collect text data related to Digital transformation in large, medium and small construction machinery industries, (2) We try to delete the numbers and English letters in the text data, delete only chinese characters,at the same time, perform word segmentation on the text data. (3)We can delete the stop words,in this part, first convert the data from the list format to the str format,otherwise, the subsequent processing reports an error. (4)We remove the stop words and create a word bag,in this step, first delete the stop words, import them into the vector space model, and create a word bag.(5)We use TF-IDF and other algorithms to determine the importance of word segmentation in the text (or text library), and select words with high importance as the calculation indicators of the model.

Next, data mining and text mining are used to determine the correlation and importance of indicators. The more frequently the indicators appear, the more important they are. This can

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preliminarily determine the digital level measurement indicators of construction machinery. After the indicators are determined, the most important thing is to determine the weights of each indicator. In the process of calculating indicator weights, in addition to using general statistical methods, we can also comprehensively use artificial intelligence related methods such as deep learning to set indicator weights and continuously adjust weights until the model is optimal.

4. Process framework for constructing digital measurement models in the construction machinery industry

Based on the above ideas, this article proposes a general research framework for constructing a digital level measurement model for the construction machinery industry, in order to provide reference significance for future research.

(1) We use bibliometric analysis methods to study the digital status of the construction machinery industry, including indicator systems and evaluation methods.

(2) By comprehensively using quantitative methods such as Python data collection, data mining, and text mining, as well as qualitative methods such as interview, questionnaire survey, and literature review, the existing digital indicator system of the manufacturing industry has been adjusted to preliminarily form an indicator system belonging to the construction machinery industry. The weights are determined through comprehensive use of principal component analysis, cluster analysis, factor analysis, and other methods, Attempting to establish a general and comprehensive model to measure its digitization level;

(3) We try to collect indicator data for empirical analysis of specific enterprises and conduct model validation

(4) We further adjust the indicator system based on empirical analysis and model validation results, and then conduct empirical analysis and model validation, iterating continuously until the model is optimal.

(5)We based on the empirical analysis results, propose paths to enhance the digital level of the machinery industry for large, medium, and small enterprises. The specific framework is shown in the following figure 1:

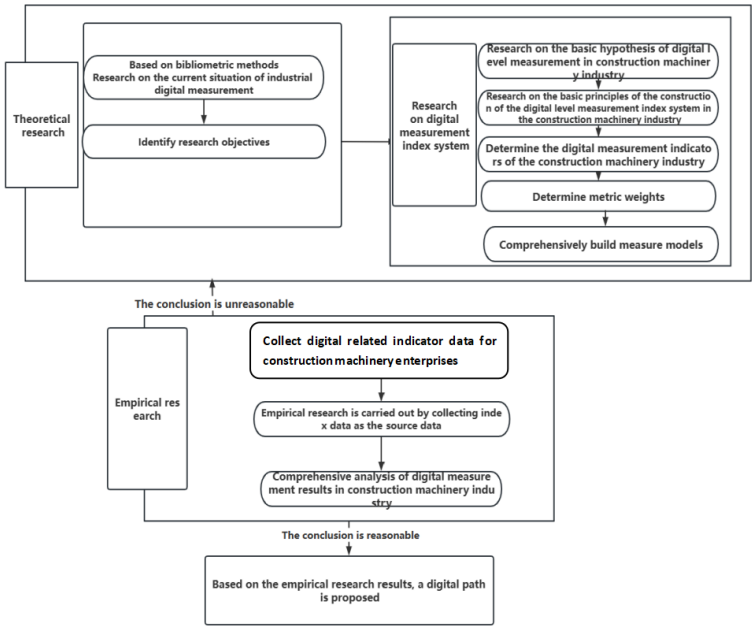

Figure 1: Construction of a Digital Level Measurement Model for the Construction Machinery Industry

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5. Summary

In the construction machinery industry, establishing the optimal digital measurement model plays an important role in improving production efficiency and quality, optimizing product design schemes, improving production processes, and improving after-sales service. Establishing the digital measurement model of the construction machinery industry can promote the Digital transformation of the entire industry, improve industry competitiveness and innovation capability, Therefore, establishing a reasonable digital level measurement model for the construction machinery industry is of great significance. In the process of establishing a practical and feasible digital measurement model for the construction machinery industry, we need to solve the following two problems: the first is the source of data, and the measurement of digital level requires a large amount of data support, including digital data from all aspects of the construction machinery industry. We need a large amount of data to support, and the second is how to determine the weight and score of indicators, how to consider the mutual influence and correlation between indicators. In addition, digital level measurement needs to consider some difficult to quantify factors, such as personnel quality, organizational management, etc. This article mainly introduces a framework concept for establishing a digital level measurement model in the construction machinery industry, and its implementation in subsequent work is our primary task.

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