Research on Evaluation of Big Data Application Capability of Intelligent Manufacturing Enterprises

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Abstract. Big data application capability is the core resource and competitiveness of intelligent manufacturing enterprises in the new era. Based on the intelligent characteristics and life cycle, this paper uses the literature measurement method to construct the evaluation index system of big data application capability of intelligent manufacturing enterprises from the perspectives of technology, resources, and innovation, and uses spss23.0 and amos23.0 factor analysis and verification of the evaluation index system. The results show that the evaluation index system of big data application capability of intelligent manufacturing enterprises consists of three dimensions: big data technology application capability, big data basic resource capability, and big data innovation capability. The index system covers 12 secondary indicators.

Keywords: Intelligent manufacturing · Big data application capability · Capability evaluation

1 Introduction

The global manufacturing industry is changing in the direction of digitization, networking, and intelligence, with advanced manufacturing technology and a new generation of information technology Intelligent manufacturing, which is characterized by the deep integration of information technology, has become the core driving force of this new industrial revolution [23]. Made in China The development of the industry is in a critical period from the expansion of quantity and scale to the improvement of quality and efficiency. As a core resource, data should be Element, releasing the huge value potential far beyond the traditional elements [5]. The application capability of big data is not only the key core resource and competitiveness of enterprises in the new era but also the power source for enterprises to obtain new performance [2]. However, the new generation of information technology driven by big data not only brings development opportunities to enterprises but also brings great impact and impact to organizations and individuals [19]. The traditional information processing technology has been far from keeping up with the "information bombing" faced by enterprises, and the valuable information required by enterprises is covered by noise data and low-quality data. Based on this, exploring the

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application status and demand of intelligent manufacturing enterprises for big data, and constructing a perfect evaluation index system of big data application ability is of urgent and great practical significance for intelligent manufacturing enterprises to evaluate their own big data application ability and accelerate the deep integration of big data.

2 Literature Review

The value of big data lies not in the data resources themselves, but in acquiring, storing, processing, and analyzing data to provide meaningful information and find business value [16]. Existing studies have evaluated the application capability of big data from different perspectives, mainly focusing on the perspective of the resource-based view, technology center view, and dynamic capability theory. The resource-based view deconstructs the big data application capability from the perspective of element structure-function, regards it as a resource, and believes that the big data application capability is the capability to obtain excellent performance through the effective allocation of big data resources, including tangible resources, intangible resources and human resources [24]. However, in a dynamic environment, the key for enterprises to enhance their competitive advantage is not to have big data resources, but to update, integrate and utilize big data resources [20]. Therefore, enterprise analysis, integration, and utilization of a series of resources are only the premise of applying big data; From the perspective of the Technology Center, analyze the characteristics of big data application capability from the perspective of technology, divide the big data application capability into data acquisition capability, data integration capability, data processing capability and data visualization capability around the data process [3], and divide the big data application capability into descriptive analysis capability Predictive analysis ability and normative analysis ability [12] However, the definition of big data application ability from the technical perspective is not rich enough [17]; The perspective of dynamic capability theory is different from that of resource-based theory and technology center. It not only reflects the dynamic development characteristics of capability, but also reflects the composition of capability elements and the synergy with other resources and capabilities of the organization [25]. It can be divided into resource integration capability, in-depth analysis capability and real-time insight, and prediction capability [20].

To sum up, scholars have conducted in-depth research on the evaluation of big data application capability from the perspective of the resource-based view, technology center view, and dynamic capability theory. However, the evaluation indicators considered for intelligent manufacturing enterprises are mainly focused on the basic indicators of technology and resources, and the evaluation of big data application capability of intelligent manufacturing enterprises has not formed a unified standard. Because of this, this paper takes intelligent manufacturing enterprises with big data application experience as the research object and takes the two perspectives of “intelligent dimension” and “manufacturing dimension” as the starting point to build a perfect evaluation index system of big data application capability, to provide a reference for intelligent manufacturing enterprises to better apply big data and improve big data application capability.

3 Requirement Analysis

The "intelligence + manufacturing" two-dimensional model vertically reflects the intelligent empowerment that runs through the whole production cycle of the manufacturing industry, and horizontally includes the intelligent empowerment of different levels of traditional and advanced manufacturing [14]. Therefore, this study will analyze the needs of intelligent manufacturing enterprises for big data application from the two levels of "intelligence dimension" and "manufacturing dimension" based on the intelligent characteristics and life cycle.

3.1 Intelligent Requirements

The requirements of the intelligent dimension of intelligent manufacturing enterprises for big data applications include five intelligent functions: interconnection, integration and sharing, system integration, emerging business forms, and resource elements.

3.1.1 Resource Elements

Intelligent manufacturing is to form a new manufacturing and service system through the comprehensive interconnection of people, machines, and things [23]. It not only expands the traditional element structure with large-scale high-end intangible element investment [10], but also realizes the full connection between elements. Data is no longer an isolated individual. It does not participate in production independently of other factors but plays its utility through other factors [18]. Enterprises collect various forms of data between business departments or enterprises by establishing big data infrastructure and technology and realize real-time decision-making through cloud technology and rapid analysis [17]. In addition, the capability of enterprises to formulate strategies based on big data technologies and tools is also highly dependent on the skills and knowledge of enterprise human resources [1].

3.1.2 Interconnection

The application of big data strengthens the effective allocation of production factors, forms a more efficient industrial chain by connecting different industries, industries, and enterprises, promotes the renewal and quality improvement of enterprise products, and realizes value creation. On the one hand, build a big data information service bridge to provide connection channels for producers and consumers, and accurately and timely meet the diversified needs of customers [4]. On the other hand, building an intelligent manufacturing decision-making terminal through big data integration technology can create a data-driven enterprise with ubiquitous interconnection and collaborative optimization, promote enterprises to form an intelligent manufacturing system with self-organization, self-operation, and self-regulation, realize micro connectivity in production, manufacturing, and sales, and support data sharing within and among enterprises, Promote the synergy of the industrial chain [26].

3.1.3 System Integration

The new generation of intelligent manufacturing is composed of three functional systems of intelligent products, intelligent production, and intelligent services, and two supporting systems of industrial intelligent manufacturing cloud and industrial intelligent network [8]. Through the deep integration of big data with entity module mechanisms such as supply chain system, production system, and logistics system [13], the information is connected to the intelligent manufacturing cloud platform by using the new generation information network technology and big data analysis and evaluation technology to analyze and make decisions on massive data, optimize the manufacturing process, maintain manufacturing equipment, save manufacturing energy and cooperate with manufacturing equipment, Avoid the problems of idle equipment, low accuracy and decision-making delay in the traditional manufacturing model, and improve capital efficiency [18].

3.1.4 Integration and Sharing

Intelligent manufacturing enterprises should build data centers for enterprise sharing and industrial interconnection, and form systems and mechanisms for data application and achievement sharing. On the one hand, the "three chains" of data chain, technology chain, and value chain are deeply integrated, the decentralized manufacturing resources are dynamically connected and mobilized, and the connection between enterprises, partners, and upstream and downstream of a supply chain is strengthened, to form a more sustainable and complete value network system [22]. On the other hand, through screening, processing, and storing data to obtain data value, form an industrial data chain, effectively allocate production resources, and realize the integration and optimization of big data and enterprise business processes, to realize process intelligence and production intelligence [2].

3.1.5 Emerging Business Types

Intelligent manufacturing is based on the comprehensive digitization, networking, automation, and digital drive to integrate and apply the new generation of information technology with the whole life cycle of intelligent manufacturing and supply chain, so as to realize the process intelligence and integration of enterprises in the design, production, sales, service and other links [13], and realize the transformation of value creation [21], It shows a new business form different from traditional manufacturing. Data-driven emerging business formats can effectively find new combinations of production factors, help enterprises identify complex relationships, distinguish market segments and new needs of users, help managers make innovative decisions based on data, transform existing business models, or provide new products and services for target markets [15].

3.2 Manufacturing Demand

The demand of manufacturing dimension of intelligent manufacturing enterprises for big data applications includes five activities: intelligent design, intelligent production, intelligent logistics, intelligent sales, and intelligent service.

3.2.1 Intelligent Design

Intelligent design has been transformed into data-driven active design mode, which improves the intelligent design and intelligent decision-making capability of enterprises through the front and rear horizontal integration. Use big data technology to obtain product evaluation from the front end, predict customer demand, obtain enterprise manufacturing and operation and maintenance data through the back end, connect the big data at the front and rear ends, and improve the intelligent design mode of the enterprise [27]. In addition, the simulation analysis, evaluation and verification functions of big data virtual simulation technology can greatly improve product technology, optimize process flow, shorten product R&D cycle, and maximize R&D and design links [11].

3.2.2 Intelligent Production

Intelligent production realizes the intellectualization of production and manufacturing links, and combines big data, cloud technology, informatization, and other means with production links to realize intelligent production [7]. In terms of product quality, big data technology is used to monitor the production process in real-time, find and screen out inferior products in time, and improve the overall quality of products; In terms of production equipment, we use big data mining technology to analyze and infer the processing results of massive data, prevent potential problems in the manufacturing of parts and complete equipment in the manufacturing industry, and improve the production efficiency of the manufacturing industry [15].

3.2.3 Intelligent Logistics

Intelligent logistics emphasizes the intelligence of logistics process data, network collaboration, and decision-making. It has three characteristics: interconnection, deep collaboration, and independent decision-making. Intelligent logistics usually supports intelligent logistics management in a platform-based way, integrates the information and logistics services of participating institutions by using the information technology of big data and supports the implementation of intelligent logistics business management, intelligent logistics supply chain, and intelligent logistics business [9]. For example, in the construction of intelligent logistics supply chain of intelligent manufacturing enterprises, with the help of big data technology, we can insight into the potential trend of consumers, predict the development law of market demand, prepare materials and schedule production targets, and realize the dynamic matching of enterprise order demand and delivery [21].

3.2.4 Intelligent Sales

Big data technology is reshaping and innovating the operation and management mode of intelligent manufacturing enterprises and promoting them to establish a new "Data-Driven" manufacturing development mode [26]. Through the business model innovation of intelligent sales, develop or introduce big data analysis technology, use the new sales model, customize different products that meet the needs of different users [11], rely on the big data cloud platform, clarify the laws of consumers' purchase preferences

and market development trends, clarify consumers' purchase intentions and marketing objectives, and design appropriate marketing schemes [6], Cultivate network precision marketing.

3.2.5 Intelligent Services

Data-driven intelligent services to integrate big data, cloud technology, Internet, and other means, use accurate process state tracking to obtain information, carry out data transmission and information transmission, actively mine and identify user consumption habits, improve the service capability of complex products in the stages of design, manufacturing, operation, and maintenance [6], meet customer needs and deeply tap customer value [9]. For example, in terms of demand analysis, intelligent services can not only analyze consumers' consumption habits, but also deeply tap consumers' hidden information, such as identity, status, income, consumption level, living, and working status, analyze and present consumers' implicit needs, and provide customers with more efficient and accurate services [9] (Table 1).

Table 1. Demand analysis of intelligent manufacturing enterprises for big data application

Demand dimension	field	Focus of work	Demand for big data application
Intelligent dimension	Resource elements	Sufficient connection between resource elements	People; Machine; matter
	Interconnection	Build a data-driven intelligent manufacturing decision-making terminal with ubiquitous interconnection and collaborative optimization	Big data resources; Big data integration capability
	system integration	Deep integration of big data and system	Big data fusion capability; Big data depth analysis and Evaluation Technology
	integration and sharing	Build a data center for enterprise sharing and industrial interconnection	Big data collection, storage, and processing; Big data business process integration and optimization
	emerging business types	Data-driven emerging business	Big data driving force; Big data innovation capability

(*continued*)

Table 1. (*continued*)

Demand dimension	field	Focus of work	Demand for big data application
Manufacturing dimension	Intelligent service	Identify, mine, and meet the needs of users	Big data mining capability; Big data transmission and acquisition capability
	Intelligent design	Form an active design mode of front and rear end horizontal integration	Big data analysis platform; Big data virtual simulation technology
	Intelligent production	Realize the intellectualization of manufacturing links	Big data mining capability; Big data analysis and decision-making capability
	Intelligent logistics	Build a smart logistics supply chain	Intelligent data; Big data technology;
	Intelligent sales	Cultivate new models such as network precision marketing, whole industry chain tracing, remote online diagnosis, and supply chain finance	Big data analysis capability; Big data cloud platform

4 Construction of Evaluation Index System

4.1 Data Sources

In this study, CNKI and ISI's web of science database were used as data sources, and "big data capability", "big data capability and" manufacturing * "," big data and "capability evaluation *" were used as subjects for retrieval. SCI and SSCI were selected as the source categories of journals, and the retrieval time was from 2000 to 2021. 163 references with strong relevance and great reference value were obtained. Using bibliometric methods such as keyword co-word analysis and content analysis to sort out the frequency, it is found that the indicators show clustering phenomenon, covering technology, resources, innovation, and other aspects. The indicators with high frequency (frequency ≥ 3) are used as the initial basis for building the evaluation index system of big data application capability. The evaluation index frequency of big data application capability is shown in Table 2.

Table 2. Statistics of frequency of relevant indicators of big data application capability in the existing literature

sort	index	frequency	sort	index	frequency
1	Big data analysis capability	50	12	Big data resource integration capability	19
2	Big data technology	17	13	Big data platform	30
3	Big data prediction capability	19	14	Big data infrastructure	8
4	Big data collection and acquisition capability	32	15	Big data talent	26
5	Big data visualization capability	7	16	Big data technology resources	3
6	Big data decision-making capability	10	17	Big data resources	5
7	Big data mining capability	20	18	Big data innovation capability	6
8	Big data storage capacity	20	19	Innovation of big data enabling mechanism	3
9	Big data application capability	10	20	Innovation of big data manufacturing mode	7
10	Big data processing capability	17	21	Big data strategy making capability	4
11	Big data perception	6	22	Big data fusion capability	6

4.2 Evaluation System Framework

Combined with the above demand analysis and frequency combing of intelligent manufacturing enterprises for big data application capability, the obtained evaluation indexes are summarized, the evaluation indexes with similar meaning and inclusive relationship are combined, and the evaluation indexes with high frequency and high importance are selected. This study intends to start from the application capability of big data technology The evaluation index system of big data application capability of intelligent manufacturing enterprises is constructed from the three dimensions of big data technology application capability,big data basic resource capability, and big data innovation capability.

5 Data Analysis

5.1 Study Design

The questionnaire design of this study refers to the measurement items widely recognized in the research at home and abroad and closely related to the content of this study.

Based on the research results of Xie Weihong, Cheng Xueqi, Liao Jianxin, Shahriar, Akter, Frankel, Li Zhongshun, Gupta, Zhang Jinlong, and other scholars, a preliminary measurement scale is designed. The questionnaire adopts the Likert five-level scale, and the respondents choose from "very disagree" to "very agree" according to their judgment. Based on intelligent manufacturing enterprises with big data application experience, 400 questionnaires were distributed, 324 valid questionnaires were obtained, and the recovery rate of valid questionnaires was 81%.

5.2 Exploratory Factor Analysis

5.2.1 Reliability Test

In this study, the Cronbach coefficient was used to test the consistency of the scale. The Cronbach's alpha coefficient of the big data application capacity scale is 0.910, and the three factors are 0.722, 0.892, and 0.910 respectively, reaching more than 0.7, indicating that the internal consistency reliability of the scale is good.

5.2.2 Validity Test

(1) Content validity. This study clarifies the relationship between indicators by combing the literature, constructs a perfect evaluation index system of big data application capability, and invites experts to revise the items repeatedly. The items can reflect the real characteristics of the respondents. Therefore, the content validity of the scale is good.
(2) Convergent validity. The load coefficients of standardized factors are above 0.6, indicating that the convergence validity meets the research standard; The combined reliability Cr and mean-variance extraction value ave are greater than 0.5, indicating that the measurement error is small, and the convergence validity results of each dimension in this study are good.
(3) Construct validity. Using spss23.0 exploratory factor analysis was conducted to test the structural validity of the scale. Kmo and Bartlett's spherical test was performed on the scale, kmo = 0.92, greater than 0.7, indicating that Bartlett's spherical test value is significant (SIG. < 0.001), and the questionnaire data meets the premise requirements of factor analysis. It can be seen from the factor analysis results in Table 3 that there are three well representative factors screened out, namely, the application capability of big data technology, the basic resource capability of big data, and the innovation capability of big data. The total interpretation capability has reached 73.293%, more than 50%. The factor load coefficients are greater than 0.5, and the cross load is less than 0.4. Each item falls into the corresponding factors, indicating that the scale has good structural validity.

5.3 Confirmatory Factor Analysis

Amos23.0 conducts confirmatory factor analysis on the survey data to verify the evaluation index system of big data application capability proposed in this study. Compare the

Table 3. Results of factor analysis

	component		
	1	2	3
A1:big data acquisition capability	0.83		
A2:big data processing capacity	0.789		
A3:big data storage capacity	0.777		
A4:big data analysis capability	0.748		
A5:big data visualization capability	0.773		
A6:big data decision-making capability	0.786		
A7:big data tangible resources		0.855	
A8:big data intangible resources		0.787	
A9:big data human resources		0.816	
A10: big data resource integration capability		0.837	
A11:big data development innovation capability			0.805
A12:big data exploratory innovation capability			0.845
characteristic value	4.023	3.092	1.681
Cumulative variance interpretation	33.521	59.284	73.293

Table 4. Comparison of the fitting degree of first-order, second-order and third-order models

Model	χ2/df	GFI	AGFI	NFI	TLI	CFI	RMR	RMSEA
First-order model	11.299	0.693	0.554	0.442	0.404	0.458	0.156	0.149
Three-factor model	1.154	0.941	0.956	0.945	0.995	0.994	0.035	0.022
Second-order model	1.154	0.941	0.956	0.945	0.995	0.994	0.035	0.022

fitting indexes of the proposed first-order, three-factor, and second-order hypothetical models to select the big data application capability evaluation model with the highest fitting degree in this study.As shown in Table 4, the adaptation indexes of three-factor model and second-order model $\chi 2/DF = 1.154$, less than the standard below 3, GFI = 0.941, AGFI = 0.956, NFI = 0.945, TLI = 0.995, CFI = 0.994, all greater than 0.9, RMR = 0.035, RMSEA = 0.022, all less than 0.08, indicating that the fitting degree of the model is good. Compared with the first-order model, the adaptation index of the three-factor model and the second-order model is more ideal.

The second-order model diagram of big data application capability is shown in Fig. 1 below: the factor load coefficients are above 0.6; The SMC of the measurement model is 0.49–0.81, both above 0.36; Because the second-order model of big data application capability is formed based on the three-factor model, the fitting complexity of the second-order model is higher than that of the three-factor model, and its scientificity and accuracy

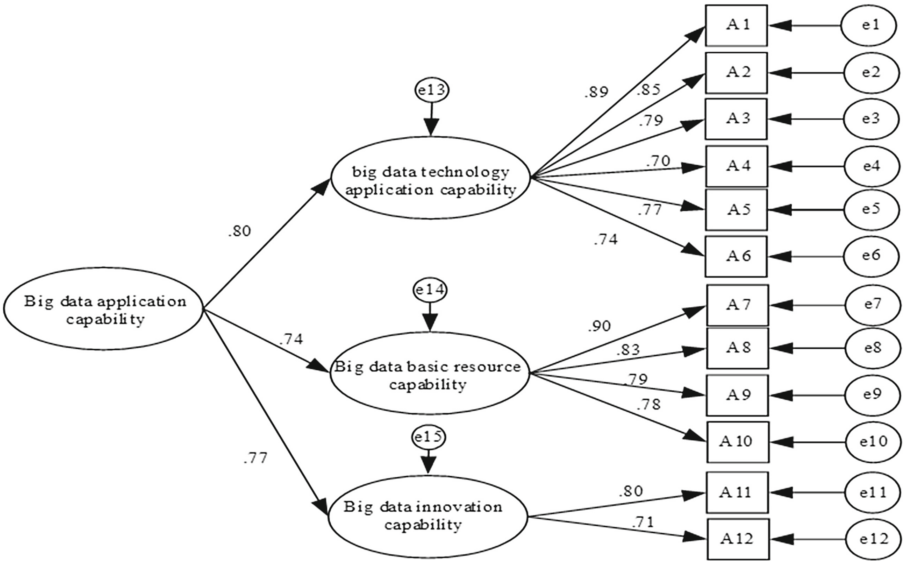

Fig. 1. Second-order confirmatory factor analysis model of big data application capability evaluation index. Photo credit: Original

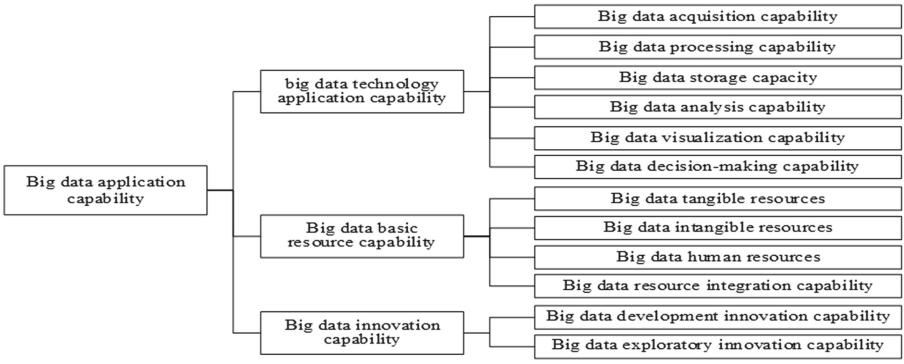

Fig. 2. Evaluation index system of big data application capability of intelligent manufacturing enterprises. Photo credit: Original

are more reliable than the three-factor model. Therefore, the fit between the second-order model and the actual data is more ideal and acceptable.

5.4 Construction of Big Data Application Capability Model

The evaluation index system of big data application capability includes three primary indicators and 12 secondary indicators of big data technology application capability, big data basic resource capability, and big data innovation capability, as shown in Fig. 2.

6 Research Conclusion

Based on summarizing the previous research results, based on literature frequency combing and demand analysis, this study constructs the evaluation index system of big data application capability of intelligent manufacturing enterprises from the perspectives of technology, resources, and innovation, and makes empirical analysis. The data results show that the fitting degree of the second-order model of the evaluation index system of big data application capability is higher than that of the first-order model, which effectively confirms the rationality and reliability of the three-dimensional model of big data application capability in this study, and finally determines the application capability of big data technology A big data application capability evaluation index system with three primary indicators and 12 secondary indicators of big data basic resource capability and big data innovation capability.The evaluation index system not only enriches the theoretical research on the evaluation of the big data application capability of intelligent manufacturing enterprises, but also provides a scientific basis for intelligent manufacturing enterprises to improve their big data application capability.

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