Analysis on the endogenous mechanism of big data and tower management framework in intelligent manufacturing enterprises

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Abstract. This paper makes an in-depth comparative analysis of years of experience in intelligent manufacturing projects and literature research related to Big Data. The 4.0 value chain model and concept are put forward to carry out the logical analysis of the endogenous relationship drive and endogenous management mechanism of intelligent manufacturing. The intelligent manufacturing business management process under the 4.0 value chain is established, and the tower Big Data management framework of intelligent manufacturing enterprises is innovatively proposed. This paper discusses the connotation, elements and drive relationship of enterprise Big Data from three dimensions of business operation, information drive and management policies. The hierarchical structure and related connotation of Big Data are revealed, and the basic characteristics of intelligent manufacturing enterprises Big Data are analyzed. The purpose of this paper is to clarify the difference of the concept between enterprise Big Data and mass data and open the Big Data fundamental research driven by digitization management. It provides basic innovative ideas and scientific research methods for the new generation of digital virtual simulation, digital factory construction and industrial chain management.

1 Introduction

Under the requirement of development of the new era, Big Data has attracted the attention of enterprises, countries, academia, scientific and technological circles on its research and application. Industrial Big Data is the core technology of industrial internet and industry 4.0. The manufacturing industry needs to open up industrialization with new Big Data thinking. It is urgently needed to integrate Big Data with business management and production operation activities. To promote the intelligence transformation and upgrading of manufacturing enterprises, especially to open up the basic cognition of Big Data and re-examine it with scientific thinking and management methods, it is necessary and important

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to build the connotation, elements, management mechanism and framework of scientific Big Data and take charge of its innovative development.

2 Current situation of the research and application of Big Data

The futurist and social thinker Alvin Toffler (1980) first proposed the concept of "Big Data" in *The Third Wave*. *Demand Survey of the Application and Control of Data Visualization* first proposed the terminology "Big Data" [1]. *Big Data Era* firstly proposed 4 v features (Volume, Velocity, Variety and Value) widely as the definition and concept of Big Data [2]. In 2008, *Nature* special issue *Big Data* introduces the challenges brought by mass data from the aspects of internet technology, network economics, supercomputing, environmental science and biomedicine, etc. In 2010, Apache Hadoop defines Big Data as: "large data sets ordinary computer software can't seize, manage or process within an acceptable time". *Big Data: The Next Frontier of Innovation, Competition and Productivity* proposes that "Big Data requires new processing modes to have stronger insight, decision-making and process optimization abilities". The concept and potential of Big Data are profoundly discussed by EMC/IDC in *Extracting Value from Chaos*. In 2011, IDC also defined Big Data: "Big Data technology describes the new-generation technology and framework system, and extracts the economic value of various mass data through high-speed collection, discovery or analysis". In April 2012, the research journal of European Association of Informatics and Mathematics, ERCIM News special issue, *Big Data*, discussed the intensive form of research on the innovation technology of Big Data and other issues. "OODA cycle model is considered the main model of Big Data supply chain", "which further extended to a Big Data driven proactive manufacturing architecture".

Technology and Framework of Industrial Big Data proposed "industrial Big Data is the general name of all kinds of data and related technologies and applications generated at each stage of the whole product life cycle surrounding the typical intelligent manufacturing model". Industrial Big Data can be subdivided into "product data, production data, value chain data and external data". According to *Technical Review of Industrial Big Data,* industrial Big Data mainly includes "enterprise information data, industrial IoT data and cross-border data". It is proposed that small data and mass data have strong correlative and structural relationship with industrial Big Data. "Big Data + industry" establishes a data-driving value chain. The new space for the development of manufacturing industry is generated through the interaction of external data and internal data.

GE construction APM cloud platform helps enterprises to create and develop industrial internet applications based on Predix standards. At Hanover industrial show in April 2017, Siemens presented the core content of MindSphere. French company Schneider integrated Schneider electric industrial interconnecting products with the application of edge control and launched the EcoStruxure platform. In April 2015, three major associations of German BITKOM, VDMA and ZVEI jointly released and proposed three core dimensional industry 4.0 basic framework and RAMI 4.0 system. In addition, domestic and foreign ERP enterprises Oracle, SAP, Sagesoft, Microsoft, Inspur, UFIDA and Kingdee all join in the development and extension of Big Data products, and launch enterprise cloud level industrial Big Data framework and technology management platform.

2.1 Research status of the application and management of Big Data

So far, problems with Big Data and even industrial Big Data are as follows:

2.1.1 Firstly, accurate definition, basic research on Big Data and clarification of concept boundaries are lacked

Up to now, no research institution or scholar has given a precise definition of Big Data. The concept of Big Data is usually confused with that of mass data. The mass data research is regarded as Big Data research and the definition of industrial Big Data and industrial enterprise Big Data is unclear. Quantized model, hierarchical elements [3], value standards, and digital-driving framework are lacked and the associated structure of Big Data and the essence of digital virtual simulation management are ignored. Keen on technology and lack of basic management research, this kind of research will inevitably lead to Big Data deviating from the basic needs and goals of enterprises and society, causing the failure of 85% Big Data projects with capital scale of millions and even tens of millions.

2.1.2 Secondly, Big Data belongs to the product of technology and the category of management

Manufacturing enterprises Big Data is the integrated product of the frontier interdiscipline. Developers of Big Data research mostly start from the category of Big Data technology and excavate the commercial value of the mass data. They try to study Big Data as a "Data nature" inclined to the natural science concept of "data boundary" [4]. It was ignored that the mainstream hot spots of Big Data should return to the high-level management application fields of the society, enterprises. The management and control driven by the innovation of Big Data should be enhanced with the return of more industrial and commercial value. For this reason, Nick Heudecker, CEO of Gantt, tweeted: "The key of Big Data isn't about technology."

2.1.3 Thirdly, not realizing to get industrial, financial and market Big Data causes enterprises to lose business opportunities

Most enterprises lack internet business awareness, mobile finance and business development thinking, and lose mass valuable data information and Big Data (mobile payment, customer finance, market sales, product performance) with the most commercial value in the market. Or it will be pushed into the hands of "third-party payment" e-commerce enterprises, thus losing or losing the main business role of e-commerce channels in the market of enterprises (important Big Data creators).

3 Endogenous management mechanism and framework of Big Data in intelligent manufacturing enterprises

3.1 Intelligent manufacturing enterprise is the creator of Big Data

Industrial manufacturing is the biggest contributor and motivator of e-commerce mass data. IT integrates industrialization and informatization together. Many industrial enterprises have crossed the boundaries to link all fields, so the integration of internal and external industries of manufacturing and production has become the direct factor affecting the Big Data ecology. Since the industrial revolution from Watt, the production efficiency and speed of machines far exceed that of manual workshops. Big Data have entered into a rapid and vigorous development condition, especially after the third industrial revolution. Since IT appeared, a vast amount of information was produced by the interconnection of all things. Data management systems such as CMIS, AIS, MRP, MES, PDM, CRM and ERP store high-density integrated data of industries, supply chains and industrial chains. Think Big, a Big Data consulting company, ranks IoT and machine data as the top priority. In

particular, industrial robots in the 4.0 era are continuously creating industrial Big Data in a high-speed, precise and large-scale way. The whole world has entered to a mode with the explosive growth of data volume.

3.2 Endogenous management and interactive mechanism of intelligent enterprise Big Data

3.2.1 4.0 Value chain of intelligent manufacturing enterprises

All enterprises should have 4 basic endogenous functions: value-added operation; profits from sales; financial analysis and control optimization. The four endogenous functional factors of Big Data related to intelligent manufacturing enterprises are in the charge of the enterprise value ecosystem: value driving chain. Michael Porter put forward the value chain theory in 1985 delineating the cost pattern, business process and value-added model created by enterprise [5]. It clarifies that the business process is created by product value and describes the drive relationship between common business elements in an enterprise. It has the following defects: firstly, in Porter Value Chain it is difficult to accurately explain and evaluate the corresponding digital value of intelligent manufacturing, intelligent logistics, intelligent finance and intelligent sales. Digital factories need more accurate digital value chain to simulate the value form of intelligent manufacturing enterprises; secondly, the endogenous drive mechanism of enterprise digital resources and automated activities of "purchase, production and sale" cannot be constructed and analyzed [6]; therefore, in today's advanced manufacturing industry 4.0, digital enterprises need to reconstruct the value chain theory [7].

Use industry 4.0 and new generation IT technology, according to the ecological reality created by value, management drive and restraint mechanism to analyze specific input elements related to the value created by enterprise products (intelligent CNC processing center, combination process, resource consumption, finance expenses and other factors) and to reveal the production cycle of enterprise value creation. The digital management simulation value chain about the overall process from the purchase of raw materials to the production of ordered goods by intelligent automated processing center is called the intelligent manufacturing 4.0 value chain. （figure 1）

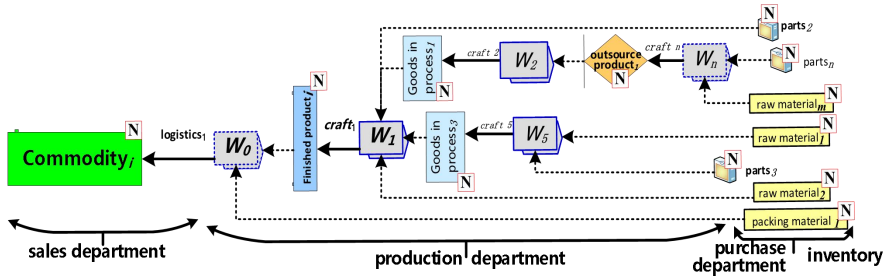

Fig. 1. The 4.0 value chain of intelligent manufacturing enterprises.

Intelligent 4.0 value chain illustrations: [N] represents the material number； W_n represents the N th MES process automated manufacturing center； ← represents the required process and processing lead time； the dotted arrow represents the material needed to supply the manufacturing equipment.

3.2.2 The internal drive management mechanism and process simulation of enterprises under the 4.0 value chain

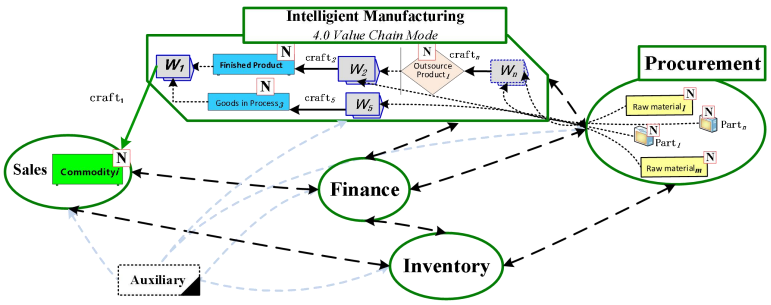

Fig. 2. Intelligent manufacturing enterprise business-driven mechanism based on 4.0 value chain.

Under the mode of industry 4.0, restrained by market size, production planning, contract orders, cost, profit, and social services, etc., the intelligent finance under E-payment can be regarded as the stimulation point of intelligent sales of E-commerce, which can trigger value creation and operation activities of "production, storage and purchase" of enterprises including process scheduling, production of goods, warehousing of supplies and procurement, synergy and outsourcing, and other main business activities. This activity also needs a certain degree of support: product research and development, investment and financing, fixed assets procurement and maintenance [8], staff recruitment, quality service, quality inspection and after-sales activities. Certain production activities will inevitably lead to the consumption of the internal and external resources of the enterprise, and thus cause financial capital management, control and ABC management of activity cost. And after the enterprise continuing to go through one or several cycles of cycle operation and accumulation and generating several business information data sets, enterprises can collect, manage and optimize data through business intelligence. Therefore, the 4.0 value chain causes the enterprise: from intelligent finance → intelligent sales → intelligent manufacturing → intelligent procurement → intelligent inventory logistics to the formation of the drive process of the internal business management relationship within the enterprise. (figure 2)

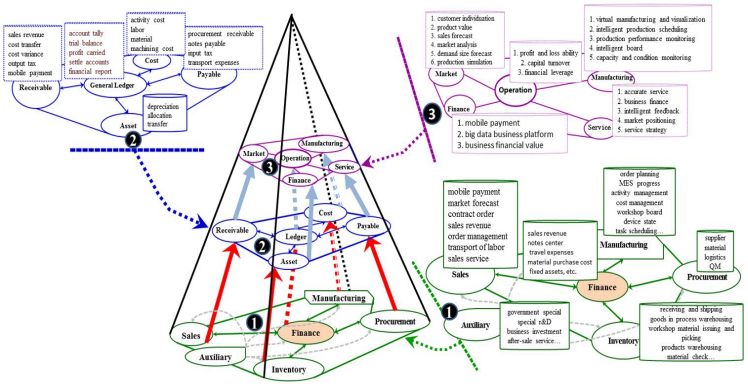

Fig. 3. Enterprise tower Big Data management framework and components.

Demand - based production pulling the interaction between logistics and capital leads to profit and loss analysis on product costs and related financial and management accounting, etc. (enterprise accounting information). Enterprises use business to drive information data storage and accumulation. This provides a deep level optimization of business decision-making, control and execution through business intelligence [9]. Therefore, the digital drive mode from below has formed the manufacturing enterprise tower Big Data management framework (figure 3). This helps enterprises to realize the intellectualization of whole-

process operation of Big Data system [10], and lay a foundation for enterprise upgrading, transformation, global layout, and capability improvement.

3.2.3 Reference conditions and rules of integrated virtual operation and management under Big Data mode

The reference conditions of digital management in enterprises virtually driven by Big Data: The enterprise has the open interface for bank E- payment, which is used for the verification, payment and authorization of the order transaction of intelligent finance; individual users need Big Data authentication system (electronic identity and security authorization authentication interface) of government human resources; the client enterprise needs the electronic authentication (safety credit) of industrial and commercial bureau and the electronic transaction e-authorization interface of bank. There are two ways of Big Data driving digital management in enterprise: order sales and planned production.

4 Analysis of the definition, classification and connotation of enterprise big data

The intelligent manufacturing enterprise Big Data consists of 3 layers and 5 levels (figure 4).

4.1 Level 1：intelligent manufacturing enterprise Big Data

Intelligent manufacturing enterprise Big Data is defined: using artificial intelligence and CPS technology, the integrated operation process of "purchase, sales and storage" driven by intelligent manufacturing in the ecological process created by enterprise value actuates the disclosure of financial accounting information and the intelligentized management and control of profit and loss analysis. The three - dimensional integration of digital data collection composed of business operation, information management and decision-making control are formed, which is called intelligent manufacturing enterprise Big Data.

Characteristics of intelligent manufacturing enterprises Big Data: authority, reliability, security credibility, value, strong correlation, interoperability, integrity, virtuality, management complexity, strong correlation, dynamic, and openness (enterprise, industry).

4.2 The second level of Big Data is divided into three layers: business, information, and BI

There are significant logical associations and drive relationship between them. (see figure 3)

4.2.1 Business Big Data (secondary data)

Based on the 4.0 value chain theory, economic activities will lead to changes in enterprise resources or values within the enterprise, from which business relationship data are generated. Business Big Data can be divided into main business / non-main business / auxiliary Big Data.

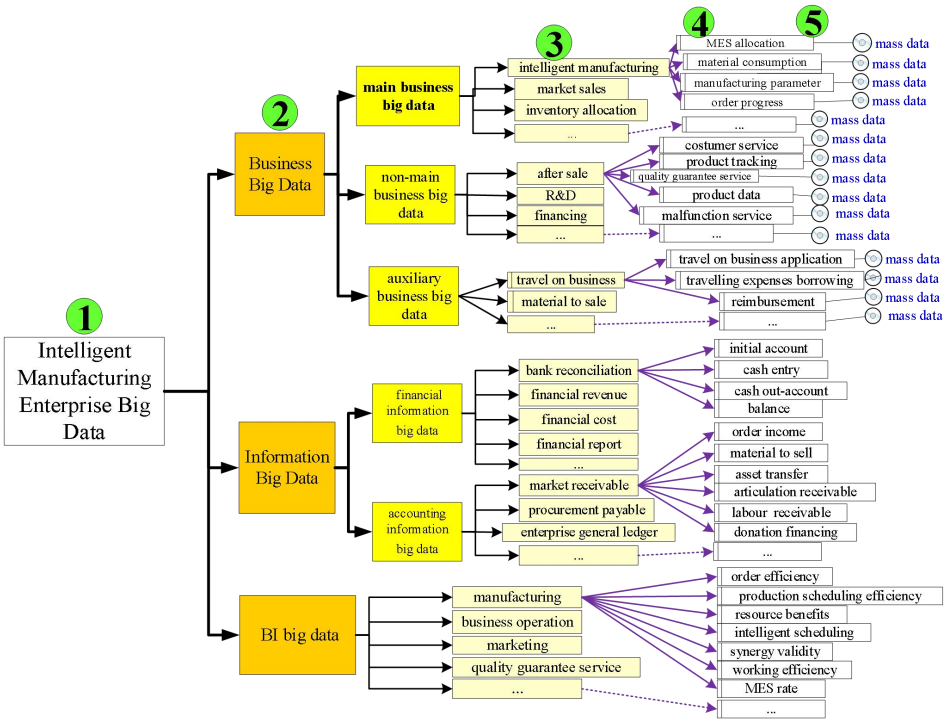

Fig. 4. Schematic diagram of intelligent manufacturing enterprise Big Data.

4.2.2 Information Big Data (secondary data)

The change of enterprise value and capital expenses caused by business operations leads to the information collection about enterprise financial payment, financial revenue and expenditure, cost accounting, profit and loss, accounting information disclosure and other information, which is called information Big Data.

4.2.3 BI Big Data (secondary data)

Enterprise Big Data BI decision layer is a large, intelligent, continuously improved, management, analysis, control and decision-making system which aims to improve and obtain the best operating efficiency of the enterprise in at least two ways: one is the industry operation data experience from many years' business management and the other is the ability of managing and controlling business information from the external competitive environment or whole business resource allocation in industrial chain network. After automated analysis, the operation parameters can be improved and optimized.

4.3 Level 3: functional Big Data

With the attribute of department management, it aims at division of labor, efficient management for enterprises and occupational division of enterprises' organizations, usually including intelligent manufacturing, financial management, inventory, intelligent logistics and market sales, etc. Although different enterprises have different functions, they are inseparable from the three basic functions of "purchase, sales and storage".

4.4 Level 4: enterprise metadata

Enterprise metadata is the smallest data unit in enterprise Big Data structure; it is also the smallest data unit in enterprise Big Data management level, which is used to constitute the smallest function and transmission unit of intelligent Big Data. Multiple metadata are used to structure and interpret the management characteristics of functional Big Data. Different from ordinary data or numbers, enterprise metadata usually has the following 6 characteristics: business subjectivity; value correlation; management drive; objectivity; safety credibility and emulation virtuality.

4.5 Level 5: mass data

Mass data is a kind of special auxiliary metadata. Information related to equipment, products, components, users and other related auxiliary characteristic data which occur on a node in a detailed field of an enterprise many times continually is called mass data. Mass process data which include details of angle, length, chip error, voltage, environmental humidity, temperature, etc. of CNC machine tools are used to reflect the working condition and equipment reliability. Characteristics of mass data: non-business subjectivity (auxiliary); legal relativity; privacy; commerce; indirection; altruistic business values.

5 Conclusion

Intelligent manufacturing enterprise Big Data is a very important concept in Big Data family, and also the foundation of simulation management such as cloud system, digital intelligent enterprise, etc. This paper starts the basic research on the definition, connotation, mechanism, research framework of intelligent manufacturing enterprise Big Data. The research on 4.0 value chain, manufacturing enterprise tower management framework, endogenous business-driven mechanism and process logic, etc. will open a new chapter of industrial digitalization and the transformation and upgrading of traditional manufacturing.

Acknowledgment

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