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Definition and Measurement of Enterprise Digital Transformation

Xiaoqin Ou

School of Econmics and Management, Southwest Petroleum University, Chengdu, 610500, China

Abstract: In recent years, with the continuous progress of science and technology such as the Internet, big data, cloud computing, and blockchain, and the rapid development of society, the digital transformation of enterprises has become one of the research fields that scholars at home and abroad focus on. This paper distinguishes and analyzes the related elements of digital transformation, such as digitization, digitization, informatization, and intelligence, and further expounds the characteristics of digital transformation and the main digital technologies that constitute digital transformation. At the same time, the measurement methods of enterprise digital transformation at this stage are classified and discussed, and it is found that the annual report text analysis method is a more reasonable method to measure the degree of enterprise digital transformation. The results of this paper have important theoretical and practical significance for promoting the digital transformation process of enterprises.

Keywords: Digital technology, Digital economy, Digital transformation, Measurement methods, Text analytics.

1. Introduction

The digital transformation of enterprises has always been a hot topic of research by scholars from all walks of life. In the 14th Five-Year Plan, China clearly pointed out that digital transformation should be used to drive the transformation of production methods, lifestyles and governance methods as a whole, and accelerate the construction of digital economy, digital society and digital government. The report of the 20th National Congress of the Communist Party of China once again emphasized the strategic goal of "building a digital China", and it is necessary to adhere to the focus of economic development on the real economy, and accelerate the construction of a manufacturing power, a network power, and a digital China. Digital transformation is an important driving force for the further development of the modern industrial system, an important fulcrum for the improvement and upgrading of various economic entities, and a strategic need to take the priority position and grasp the initiative in development in the fierce international competition. At present, the definition of digital transformation in industry or academia is relatively vague, and most of them equate digital transformation with the use of data or digital technology. Based on this, this paper will sort out and summarize the definition of digital transformation, clarify the relationship between digital transformation, digitalization and digital technology, and elaborate on the main digital technologies, so as to lay a foundation for future research on enterprise digital transformation.

2. The Concept and Characteristics of Digital Transformation of Enterprises

Scholars from all walks of life have different views on the concept of digital transformation, and there is still no unified expression. When it comes to digital transformation, many scholars associate it with data, informatization, digitization, and intelligence, and are all related to major digital technologies such as cloud computing, blockchain, and big data, but there are also big differences. Dataization and digitalization are the foundation of enterprise digital transformation, and most scholars believe that the increment of these two stages can achieve digital transformation [1]. Informatization is an important element of digital transformation, and intelligence is an important goal of enterprise digital transformation. Based on this, this paper distinguishes between data, digitization and informatization, and intelligence and digital transformation.

2.1. Dataization

Dataization refers to the process of converting information, data and other analog data in the physical world into binary codes represented by 0 and 1, structured (such as tabular data in a database, etc.), semi-structured (such as HTML documents, JSON, XML, etc.) or unstructured (such as office documents, text, pictures, etc.) data forms for easy storage, management and analysis. Dataization can provide companies with the tools to better understand market demand, customer behavior, product performance, and other information to make better decisions and management.

2.2. Informatization

Informatization refers to the organic combination of information resources and information technology in the enterprise to realize the collection, transmission, storage, processing and utilization of information, so as to improve the management level and efficiency of the enterprise. "Informatization" requires tacit knowledge, not just "automating" the explicit understanding of the past [2]. In the process of informatization, enterprises need to use various information technologies, such as computers, networks, databases, software, etc., to integrate and manage various information resources in the enterprise. Through informatization, enterprises can achieve the goals of business process automation, information sharing and collaboration, and customer service upgrades.

2.3. Digitization

Digitization is a well-known concept that refers to the

process of transforming information into a tabulable analysis of data that can be structured and identified, and a computer can read the quantified form of the data [3]. In the digital era, digital technologies and tools such as big data, cloud computing, artificial intelligence, virtual reality and augmented reality, and blockchain have subverted the foundation of the industrial economy, and various business models, production methods and social mechanisms have been reconstructed to achieve new economic growth and social progress 4. Digitalization combines the three dimensions of matter, energy, information, and people to enhance efficiency, improve quality, and optimize experiences. Digitalization can not only improve the efficiency of data storage and processing, but also make it easier to transmit, share and utilize.

2.4. Intelligence

Intelligence refers to the combination of artificial intelligence technology and enterprise management to achieve the goals of business process automation, intelligent decision-making and management upgrading. In the process of intelligence, enterprises need to use various artificial intelligence technologies, such as machine learning, natural language processing, computer vision, etc., to analyze and mine the data in the enterprise, so as to optimize and upgrade the business process. Intelligence can improve the management level and efficiency of enterprises, reduce labor and time costs, and bring better customer experience. Digital intelligence is the ultimate goal of enterprise digital transformation.

2.5. Digital Transformation

In existing research, domestic scholars usually use concepts 5 6 such as "Internet transformation", "'Internet +' transformation" and "Internet transformation". Foreign scholars mainly use the concept of "digital transformation (DT)", and the common expressions are "digitization" and "digitalization". The concept of digital transformation comes from the practice of private enterprises. Generally speaking, the digital transformation of enterprises is defined in terms of digital achievements and applications at the level of digital technology, strategic guidance, technology drive, and organizational empowerment at the company level.

From the perspective of technology, Gemini believes that the core of digital transformation lies in innovative technology [4] on the one hand, the use of digital technology to improve production efficiency or technical level to achieve the improvement of enterprise economy, on the other hand, the use of digital technology can break the data silos between different levels of the industry, promote the operational efficiency of enterprises, and then build a new digital economic structure [5]. Berman believes that the digital transformation of enterprises is more focused on a change in the way of thinking, by expanding the customer base and using digital technology to update the operating model [6], so as to improve the value creation and business model of the enterprise, and then strengthen its core competitiveness. Matt et al. see a digital transformation strategy as a blueprint to support companies in managing the changes brought about by the integration of digital technologies and to support a transformed operating model [7]. According to scholars such as Agarwal [8] and Majchrzak [9], digital transformation refers to the profound transformation of society and industry through the use of digital technologies. According to Tobias et al., digital transformation is built on the foundation of digital technology, leading to unique changes in the way enterprises operate, business processes, and create value [10]. An Xiaopeng believes that the core of digital transformation is to make full use of digital technology and data resources to solve complex and uncertain problems, which can not only improve efficiency, but also significantly improve the capabilities of enterprises, and then build new competitive advantages of enterprises [11]. Through the application of digital technologies, digital transformation aims to seek fundamental transformations in an organization's infrastructure, products and services, business processes, business models and strategies, or inter-organizational relationships or even organizational networks [12].

At the company level, Vial (2019) uses a semantic analysis method to analyze the definition of digital transformation in relevant literature, and points out that digital transformation should clearly state the analysis unit, the scope of transformation, the transformation process and the expected results, so that digital transformation is defined as a reform process and an inductive framework, respectively. Digital transformation can be defined and understood from two main perspectives. First, as a process of change, digital transformation refers to the process of integrating information, computing, communication, and connectivity technologies to trigger significant changes in entity attributes and improve them. Second, as an inductive framework, digital transformation describes how organizations respond to changes in their environment by adopting digital technologies to change the way they create value [13]. The concept of digital transformation has been further expanded with the widespread application of digital technologies in various industries. It is generally accepted in the academic community that digital transformation should be characterized by two main characteristics: the widespread application of digital technologies and the profound transformation of organizational structures. In contrast, Verhoef points out, digitization, which only converts analog information into digital form, is more concerned with changes in business processes and the reshaping of strategic models [14]. Although there is still a general consensus on the exact definition and scope of digital transformation, the application of digital technologies such as big data, artificial intelligence, and cloud computing has been widely recognized as a key factor in promoting the innovation of enterprise production methods [15]. Therefore, digital transformation has been widely recognized as a research direction. In short, digital transformation is a process of transformation and reshaping of the economy, society and enterprises driven by the continuous innovation of information technology applications and the continuous growth of data resources. In the process, companies are leveraging emerging technologies for eco-positioning, business model innovation, business and organizational process optimization, and improved relationships with employees, customers, suppliers, partners, and other stakeholders to compete more effectively in the ever-changing digital economy.

Digital transformation is not only information or IT transformation, but also an all-round transformation process involving various functions of the enterprise. It does not simply digitize enterprise data, but uses emerging digital technologies to establish a digital information infrastructure that adapts to its own needs, and organically integrates digital technology with enterprise management, strategy, business,

and organizational aspects to promote enterprises to achieve profound changes in corporate governance, organizational structure, production and operation [16]. Digital transformation aims to drive the transformation of business models and business models of enterprises, as well as adjust the way enterprises operate and strategic thinking [17]. Through digital transformation, enterprises can use digital technology to improve their core business, enhance their ability to collate, analyze, and communicate, and optimize the efficiency of collaboration between different entities, thereby improving their operational level and efficiency. This process finally realizes the industrial upgrading and reengineering of the enterprise, and promotes the enterprise to move towards high-quality development.

3. Major Digital Technologies

As the foundation of digital transformation of enterprises, digital technology has subversive changes to the business model and people's life patterns, and provides innovative solutions to solve global problems. At the same time, the digital transformation of enterprises the innovation of business models and corporate culture of enterprises has further put forward the demand for digital technology, and promoted the updating 21 of digital technology to a higher level [18]. These technologies are innovative and revolutionary in their own right, and when combined, fundamentally change business and society, destroying old business models and creating new leaders. This paper uses the text analysis method to extract the text of the annual report of listed companies (excluding the management discussion and analysis part), and selects some high-frequency words related to digital transformation by word segmentation processing and word frequency statistics of the text, which include multi-dimensional enterprise digital transformation word segmentation dictionaries such as technology empowerment, organizational empowerment and digital application. Technology empowerment keywords: robots, Internet of Things, cloud computing, unmanned driving, cloud technology, artificial intelligence, cloud computing, virtual reality, data mining, face recognition, cloud storage, edge computing, machine learning, data visualization, natural language processing, etc. 62. In this paper, we select the six digital technologies with the highest word frequency to illustrate them separately.

3.1. Robots

Robotics is an important field of modern science and technology, which refers to the intersection of artificial intelligence and mechanical engineering, covering control systems, perception systems, decision-making systems, operating systems and mechanical systems. With the continuous development of artificial intelligence and mechanical engineering technology, the application range of robots has also been further expanded. In the field of manufacturing, through advanced manufacturing technology, the production cost of robots is gradually decreasing, so the application range of robots is also expanding, covering both industrial and civilian fields. In terms of control, the autonomous operation, remote control and program control technology of robots have been greatly improved, and humans can remotely control or even escape dangerous situations. In terms of perception, robots can perceive objects, sounds, lights and other information in the environment through sensors, so as to better complete tasks. In the industrial sector, robots can complete dangerous or repetitive tasks, thereby reducing reliance on labor and increasing productivity. In the civilian field, robots can be applied in medical care, education, home services and other fields to help people live and work better. The continuous progress and application of robot technology is not only conducive to the production and life of human beings, but also promotes the in-depth research of human beings in artificial intelligence and other fields, providing a broader development space for the development of future science and technology.

3.2. Internet of Things

The Internet of Things, with its limitless potential, is connecting all kinds of objects and devices in the world. Through sensors and networks, IoT technology enables intelligent interconnection of devices, vehicles, and homes. This technology is applied in various fields, such as smart cities, industrial automation, and agricultural management, resulting in increased efficiency and convenience.

3.3. Cloud Computing

Cloud computing offers new ways to share resources and services. Through the internet, cloud computing allows users to access computing power, storage, and application services on demand without having to own physical equipment. This flexibility and scalability save businesses and individuals costs while also increasing efficiency.

3.4. Unmanned

Unmanned driving technology refers to a technology that uses artificial intelligence, machine learning, sensors, maps and other technologies to enable vehicles and other vehicles to autonomously complete driving, obstacle avoidance, parking and other operations without human driving, so as to achieve autonomous driving. Unmanned driving technology mainly uses lidar, camera, millimeter-wave radar, GPS, inertial navigation and other sensors to perceive and identify the surrounding environment of the vehicle, and then uses machine learning, deep learning and other artificial intelligence technologies to process and analyze the perceived data, so as to achieve autonomous driving. Specifically, unmanned driving technology includes four aspects: sensor technology, perception and recognition technology, decision-making and planning technology, and control and execution technology.

3.5. Cloud Technology

Cloud technology refers to cloud computing-based technology, which includes a series of cloud services and solutions such as cloud storage, cloud database, and cloud computing platform. To put it simply, cloud technology is the use of the Internet to provide computing resources and services, allowing users to access, use, and manage these resources and services anytime, anywhere. With cloud technology, users can reduce IT costs, increase productivity, and scalability.

3.6. Artificial Intelligence

As the core of digital technology, artificial intelligence enables machines to learn and make judgments autonomously by simulating human thinking and decision-making capabilities. Technologies such as machine learning and deep learning are constantly evolving, enabling computers to derive information from data, enable image and speech

recognition, and even make decisions in complex scenarios. Artificial intelligence is playing a role in medical diagnosis, financial analysis, autonomous driving, and other fields.

4. Measurement of Enterprise Digital Transformation

This paper summarizes the relevant literature on the research on the degree of digital transformation of enterprises, and the measurement methods of the degree of transformation mainly include questionnaire survey and annual report text analysis.

4.1. Questionnaire Survey Analysis

This type of literature is mainly used to understand the digital capabilities of enterprises by sending questionnaires to middle and senior managers of enterprises. For example, Chi Maomao et al. (2020) collected data from small and medium-sized medical device manufacturing enterprises in Hubei Province through online and paper questionnaires, focusing on three indicators of digital technology operation, integration, and transformation in the digital transformation of enterprises [19]. Xie Kang et al. (2020) used mature scale questions for EMBAs, MBAs, and business chambers of commerce in colleges and universities, covering data resources in four aspects: human, financial, physical, and data, to understand their digital transformation [20]. Yi Jiabin et al. (2022) investigated the cognition of senior managers of enterprises on digital capabilities through a "snowballing" approach, including on-site distribution, WeChat link, and questionnaire star filling, mainly focusing on three dimensions: digital operation, perception, and resource collaboration [21]. Meng et al. (2021) evaluated the performance of enterprises in the process of digital transformation in three aspects: operation, integration, and transformation by sending a questionnaire to managers and technical employees of digital transformation enterprises [22].

4.2. Analysis of the Text of The Annual Report

These studies evaluate the degree of digital transformation of companies by analyzing the number of keywords related to "enterprise digital transformation" in the annual reports of listed companies. For example, Yang Deming and Liu Yongwen (2018) use the number of keywords related to "Internet+" in the annual report to measure the degree of "Internet+" of enterprises [23]. He Fan and Liu Hongxia et al. (2019) sorted out the temporary and periodic announcements of enterprises in their research, and introduced binary dummy variables to reflect whether enterprises are undergoing digital transformation, with a value of 1 indicating that the enterprise underwent digital transformation in that year, otherwise the value of 0. Zhao et al. (2021) constructed a detailed evaluation index system for the degree of enterprise digital transformation through expert scoring and text analysis [24]. From the perspectives of Internet business model, intelligent manufacturing and digital technology application, the annual reports of listed companies were analyzed in text to create the enterprise digital transformation index. Yuan et al. (2021) first established a thesaurus of enterprise digital transformation terms, and then calculated the ratio of the frequency of relevant words in the annual reports of listed companies to the length of some paragraphs of "Management Discussion and Analysis" (MD&A) to measure the degree of digitalization of enterprises [25]. Wu Fei et al. (2021) summarized and sorted out the keyword database of digital transformation, divided it into two categories: "underlying technology application" and "technology practice application", and then took the logarithm of keyword frequency to comprehensively evaluate the digital transformation level of enterprises. Chen et al. (2021) compiled a glossary of 20 keywords including informatization, networking, and digitalization, and obtained the frequency of keywords to reflect the level of digital transformation of enterprises by conducting text analysis according to these words in the annual reports of listed companies [26]. Xiao et al. (2022) used text analysis methods to construct a digital dictionary containing the semantic expressions of national policies related to the digital economy, and then quantified the degree of digital transformation of enterprises by calculating the total word frequency of digital keywords in the annual report divided by the length of the MD&A part of the segment [27].

Compared with the analysis of the survey questionnaire, the text analysis of the annual report has significant advantages in measuring the degree of digital transformation of enterprises. First, the depth and breadth of digital transformation is not fully reflected in the use of computers in enterprises, because simple web applications do not represent true digital transformation. The text analysis of the annual report can objectively reflect the actual progress and investment of enterprises in digital transformation by analyzing the frequency of keywords. Second, the data sample size of the questionnaire is usually limited and may not be fully representative of the business group, so it is relatively weakly representative. In contrast, the annual report, as the official public information of the enterprise, has a higher authority and representativeness. The frequency of digital transformation keywords in the annual report text reflects the importance and implementation of the strategy, so it can depict the digital transformation process and strategic orientation of the enterprise in a relatively comprehensive manner. Wu Fei et al. (2021) pointed out that the digital transformation of enterprises is not only simple digitization, but with data as the core resource, combined with digital technology and hardware systems, to promote the digital upgrading of enterprise production materials and production processes, so as to achieve a comprehensive transformation of management mode and business model. This deep transformation process is often reflected in annual reports, which are not only a disclosure of a company's financial status, but also a reflection of its strategic planning and future prospects. In summary, it is scientific and reasonable to use the text analysis of annual reports to measure the degree of digital transformation of enterprises, which can provide researchers and decision-makers with an important basis for in-depth understanding of the strategic direction and development path of enterprises.

However, although the text data of the annual report can reflect the extent to which the listed company has applied digital technology, these texts are often highly subjective. In the context of the country's active digital transformation strategy, there is a risk that corporate management may exaggerate information disclosure due to the motivation of resource acquisition and market value management. In order to accurately measure the true degree of digital transformation of enterprises, avoid missing key data and reduce information exaggeration, some scholars have improved the measurement methods of digital transformation on the basis of text data analysis of annual reports. Hong Junjie et al. (2022) and

Zhong Xiaolong et al. (2022) used principal component analysis (PCA) to synthesize the digital transformation index based on the digital transformation word frequency in the annual reports of listed companies and related hardware and software investment data [28, 29]. On the other hand, Yu et al. (2022) used the Peking University Commercial Bank Digital Transformation Index, which includes three secondary indicators: cognitive digital transformation, organizational digital transformation, and product digital transformation [30]. Among them, cognitive digital transformation is analyzed according to the digital finance keywords in the annual reports of commercial banks, organizational digital transformation considers factors such as digital financial patents and product layout, and the degree of product digital transformation takes into account the participation of digital financial departments and information technology directors. These studies verify the validity of the digital transformation indicators constructed by using the text analysis of annual reports through robustness tests. Even in the absence of digital transformation-related investment and digital patent data, these indicators maintain the consistency of research conclusions. As a result, text analytics methods show scientific and sound advantages when it comes to measuring digital transformation.

5. Conclusion

At present, digital transformation is attracting attention in academia and business environments, and related research and discussion are increasing. This paper systematically summarizes the concept, main digital technologies, and measurement methods of enterprise digital transformation. The main findings are as follows: First, digital transformation and its related terms such as digitization and digitalization are clearly distinguished, and the core elements of enterprise digital transformation are summarized. This paper defines the process of enterprise digital transformation as a process for enterprises to reshape products and services, business processes, organizational structures, business models, and cooperation models through the integration of information, computing, communication, and connectivity technologies, with the aim of designing enterprise business activities more effectively and thereby improving the ability of enterprises to create and capture value. Secondly, this paper uses the text analysis method to extract the keyword frequency of enterprise digital transformation, and systematically summarizes and sorts out the characteristics and advantages of the main digital technologies that form the basis of digital transformation. Finally, this paper reviews the measurement methods of enterprise digital transformation, and believes that the text analysis of annual reports is one of the more reasonable measurement methods at present. By defining the concept of enterprise digital transformation, a clear cognitive framework can be formed; Summarizing the major digital technologies helps businesses and organizations choose the right tools and platforms; Inductive and summarization measurement methods can help to evaluate the actual effectiveness of digital transformation. In conclusion, this study not only helps academics and practitioners to understand and apply digital transformation more deeply, but also helps to promote the success of enterprises and organizations in the process of digital transformation.

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