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A Review of Research on Enterprise Digital Capability Assessment

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Abstract. Digitalization is a revolution taking place. How enterprises can improve their digital capabilities has been a hot topic recently. By reviewing the researches on enterprise capability theory and digitalization, this paper defines the concept of enterprise digitalization capability, summarizes the features of enterprise digitalization capability maturity model, and offers proposals for further researches on enterprise digital capability assessment.

Keywords. enterprise capability, digitalization, maturity model

1. Introduction

A digital transformation is happening in most industries. Digitalization endows the real world with digital characteristics, and deeply integrates the information world with it. This integration brings unprecedented opportunities and challenges to enterprises. If an enterprise wants to take advantage of the digital transformation, it must realize the connotation of the enterprise's digital capability properly, as well as a clear point of view of the status and potential of its own digital capability, in order to guide the decision-making and implementation of digital transformation in the future.

Firstly, this paper reviews the classic literatures on enterprise capability theory, clarifies the connotation of enterprise capability, and finds theoretical support for defining the concept of enterprise digital capability. Secondly searches domestic core journals, foreign journals, and research reports with keywords “enterprise digital transformation”, “enterprise digitalization” etc. Papers related to enterprise “digitalization” and “digital transformation” were screened. On the basis of summarizing the conclusions of existing literature research, this paper discusses the connotation and influencing factors of enterprise digitalization capabilities. Additionally, this paper collects the maturity models of enterprise digital capability assessment which have been most influential in recent years. The features and core elements of these models are compared and analyzed. The common future research focus and development direction of the maturity model of enterprise digital capability assessment are discussed as well. Lastly suggestions to further improve the enterprise digital capability evaluation model are proposed.

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2. Review of research on enterprise capability theory

The enterprise capability theory uses the concept of capability as its core to analyze and solve enterprise problems. The enterprise capability theory defines the enterprise as a collection of knowledge and ability, and then discusses the infrastructure of an enterprise's sustainable competitive advantage. [1] The research on enterprise capability can be traced back to Penrose 's *the Theory of the Growth of the Firm*[2]. Penrose reveals the internal driving force of enterprise growth by constructing an analysis framework of enterprise resources-capabilities-growth.

Since the 1980s, the enterprise capability theory has been continuously enriched by theories such as the resource-based view of the firm, the core competence theory, and the dynamic capability theory, and it has played a strong practical explanatory power in business management, especially in the field of strategic management.

WERNERFELT's resource-based view of the firm [3] defines the resource as anything which could be thought of as a strength or weakness of a given firm, or as assets which are tied semi-permanently to the firm. Resources that bring competitive advantage can be identified. By proposing and analyzing the market of strategic elements, BARNEY [4] believes that enterprises can obtain strategic resources from the market. BARNEY [5] also expounds on the conditions for enterprise resources to become the source of sustainable competitive advantage for enterprises: valuable, rare, difficult to imitate, and non-substitutable.

PRAHALAD and HAMEL's core competence theory [6] reveals that the real sources of advantage are to be found in management's ability to consolidate corporatewide technologies and production skills into competencies that empower individual businesses to adapt quickly to changing opportunities. The ability to determine the competitive advantage of an enterprise is the organic combination of the organization's accumulated knowledge and various skills and technologies.

LEONARD-BARTON [7] defines core capability with a knowledge-based view of the firm. She considers the core capability as the enterprise knowledge set that differentiates and provides competitive advantages. She checked the product development of an enterprise and found that traditional core capabilities have a downside that inhibits innovation, called core rigidities. Core capability and core rigidity act on the enterprise at the same time.

TEECE, PISANO, and SHUEN [8] summarized the Terminology of capability theory. They put forward the dynamic capability theory. Dynamic capabilities are the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions.

Dong Baobao, Ge Baoshan, and Wang Kan [9] integrated the resource-based view of the firm and the dynamic capability theory into a research framework and constructed a new theoretical model. Their research argued that competition forces firms to continually restructure their resource bases according to the external environment. The resources can from within or outside the enterprise. Enterprises need to integrate resources through specific processes.

With the development of enterprise capability theory, the connotation of enterprise capability has gradually become clear. Scholars define capability as organizational routines and processes, so that enterprise capability is no longer an illusory concept, but is implemented in organizational routines and processes. Enterprise capability is the

"possibility" of transforming an input resource into an output resource. The greater the capability, the greater the probability of achieving the process goal. An enterprise is a coupling of different processes and, capabilities. The transformation of resources is constantly taking place within an enterprise. Both core capability and dynamic capability are important sources of corporate competitive advantage and are the driving factors behind different business processes. Thus, the theoretical foundation has been laid for linking the assessment of enterprise capabilities with organizational routines and processes in the future.

3. The concept of digital capability and the influence factors

Digitalization is a transformative force that fundamentally changes the enterprise. This force originated with the emergence of digital technology in the 1950s.

Digital technology refers to the technology of transforming an analog signal into a binary digital signal and processing it. In the 1960s and 1970s, with breakthroughs in the field of microelectronics, digital technology provided convenient and related technologies for information processing for the first time in history. The information technology industry is developing vigorously. A large amount of digital information, including pictures, texts, sounds, images, etc., can be processed at high speed, low cost, with minimal energy consumption. [10] The processing mainly includes operation, storage, transmission, propagation, restoration, etc.

With the wider and deeper impact of information technology on society, the concept of informatization has been put forward. [11] Enterprise informatization is an extension of the concept of informatization in the enterprise field. Information technology has been continuously promoted and applied in the process of business management. [12,13] With the promotion and development of information technology applications, people use digitalization to express the further integration of digital technology and society. In other words, informatization can be regarded as the pre-stage of digitalization and the foundation of digitalization; digitalization is the new development and subsequent stage of informatization, and the upgrading and deepening of the application of digital technology. The most direct definition of digitalization is the application of digital technology in related work. [14] There is still a need to distinguish between the connotations of digitalization and informatization, although both are also applied digital technologies

PAULIN [15] divides technological change into four different stages, namely mechanization, automation, computerization & digitalization[2] , and informatization, and compares their differences. In the mechanization and automation stages, the control mechanism was determined by designed technical artifacts. In the computerization & digitalization stage, the control mechanism was determined by designed software. An important feature of informatization stage is to describe and process the characteristics and status of the system with the help of information tools. PAULIN did not discuss the digital trend emerging nowadays, but following the clues given by PAULIN, we can discuss the difference between informatization and digitalization, and clarify the connotation of digitalization.

[2] PAULIN used the word "digitalization", but its meaning is different from the concept of "digitalization" referred to in this article, its meaning is more like the word "digitization". The difference between "digitization" and " digitalization " has been discussed and clarified by PRAUSE.[16]

Informatization converts the characteristics and states of many objects in the real physical world into information objects that can be processed by the information system, thereby improving the efficiency of production in the real physical world, and the basic model of the real physical world will not change. Digitalization assigns digital features to numerous objects in the real physical world, deeply integrates the information world with the real physical world, build a digital space that closely interacts with the real physical world, and improve the efficiency of production organization by reproducing or even reconstructing the production and lifestyle of the real physical world.

Digitalization for enterprises is mainly reflected in the use of digital technology to restructure their business, so that all aspects of the enterprise process rely on the support of digital technology. For example, products delivered through digital channels, digital services, business models innovations based on digital technologies, etc.

In recent years, the digital transformation of enterprises is a topic often discussed. FITZGERALD [17] et al. define enterprise digital transformation as the application of new digital technologies (social media, mobile, analytics, or embedded devices) to achieve significant business improvements (such as enhancing customer experience, streamlining operations, or creating new business models). WARNER and WÄGER [18] propose that the digital transformation of enterprises is a dynamic capability. Digital transformation is the use of new digital technologies, such as mobile communications, artificial intelligence, cloud computing, block chain, and Internet of Things (IoT) technologies, to achieve Significant business improvements to enhance customer experience, streamline operations or create new business models. LIU, CHEN, and ZHOU [19] propose that enterprise digital transformation is "an organizational transformation that integrates digital technology and business processes in the digital economy." Li Xin et al. [20] summarized the views of different enterprises or institutions on digital transformation. Although different scholars and institutions have different descriptions of the definition of enterprise digital transformation, a consensus has been reached on key connotations such as model innovation, technology drive, and data empowerment that enterprise digital transformation needs to involve. It can be seen that the connotations of enterprise digital transformation and enterprise digitalization are the same.

In recent years, the research on enterprise digital capabilities has focused on the content, elements, and evolution mechanism of enterprise digital capabilities; the relationship between enterprise digital capabilities and competitive advantages.

WARNER and WÄGER [18] proposed that digital transforming capabilities consists of micro foundations relating to (1) navigating innovation ecosystems, (2) redesigning internal structures, and (3) improving digital maturity. Then, a framework for building digital transformation capabilities is proposed.

NAMBIAN [21] describes three distinct but related elements of digital technology embodied in the field of entrepreneurship, namely Digital Artifact, Digital Platforms/Ecosystems, and Digital Infrastructures. Digital Artifact is defined as a digital component, application, or media content that is part of a new product (or service) and provides a specific function or value to the end user. Digital Platform refers to a set of shared, common services and architectures for hosting complementary products, including digital products. Digital Infrastructure refers to digital technology tools and systems that provide communication, collaboration, and computing capabilities to support innovation and entrepreneurship (e.g. cloud computing, data analysis, online communities, social media, 3D printing, digital manufacturing space, etc.). Although

NAMBISAN discusses the division of digital technology elements in the field of entrepreneurship, it is worth learning from companies in other life cycle stages.

Qian Jingjing and He Yun [22] studied the digital capabilities of enterprises based on the perspective of dynamic capability. According to the dynamic capability theory, they divide the digital capabilities of enterprise into three dimensions: perception capability, acquisition capability, and transformation capability. Through case studies, the construction mechanism of enterprise digital capabilities is described. Zhang Yuan, Sun Xinbo, and Qian Yu [23] studied the evolution process of enterprise digital transformation based on resource orchestration theory. They believe that the differences in the generation of capabilities and the realization of value creation in different stages of enterprise digital transformation stem from the differences in the resource orchestration process. Su Jingqin, Sun Yue, and Gao Xin [24] studied the evolution mechanism of digital capabilities under the background of continuous digital transformation based on the perspective of resource orchestration. Through case studies, Chen Xiaoying and Qiu Guodong [25] proposed that capability reconstruction is an intermediate mechanism for enterprises to achieve leading logic upgrade in digital transformation, that is from product-led logic to service-led logic transformation, which is specifically manifested as adaptability reconstruction, learning capability reconstruction and innovation capability reconstruction. Meng Tao, Zhao Feifei, and Zhang Bingchao [26] construct a theoretical model of the impact of enterprise digital transformation on business model adaptation， and discuss the mediating effect of dynamic capability between the two. Yao Xiaotao, Qi Hui, and Liu Linlin [27] elaborated on the connotation, motivation, and key factors of enterprise digital transformation, and constructed a dynamic process model of enterprise digital transformation according to the logic of "cognition-strategic positioning-strategy implementation".

Based on the above viewpoints, enterprise digital capabilities refer to the ability to use digital technology to update business processes, customer experience, organizational culture, and create new business models to continuously meet business and market needs. The enterprise's digital capability is its dynamic ability to reconstruct various enterprise processes inside and outside the enterprise. Effectively identifying the key factors and mechanisms of digital capabilities, building digital capabilities, and promoting digital transformation will help companies break core rigidities and gain sustainable competitive advantages.

4. Enterprise digital capability assessment model

As pointed out by Zhao Xiaoqing and Xu Qingrui [28], due to the implicit, systematic, and path-dependent nature of technical knowledge, and the interconnection and adaptation between the use of technology and enterprise organization, culture, and strategy, the evaluation of technical capability is a multi-dimensional, multi-factor, comprehensive evaluation. The connotation of an enterprise's digital capability is richer than its technical capability, and the evaluation of an enterprise's digital capability should also be a comprehensive evaluation of multiple factors. The key link in a multi-factor, comprehensive evaluation is factor analysis and indicator construction. From the point of view of enterprise capability theory, the evaluation of enterprise digital capability should be oriented to the evaluation of enterprise processes. Among the many comprehensive evaluation methods, the maturity model is oriented toward the enterprise

process. In recent years, almost all studies on the evaluation of enterprises' digital capability have adopted this model.

In the late 1980s, the Software Engineering Institute (SEI) of Carnegie Mellon University developed a software process-oriented Capability Maturity Model (CMM). Created for the U.S. Department of Defense to assess the quality and capability of its software contractors, the model is considered the world's first maturity model.

After the development of CMM, SEI developed other types of capability maturity models based on it, among which the more important ones include the human resource maturity model, integrated product development capability maturity model, systems engineering capability maturity model, and software acquisition capability maturity model. To meet the needs of enterprises that use multiple models to improve their multi-faceted process capabilities, SEI integrates multiple maturity models based on CMM and develops Capability Maturity Model Integration (CMMI), which is considered the first integrated maturity model. In 2018, SEI's CMMI iteratively launched version 2.0.

CMM and CMMI guide software enterprises to choose improvement strategies by judging their current process maturity and selecting improvement strategies for the most critical issues in software quality and process improvement. Focusing on concrete and achievable goals, achieving them through the measures and means provided in the model, it enables enterprises to continuously, gradually, and smoothly transition to the advanced stage. [29]

The Capability Maturity Model was quickly adopted outside of the software industry. In 2008, IBM Corporation, the American Productivity and Quality Center (APQC) and the Global Smart Grid Alliance jointly researched and proposed a smart grid maturity model (Smart Grid Maturity Model, SGMM). [30] This is the first maturity model of a digital technology system.

In the 1990s, shortly after CMM was proposed, scholars in the field of software engineering in China introduced this methodology to China. [31-33] Its application field soon expanded to many related fields of business management. [34-48]

In recent years, with the introduction of the concept of enterprise digitalization, many institutions and scholars have carried out research and developed the enterprise digitalization capability maturity model.

The international organization TM Forum (Telecommunications Management Forum) [49] developed an industry-standard digital maturity assessment method in 2018 to benchmark the company's own progress against peers. The evaluation model and method developed by TM Forum is a digital evaluation method focused on the characteristics of the communication industry.

The National Standards Committee released three relevant recommended national standards in 2018 and 2020 respectively. Those are “GB/T 36073-2018 Data management capability maturity assessment model” [50] “GB/T 39116-2020 Maturity model of intelligent manufacturing capability” [51] and “GB/T 39117-2020 Maturity assessment method of intelligent manufacturing capability” [52]. All three standards were drafted by the China Electronics Standardization Institute. At present, the China Electronics Standardization Institute is drafting the recommended standard “ Information technology service - Digital transformation - Maturity model and evaluation”. This series of standards provides standardized guidance for relevant enterprises to promote the evaluation of digital capability at different levels such as the data capability layer, the common capability layer, and the business feature capability layer of the enterprise.

Capgemini Consulting and MIT’s Digital Business Center have jointly built a Digital Maturity Index model to measure the maturity of an enterprise's digital

capabilities. [53] The model divides enterprises into 5 levels according to their digital maturity and then discusses the challenges or experiences faced by different maturity levels in the process of digital transformation based on the maturity model and survey data. They also pointed out 9 obstacles that may exist in the process of enterprise digital transformation in terms of leadership, system, execution, etc.

Accenture [54] constructed an exponential model to evaluate the digital transformation of enterprises. Accenture's model is divided into three dimensions: intelligent operation, main business growth, and business innovation. Intelligent operations encompass intelligent production and manufacturing, as well as intelligent support and control; main business growth encompasses digital channels and marketing; product and service innovation; and business innovation encompasses digital business models, digital venture capital, and incubation.

Deloitte [55] divides the evolution path of digital technology into three stages: connection, analysis, and intelligence. Digital technology continues to evolve along the evolution path in six application directions, including optimizing decision-making, improving efficiency, improving products, controlling risks, managing customers, and optimizing experience. Deloitte believes that enterprise digital technology has evolved to the intelligent stage, and has further proposed a capability framework for enterprise intelligent transformation, which includes six key capabilities: intelligent strategy, intelligent talent system, intelligent operation, intelligent demand, intelligent technology and intelligent data, which are subdivided into 20 secondary capabilities under the key capabilities. Deloitte proposes an Intelligence Maturity Scale. The scale divides intelligence maturity into five levels: cognition, exploration, application, systematization, and comprehensive transformation.

PricewaterhouseCoopers [56] constructed a maturity model for evaluating Industry 4.0 capabilities, and divided capabilities into four levels: digital starter, vertical integrator, horizontal collaborator, and digital winner. Assessment dimensions include: digital business model and customer contact, digitalization of products and services, horizontal and vertical digitalization and integration of the value chain, data and analysis as core competencies, agile IT architecture, compliance-security-legal-tax, organization-employee-digital culture.

The goal of a maturity model is to assess process capability and ultimately achieve process capability improvement. From the existing enterprise digital capability maturity model, it can be seen that the difference between different maturity models mainly lies in the identification and division of enterprise processes. The business process has the characteristics of a hierarchy. Some models emphasize the assessment of enterprise data management capabilities. Some models emphasize business characteristics, bringing them closer to the operational practices of businesses in various industries. More models cover all common processes of enterprises, assess their digital capabilities at various levels such as strategy, organization, operation, technology, and data, and the criteria for dividing capability domains are different, depending on the developer's understanding and interpretation of digitalization’s connotation and mechanism.

5. Conclusion

It is an important point of view and contribution of the enterprise capability theory to regard the enterprise as a collection of capabilities and think that the capabilities are mainly embodied in the routines and processes of the enterprise. The enterprise itself can

be regarded as an overall process of inputting production factors and outputting products or services to meet customer demand. This overall process of an enterprise is the result of the coupling of various enterprise processes. According to the value chain analysis, enterprises include two types of value activities: basic value activities such as input logistics, production operations, output logistics, marketing and sales, etc.; and auxiliary value activities such as enterprise infrastructure, human resource management, technology development, procurement, etc. All these activities can be considered business processes. The ability of an enterprise to realize its strategic goals and exert its competitive advantages is contained in the structured enterprise process.

Productivity determines production relations. When there is a breakthrough in productivity, the dynamics of production will inevitably change. The same principle applies to enterprises as microeconomic organizations. Digitalization introduces data as a factor of production in enterprises, which brings great changes to productivity and inevitably leads to changes in the internal and external production relations of enterprises. The enterprise digital capability is the ability to reconstruct enterprise processes at all levels in the context of the digital economy.

Firstly, reconstruction of the enterprise-market interface. For example: reconstructing processes to understand business environment based on data analysis, building business intelligence services, and reconstructing decision-making capabilities and mechanisms; reconstructing capabilities and mechanisms to continuously optimize the customer experience based on digital technology; enabling enterprises to co-evolve and deeply embed with their ecological space and related groups by adopting new technologies, equipment, and services supported by ubiquitous computing environments.

Secondly, reconstruction of the internal process interface of the enterprise. The reconstruction of the internal processes of the enterprise involves process optimization across departments and levels. Realizing the seamless connection between data flow and business flow across departments; building a decision-making system and control system based on data analysis; using digital technology to realize agile development and cooperative research and development; using digital technology to realize intelligent manufacturing and a flexible supply chain; building a digital workspace to enhance the enterprise's internal process capability. A digital workspace is an integrated technology framework that enables real-time access to applications and data from any location on any device.

Thirdly, construction of digital infrastructure. Building a technology innovation organization and innovation mechanism, continuing to follow up to technology development trends, and fully grasping the digital technologies and their combinations that have an innovative impact on business models and processes. Digital business innovation technologies mainly include cloud computing, big data, mobile computing, social computing, the Internet of Things, intelligence, edge and personal domain computing, block chain, and network security technologies, etc. According to the digital goals and business needs, several technologies can be selected to form a combination to support the effectiveness of digitalization at the technical level.

Fourthly, planning and agile iteration of digitalization are the most important things. Building a digital governance system and mechanism, clarify rights and responsibilities, and ensure scientific and effective decision-making; building a management system and mechanism for overall planning and promotion of digital business, and improving organizational adaptability for digital promotion; building a network and data security compliance for digital business review and improving the mechanism; establishing a working mechanism to ensure continuous agile iteration of digital capabilities to adapt

to the rapid changes in the digital business environment in order to achieve continuous innovation of business and services; ensuring that organizational culture supports digital transformation.

Presently, many achievements and experiences have been accumulated in the research and practice of enterprise digital capability assessment, but at least, the research in the following two directions needs to be further expanded and deepened. The first direction is the empirical study of the impact of digital capability at different levels on firm performance. Verifying the supporting role of digital capability on enterprise performance is useful for understanding the relationship between digital capabilities at various levels, enterprise performance, and competitive advantage, as well as the mechanism of interaction between them, and it serves as a foundation for assessment index screening. The second direction is the research and development of maturity models oriented to industry characteristics. There are large differences in business characteristics in different industries. Although there has been some research and accumulation in the evaluation of digital common capabilities and digital technology infrastructure capabilities, there are still few evaluation models for specific industries. For example, the relevant research work on the digital capability assessment of logistics and circulation enterprises has not yet been carried out.

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