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The Impact of Digital Technology on Business Operational Performance: A study on Chinese SMEs

RAO Yong

Doctor of Management

Supervisors:
PhD Isabel Alexandre, Assistant Professor,
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Declaration

I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: Rao Yong　　　　Date: 2022.9.30

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Abstract

The existing research shows that digital technologies are effective in improving organizational performance. However, the current research is yet to answer exactly which dimensions of the firm's capabilities are shaped by the use of digital technologies and how these capabilities affect the firm's operational performance. Therefore, this thesis tries to address the following questions based on the above discussions: (1) How do digital technologies affect operational performance? (2) How do digital technologies shape different dimensions of firms' capabilities? (3) How do firms' capabilities affect firms' operational performance? (4) What factors moderate the relationship between digital technology and operational performance?

In order to address the above questions, this study used a combination of qualitative and quantitative research methods. Specifically, over 260,000 words of interview data from 46 senior corporate executives were collected. Then, following the steps of the procedural grounded theory analysis, this thesis proposes a model framework. Furthermore, based on the model framework, this thesis empirically validated how digital technologies affect the firms' operational performance by using questionnaires and structural equation modeling. The results show that the application of digital technology is positively related to the ability of digital empowerment of enterprises. Employee engagement positively moderates the relationship between digital technology and digital technology-enabled capabilities. Digital technology-enabled dynamic capability in turn is positively related with organizational innovation performance. Industry competition enhances the role of digital technology-enabled dynamic capability in promoting innovation performance. Enterprise innovation performance is positively associated with enterprise operation performance.

Keywords: digital technology, dynamic capacities, innovation performance, operational performance, Grounded Theory approach, PLS-SEM

JEL: O32; Q55; M11

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Resumo

A investigação existente mostra que as tecnologias digitais são eficazes na melhoria do desempenho organizacional. No entanto, é ainda necessário identificar exatamente quais as dimensões das capacidades da empresa que são moldadas pelo uso de tecnologias digitais e como essas capacidades afetam o desempenho operacional da empresa. Portanto, esta tese tenta abordar as seguintes questões: (1) Como é que as tecnologias digitais afetam o desempenho operacional? (2) Como é que as tecnologias digitais moldam diferentes dimensões das capacidades das empresas? (3) Como é que as capacidades das empresas afetam o desempenho operacional das empresas? (4) Quais os fatores que atuam como moderadores da relação entre a tecnologia digital e o desempenho operacional?

Com o objetivo de responder às questões acima, este estudo usou uma combinação de métodos de pesquisa qualitativos e quantitativos. Especificamente, foram recolhidas mais de 260.000 palavras a partir dos dados das entrevistas a 46 altos executivos empresariais. De seguida, tendo em conta a análise a *procedural grounded theory*, esta tese propõe um modelo de enquadramento. Além disso, com base na estrutura do modelo, esta tese validou empiricamente como as tecnologias digitais afetam o desempenho operacional das empresas usando questionários e modelação de equações estruturais. Os resultados mostram que a aplicação da tecnologia digital está positivamente relacionada com a proficiência na digitalização das empresas. O envolvimento dos funcionários impacta positivamente a relação entre a tecnologia digital e os recursos ativados por essa tecnologia digital. O dinamismo potenciado pela tecnologia digital, está por sua vez, positivamente relacionado com o desempenho da inovação organizacional. A competição da indústria aumenta o papel da capacidade dinâmica habilitada pela tecnologia digital na promoção do desempenho da inovação. O desempenho da inovação empresarial está positivamente associado ao desempenho operacional da empresa.

Palavras-chave: tecnologia digital, capacidades dinâmicas, desempenho inovador, desempenho operacional, abordagem Grounded Theory, PLS-SEM

JEL: O32; Q55; M11

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摘 要

现有研究已经表明，数字技术可以有效地提高组织绩效。但目前的研究尚未回答数字技术使用如何形成企业能力，以及这些能力如何影响企业运营绩效。因此，本研究试图在上述讨论的基础上来解决以下问题：（1）数字技术如何影响运营绩效？（2）数字技术如何塑造不同维度的企业能力？（3）企业的能力如何影响企业运营绩效？（4）哪些因素会调节数字技术与运营绩效之间的关系？

为了解决上述问题，本研究采用了定性和定量相结合的研究方法。具体而言，我们收集了超过 26 万字的关于 46 位企业高层管理者的访谈数据。然后，按照程序化的扎根理论分析方法的过程和步骤，本文提出了模型框架。基于该模型框架，本文通过使用问卷调查和结构方程模型方法，实证验证了数字技术如何影响企业运营绩效的机制。结果显示，数字技术的应用与企业的数字技术赋能能力呈正相关。员工参与正向调节数字技术和数字技术赋能的能力之间的关系。数字技术赋能的动态能力反过来又与组织创新绩效正相关。行业竞争增强了数字技术赋能的动态能力对创新绩效的促进作用。企业创新绩效与企业运营绩效呈正相关。

关键词：数字化技术，动态能力，创新绩效，运营绩效，扎根理论方法，PLS-SEM

JEL: O32; Q55; M11

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In a flash, five years of doctoral studies are coming to an end. Looking back on these five years of study and work, doing research on doctoral dissertation topics, there is both pain and pleasure, and of course more joy and pleasure after doing a good dissertation.

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致　谢

时光荏苒，转瞬五年博士研究生学习生涯即将结束，回顾这五年的学习工作，做博士论文课题研究，既有痛苦，又有快乐，当然更多是做好论文后的快乐和愉悦。

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List of Abbreviations

3DDT3D Design Digital Technology

AGVAutomated Guided Vehicles

AIArtificial Intelligence

AIPCAnalytical Information Processing Capability

ANOVAAnalysis of Variance

APIApplication Programming Interface

ARAugmented Reality

BCTBlockchain Technology

BDABig Data Analytics

BDA-AIBig Data Analytics and Artificial Intelligence

BDACBig Data Analytics Capability

BERBit Error Rate

BLEBluetooth Low Energy

BOTBuild–Operate–Transfer

BPMBusiness Process Management

BSNsBody Sensor Networks

BTBlockchain Technology

CCCloud Computing

CDOChief Digital Officer

CECultural Enablers

CEOChief Executive Officer

CFAConfirmatory Factor Analysis

CFO Chief Executive Officer

CICSChina Industry Classification Standard

CIOChief Information Officer

CPSCyber-Physical System

CSRCorporate Social Responsibility

CSSCyber Security Systems

CTCloud Technology

DBSDevelopment Bank of Singapore

DESDiscrete Event Systems

DOSOperational Services
DTsDigital Technology
DVDependent Variables
E-HRMElectronic Human Resource Management
EDEmployee Development
EDIElectronic Data Interchange
EIEmployees' Involvement
ERPEnterprise Resource Planning
EVMError Vector Magnitude
FsQCAFuzzy set Qualitative Comparative Analysis
GSCMGreen Supply Chain Management
GSMGlobal System for Mobile Communications
HCHealthcare
HISHealth Information Systems
ICTInformation and Communication Technology
IGPDInnovative Green Product Development
IIoTIndustrial Internet of Things
ILPInnovation and Learning Performance
IMSInformation Management System
IOTInternet of Things
IRIdiosyncratic Risk
ISInformation Systems
ITInformation Technology
IVIndependent Variables
LALean Automation
LMEsLarge and Medium-Sized Enterprises
LPLean Production
MFIsMicrofinance Institutions
MOOCsMassive Open Online Courses
NFCNear Field Communication
NLPNatural Language Processing
OLOrganizational Learning
OSOrganizational Size
PCIProduct-Focused Customer Involvement

PSSProduct-Service Systems

QAMQuadrature Amplitude Modulation

QLQuadrifilar Loop

QoSQuality-of-Service

R&DResearch and Development

RFIDRadio Frequency IDentification

RIPCRelational Information Processing Capability

ROIReturn on Investment

ROSReturn on Sales

SBPSustainability Business Practices / Performance

SCSupply Chain

SCCESupply Chain Cultural Enablers

SFPVSichuan Fishery-PV Wulian Technology Co., Ltd.

SKSSupportive Knowledge and Skills

SLAService-Level Agreement

SLRSystematic Literature Review

SMEsSmall and Medium-Sized Enterprises

SMIDTSmart Manufacturing-related Information and Digital Technologies

SOAService Oriented Architecture

SRTSmart Retail Technology

SSCOSustainable Supply Chain Outcomes

SVMSupport Vector Machine

TAMTechnology Acceptance Model

TOETechnological-Organizational-Environmental

TSCHTime Synchronized Channel Hopping

UMLUnified Modeling Language

UTAUTUnified Theory of Acceptance and Use of Technology

VRVirtual Reality

WBANsWireless Body Area Networks

WIPWork-in-Process

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Chapter 1: Introduction

1.1 Research background

In recent years, various digital technologies, such as big data, cloud computing, the Internet of Things (IOT) and data analytics (e.g., machine learning and data mining) and their applications have encouraged organizations in many industries to innovate their value creation processes and improve their operational performance (Chi et al., 2018). Sichuan Fishery-PV Wulian Technology Co., Ltd. (abbreviated as SFPV) also adopt digital technologies in their business areas, which consist of fisheries and aquaculture, photovoltaic power generation, and travel service. The company expects significant improvements in operational performance (including economic and environmental performance, etc.). For example, by deploying intelligent IOT system, remote distributed video monitoring system, Radio Frequency IDentification (RFID) technology, Geographic Information System (GIS) technology and establishing data center, the company has established a new model of e-commerce with eco-farm and quality tracing service to provide fresh data products to target customers or users. A detailed illustration of the operation process is shown in Figure 1.1. However, the impact of digital technology on operational performance has not received sufficient attention, for example, 1) does digital technology have an impact on operational performance, and 2) if so, what are the mechanisms by which digital technology contributes to operational performance?

Figure 1.1 Digital technologies in fishery industry of SFPV

Source: SFPV Co., Ltd. internal information

Similarly, there are many companies that are investing heavily in digital transformation and digital technology with the expectation of achieving higher operational performance. A report released by Accenture titled "Digital Transformation Index for Chinese Companies 2021" states that 27% of traditional retail companies, 25% of companies in logistics and 25% of companies in electronic components and materials will increase their digital investments in the next year or two. A detailed illustration of the company proportion in various industries with significantly increased digital investment in the future is shown in Figure 1.2 (the left panel). However, the report also states that these companies are less than 60% satisfied with digital transformation in 2021. A detailed illustration of the company satisfaction of digital transformation in multiple dimensions is illustrated in Figure 1.2 (the right panel). These companies are struggling to reap the expected benefits of digital technology adoption and still face the challenge of determining the best way to build sustainable operational capabilities. Companies in the midst of digital transformation face a practical question: Whether and how digital technologies can have an impact on operational performance.

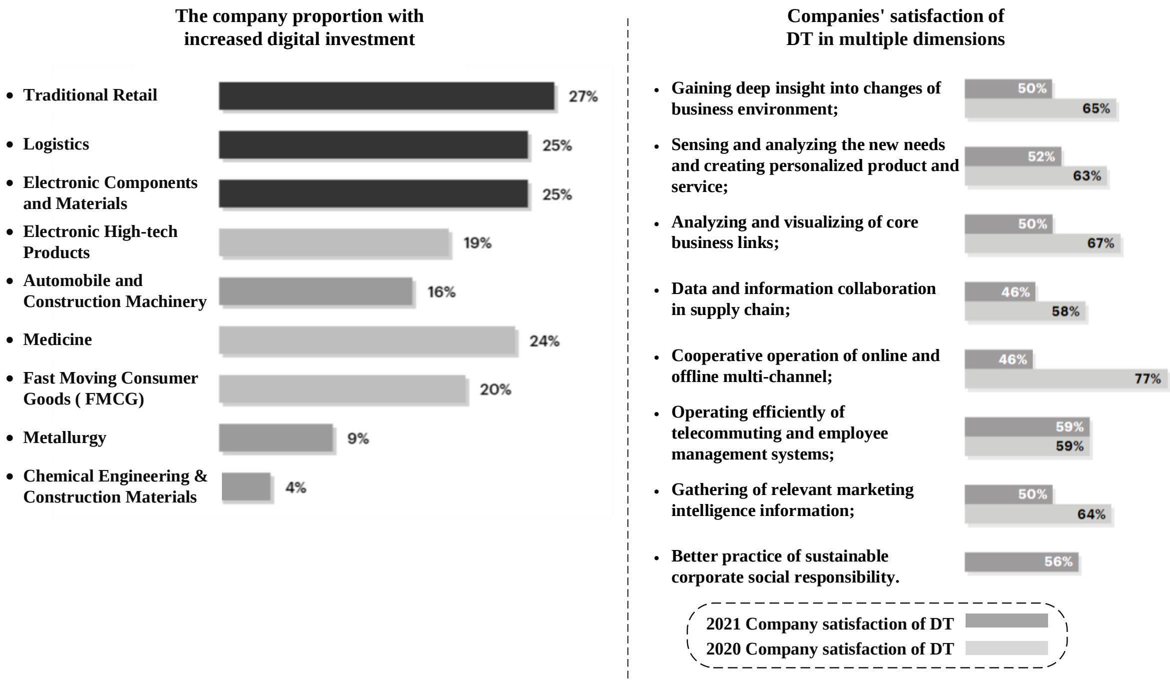

Figure 1.2 Digital transformation index for Chinese companies 2021

Source: Accenture (2021)

The problems in practice have attracted and encouraged researchers to explore the relationship between digital technologies and operational performance, particularly the long-term beneficial consequences of digital technologies. Previous business and management research has focused on the impact of specific Industry 4.0 technologies on supply chain management, lean automation, and circular economy (Frederico et al., 2021; G. Tortorella et al., 2021; W. Yu et al., 2021). For example, Frederico et al. (2021) explored the relationship between digital technologies and supply chain processes (SCPs) performance in the field of operations and supply chain management (SCM). In addition, the study explored the mediating role of integration, collaboration, efficiency, transparency, and responsiveness in the supply chain (SC) and the moderating role of interoperability in the supply chain (SC). G. L. Tortorella et al. (2021) examined the relationship between lean automation (LA) principles (i.e., sociocultural-oriented and technology-oriented) and firm operational performance, primarily in the food, textile, and chemical industries. In addition, the study explored the mediating role of lean automation practices (primarily oriented to the workplace level, referred to as the micro level, and the value stream, referred to as the middle level), the extended value stream or supply chain, referred to as the macro level) and the controlled hierarchy, and firm size. W. Yu et al. (2021) explores the relationship between digital technologies and business operations in the automotive industry. In addition, the study explores the mediating role of circular economy and supply chain capabilities.

Existing literature argues that digital technology, which is considered a key resource, is necessary for firms to reap its benefits and that the use of digital technology can improve operational performance (Chi et al., 2018; W. Yu et al., 2021). However, existing studies have not reached clear conclusions on the operational performance impact of digital technology (L. Guo & Xu, 2021; W. Yu et al., 2021). In addition, two limitations remain in past research. First, no study has focused on how digital technology affects operational performance from the perspective of building organizational capacity. The perspective of prior studies includes contingency, novelty perspective, and information processing perspective (Dubey et al., 2020; Frederico et al., 2021; Y. Li et al., 2020). However, existing research reports that organizational capacity building, which plays an important role in digital transformation, is critical in the creation of value from digital technologies. Those capabilities that are harder to replicate and are used to respond to rapidly changing situations have been found to support lasting competitive advantage for businesses (Matarazzo et al., 2021; Teece, 2007). Therefore, it is necessary and valuable to explore whether and how digital technologies build different organizational capabilities. This will help business managers better understand the mechanisms underlying the application of digital technologies to improve the operational performance of their companies, open the black box of how digital technologies help companies create competitive advantage, and help companies better evaluate the effectiveness of the application of digital technologies in a targeted manner.

Secondly, although existing scholars have studied the impact of Industry 4.0 technologies on performance, most of the studies are based on deductive approach and no study has used inductive research paradigm to propose a theoretical model of digital technology and operational performance. Deductive method, which relies on researchers' knowledge and experience, is typically associated with a top-down method to build research model that begins with the existing knowledge (Shepherd & Sutcliffe, 2011). Research models based on the deductive approach have been criticized for being limited by potential theoretical contributions and leading to uninformative conclusions when theoretical models are inaccurate (Shepherd & Sutcliffe, 2011). Moreover, new phenomena cannot be directly explained by existing theoretical knowledge. In contrast, the inductive and grounded theory approach is designed to enable new theoretical discoveries about new phenomena. It is applicable to the study of problems that have been explored in limited existing research and are required to build theory, and allows the researcher to construct theoretical explanations for general features of the subject matter based on empirical data and observations (Wiesche et al., 2017). Given the novelty of studying the relationship between digital technology and operational performance from a firm's capability building perspective and the inability to deduce reasonable research hypotheses from existing established theories, it is necessary to use an inductive approach to explore the mechanisms of the impact of digital technology on firm operational performance.

1.2 Research objectives and questions

To stay competitive in the digital age, digital technologies such as IoT, cloud computing, artificial intelligence and big data analytics play a key role in the operational management of organizations. Such technologies support the implementation of effective digital business strategies. The raging COVID-19 pandemic has further accelerated the deeper adoption of digital technologies. As we pointed out in the background section of the thesis, although digital technologies have been used by an increasing number of firms in their operations, and the role of digital technology in enabling the management of company operations has attracted much attention in academic research. In particular, the business value of digital technology has been widely recognized in the field of information systems (IS) and information technology (IT) research, even though not all companies are sure of the business values of digital technologies, given the high costs it requires. According to the results of a large body of existing research work related to the economic valuation of IT, the investment or use of digital technology has been shown to be effective in improving organizational performance, including operational and financial performance (Devaraj & Kohli, 2003; Melville et al., 2004; Rieger et al., 2018). In this sense, digital technology is not only effective in streamlining business operations, but also presents opportunities for value creation and business growth, thereby increasing profits.

However, the current research is unable to answer exactly which dimensions of the firm's capabilities are shaped by the use of digital technologies in business processes and how these capabilities affect the firm's operational performance. Because the cost of deploying digital technologies is no longer like the traditional investment in simple stand-alone digital technologies or information systems, the new generation of digital technologies such as artificial intelligence, big data analytics, and the Internet of Things may instead affect business process change and organizational transformation at the enterprise-wide level, and such change and transformation will bring much higher integration and management costs than those associated with the deployment of traditional information technology. Clearly, proper evaluation of the potential benefits of digital technologies to the enterprise and comparison with them and the costs of implementing these technologies are necessary to make the right decisions. Given that understanding the mechanisms inherent in the impact of digital technology on business performance will help business managers to better understand how digital technology works and the mechanisms at play, so that they can make informed decisions about investing in digital technology, it is necessary and important to conduct research in this area.

Based on the above considerations, the purpose of this study is to apply a combination of qualitative and quantitative research methods to explore the processes and the mechanisms inherent in the impact of digital technologies on firms' operational performance. In addition to direct impact effects, this thesis focuses more on indirect impact mechanisms, specifically, we will explore how digital technologies shape different dimensions of firms' capabilities and how these capabilities affect firms' operational performance. To our knowledge, this is the first study to examine the influence of digital technologies on firm performance from the perspective of firm capabilities. The specific aims of this thesis include:

i. To uncover the different paths through which digital technologies affect operational performance including direct and indirect effects.
ii. To explore how digital technologies shape different dimensions of firms' capabilities.
iii. To reveal how these capabilities affect firms' operational performance.
iv. To analyze the boundary conditions of digital technologies affecting operational performance (moderating effects).
v. To provide practical management strategies to enhance the deployment of improved digital technologies in enterprises and help them better leverage digital technologies to improve their operational performance.

This research tries to address the following questions based on the above discussions:

RQ1. How do digital technologies affect operational performance?

RQ2. How do digital technologies shape different dimensions of firms' capabilities?

RQ3. How do firms' capabilities affect firms' operational performance?

RQ4. What factors moderate the relationship between digital technology and operational performance?

1.3 Research significance

Ubiquitous digital technologies are bringing about profound social and industrial changes. Digital technology is regarded as a powerful weapon for companies to build and maintain a competitive advantage in the digital age. Although a number of studies have investigated the potential benefits of digital technology, the existing literature on digital technologies and firm performance is still in the exploratory stage and lacks systematic in-depth research, because most academic studies focusing on the impact of a specific digital technology on firms. Although the link between the technology and various organizational performance metrics (e.g., innovation performance, firm growth, financial performance, and market performance) has mostly been found in industry reports. In practice, firms often deploy multiple different digital technologies, and digital technologies now often do not work alone but in concert, for example, big data analytics is often closely related to cloud computing and the application of IoT and even artificial intelligence technologies. Therefore, studying the performance impact of a specific digital technology on firms in isolation does not provide a comprehensive and accurate picture of the impact of the overall strategy of digital technologies on firm performance.

In terms of the mechanisms by which digital technology affects the operational performance of firms, the existing studies report that digital technology improves business operations by reducing transaction costs, improving the efficiency of corporate assets, increasing employee productivity, and optimizing the supply chain (Athey, 2017; C. Li et al., 2018). However, Björkdahl (2020) discusses the digitalization efforts of 26 leading manufacturing firms, and he finds that many businesses are far from ready to benefit from digitization and are primarily focused on achieving greater efficiency through digitization rather than pursuing a growth. We extend this line of studies by exploring the impact mechanisms of digital technology on the operational performance from the perspective of firms' capacities. We speculate that digital technologies can shape different dimensions of firm capabilities, which can further contribute to the innovation performance including innovation efficacy and innovation efficiency. Innovation performance, in turn, ultimately enhances the operational performance of the firm. We also intend to clarify several boundary conditions under which digital technologies affect firm performance. By doing so, this thesis unveils factors with moderation tendencies on the relationship between digital technologies and operational performance, enriching the literature on the organizational performance effects of digital technologies. To test our research hypothesis, we applied a combination of inductive and deductive research paradigms, combined with a grounded theory analysis approach to generate our research model and empirically tested the proposed research model using a large sample using structural equation modeling techniques. To the best of our knowledge, this is the first study to employ the grounded theory approach in the study of the impact of digital technology on firm performance.

The findings of this research have important practical implications. To begin with, the research helps business managers understand the paths and ways in which digital technology affects the operational performance of the business, leading to a more targeted management of digital technology implementation strategies. Also, the findings can help managers recognize which capabilities digital technology can shape in the business, leading to a better understanding of the value of digital technology to the business and the need for implementation. Second, by revealing the boundary conditions of the relationship between digital technology and business performance, it helps business managers to develop the necessary strategies and measures to facilitate the positive impact of digital technology on operational performance, thus ensuring that the huge investment in digital technology can yield a good ROI. Understanding the existence of such boundary conditions is even more essential for digitally transforming businesses, as it determines the success of digital transformation and the survival of the business.

1.4 Research method

Grounded theory analysis will be used as the main method in this thesis. Grounded theory, a qualitative research method, was originally proposed by Anselm Strauss and Barney Glaser in 1967 to extract new concepts and ideas from empirical facts, and combines the depth and richness of qualitative interpretive traditions with the logic, rigor and systematic analysis inherent in quantitative survey research (Dunne, 2011; Walker & Myrick, 2006). According to grounded theory, researchers conduct empirical generalizations directly from survey, rather than proposing theoretical hypothesis in advance and extracts concepts reflecting social phenomena in the process of continuous comparison, and develops categories and between categories, eventually sublimated into theory.

The operating procedures of grounded theory generally include: (1) generating concepts from data and coding data step by step; (2) continuously comparing data and concepts, and systematically considering generative theoretical questions related to concepts; (3) developing theoretical concepts and making connections between concepts; (4) coding data, formulating concepts and forming categories based on data; (5) constructing a systematic theoretical framework, and judging whether the theory has reached saturation. The most important part of grounded theory is the coding of data in stages, which includes three levels of coding, as shown in Figure 1.3.

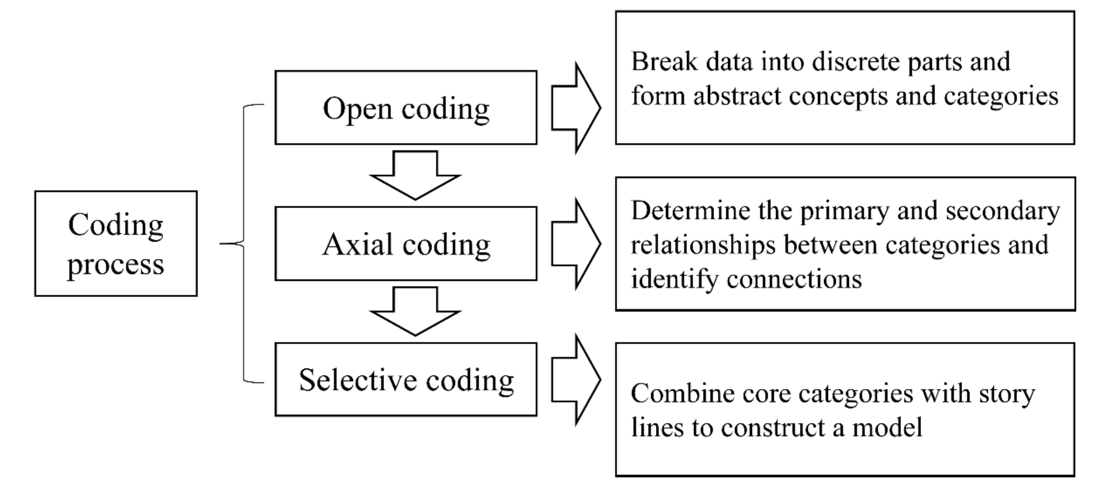

Figure 1.3 Coding process of grounded theory analysis

Open coding is the first step into the coding process. Researchers should read all the words, paragraphs, pictures, etc. in the data in detail, without omitting any important information, and without any pre-formed concept in the mind, and immerse themselves in the data through line-by-line analysis, coding the data in as many ways as possible and writing memos about the conceptual and theoretical ideas that emerge during the course of analysis. It is an operational process of breaking up collected data, giving it concepts, and then putting it back together in new ways. The process of open coding is similar to a funnel. The scope of coding is relatively wide at the beginning, and then the scope is continuously narrowed until the code number is saturated. When coding in the data, the researcher should find out some specific and conceptual questions about the content of the data, keep original research goals in mind, and consciously extract goals that are not anticipated in advance.

Second-level coding, also known as axial coding, aims to discover and establish various connections between conceptual categories, which express the organic associations between various parts of the data. This connection is made through the application of a coding paradigm focusing on three aspects of a phenomenon: the conditions or situations where the phenomenon occurs; the actions or interactions of people in response to the occurrence of the situation; and the consequences or results of action taken or inaction. In the process of axial coding, researchers strive to understand the relationship between categories and other categories and their subcategories. Only one category is deeply analyzed at a time, and correlations are found around this category, so it is called "axis". As the analysis progresses, the various relationship between the various categories should become more specific. When conducting association analysis on concept categories, researchers not only consider the associations between these concept categories themselves, but also explore the intentions and motivations of the respondents who express these concept categories, and put their words into the situation and the social and cultural context in which they live. After the relationship between each set of conceptual categories is constructed, it is necessary to distinguish what is the main category and what is the secondary category. Further, after these different levels of categories are identified, researchers can link their relationships through comparisons.

Three-level coding, also known as core coding or selective coding, is a more focused process. The researchers re-code the conceptual categories found in the axial coding, and analyze and summarize a "core category". The core category must be repeatedly shown to be dominant in comparison with other categories, capable of encompassing the greatest number of findings within a relatively broad theoretical range. The specific steps of core coding are: (1) clarifying the story line of the data; (2) describing the main category, sub-categories and their attributes and dimensions; (3) examining the established preliminary assumptions and fill in the concepts that need to be supplemented or developed; (4) extracting the core concept categories; (5) establishing systematic connections between the core categories and other categories. If more than one core category is found at the beginning of the analysis, the related categories can be connected by continuous comparison. Finally, combined with the research purpose, based on logical clues, story lines, etc., a model framework is constructed.

1.5 Research framework

The overall structure of this thesis as shown in Figure 1.4:

Chapter 1 introduces research background, research objectives and questions, research significance, research method and research framework.

Chapter 2 conducts a literature review. The concept, antecedents and consequences of enterprise digital transformation are introduced. Next, it systematically reviews the concept, type, application situation and adoption behavior of digital technology in different fields. Finally, it discusses the economic value, efficiency and capital structure of digital technology-enabled business operational performance.

Chapter 3 makes an introduction about application of digital technologies in Sichuan Fishery-PV Wulian Technology Co., Ltd, including the company profile, fishery and photovoltaic integrated operational model and the use of digital technology in operational processes.

Chapter 4 proposes the mechanism model of digital technology on business operational performance. Following a standarded grounded theory coding procedure, combined with data collected from semi-structured interviews, the theoretical model is constructed.

Chapter 5 examines the mechanism model of digital technology-enabled operational performance using a relative large company samples. According to the theoretical model proposed in Chapter 4, the structural relations between the constructs are illustrated, and the research hypothesis is developed. The data of the questionnaire is further used to conduct structural equation modeling, and finally the results is obtained.

Chapter 6 is the conclusion and discussion. This chapter summarizes the main findings and core conclusions of the study, highlights the theoretical and practical contributions, and presents the limitations of the thesis as well as future research directions.

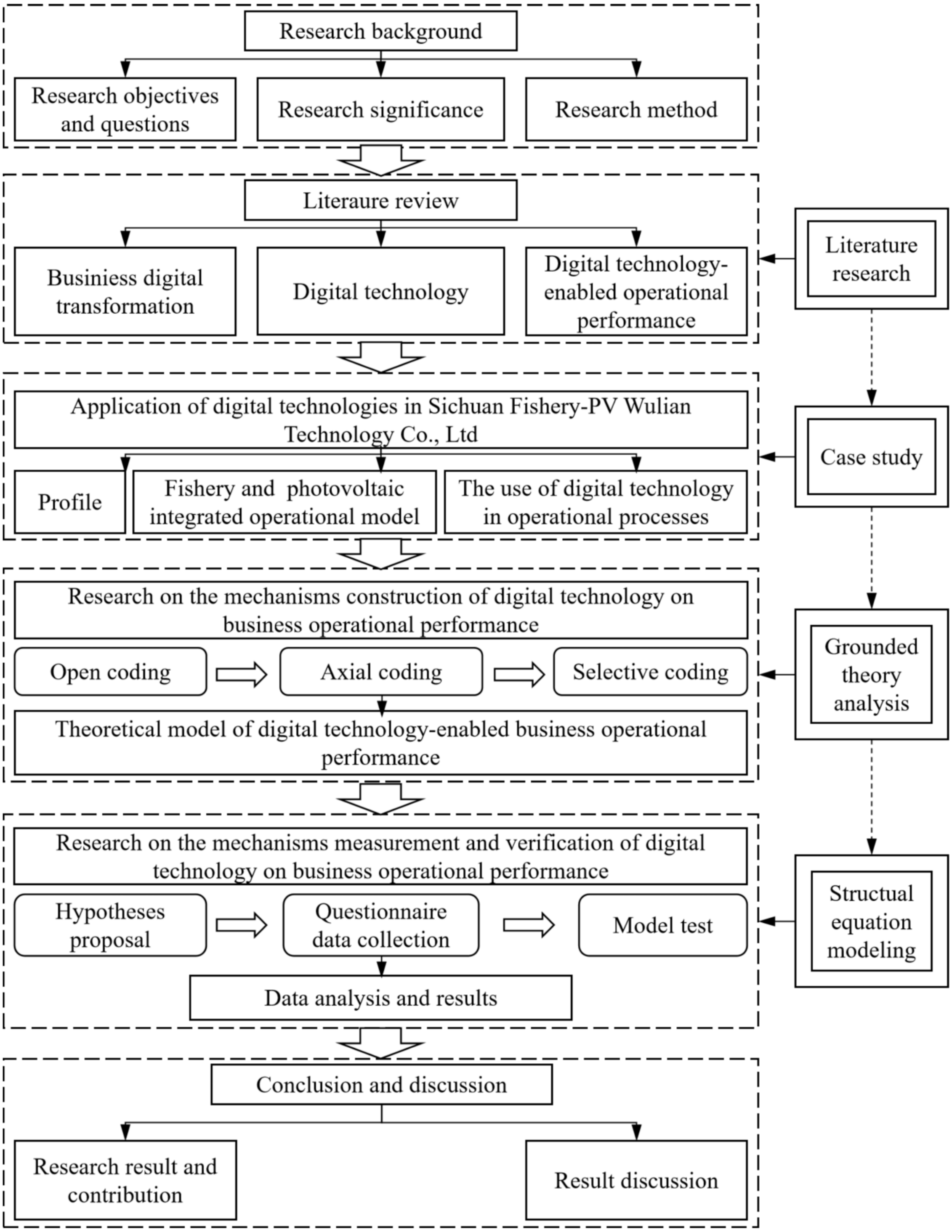

Figure 1.4 Research framework

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Chapter 2: Literature Review

2.1 Businesses digital transformation

Warner and Wäger (2019) defined digital transformation as the use of new digital technologies to achieve significant business improvements to enhance the customer experience, simplify operations, or create new business models. The author constructed the dynamic capability model of digital transformation of existing companies in traditional industries. The external triggers of the model include disruptive digital competitors, changing consumer behavior and disruptive digital technology. In addition, three core drivers and three core obstacles will affect the model.

Verhoef et al. (2021) identified three main external factors driving the demand for digital transformation, namely big data and emerging digital technologies, competition pattern, consumer behavior. In addition, the author discussed the strategic points brought by digital transformation, which is composed of the following four parts: (1) digital resources; (2) Organizational structure, including independent business units agile organizational forms and digital functional areas; (3) Growth strategy; (4) Indicators.

H. Chen and Tian (2022) revealed the mechanism affecting the enterprise digital transformation and proved that the digital transformation is driven by the interaction between the external pressure of environmental uncertainty and the internal pull of resource coordination, rather than by a single element. In addition, the author pointed out that the synergy of environmental uncertainty and resource arrangement can jointly promoted the digital transformation.

Vial (2021) combed 282 related works about digital transformation culled from IS and gave a conceptual definition of digital transformation as “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies”. This study also proposed a framework where digital technologies induce disruptions resulting strategic responses from enterprises that attempt to change their value creation paths. Structural changes and organizational barriers moderate positive and negative outcomes of this process

In recent years, there has been a surge of interest in Small and Medium Enterprises (SMEs).

Papadopoulos et al. (2020) called for studies about how this type of enterprise responds to extreme events (e.g., Covid-19) through digital transformation and gives scholars some potential research directions.

Kozanoglu and Abedin (2020) provided the concept of digital literacy, regarded digital literacy as the process of employees participating in digitization, and pointed out that employees' digital literacy is the key factor of enterprise digital transformation. The author used cognitive ability / ability development information availability to measure employees' digital literacy, and social practice helped to express availability. Employees' digital literacy can improve the use of digital technology.

G. Li et al. (2021) collected the data of 173 companies in Indonesia and constructed a structural equation model, which proved that the process of social knowledge was positively affecting the digital business transformation of enterprises. At the same time, the process of social knowledge had a positive impact on the enterprise's IT / IS initiative. In addition, the author found that the intermediary role of IT / IS initiative ability between social knowledge process and digital business transformation was not significant, while IT / IS initiative ability fully mediates coding knowledge process and digital business transformation.

Genzorova et al. (2019) identified the skills of organizational digital transformation through content analysis of second-hand data, including artificial intelligence and nanotechnology, robotics, Internet of things, augmented reality and digitization. Organizations use digital learning to cultivate the skills of organizational digital transformation, and participants, learning environment, learning process and learning promoters interact with each other.

Bharadwaj et al. (2013) identified four key themes of digital business strategy under the trend of a fusion between IT strategy and business strategy, from which elaborated the success metrics and potential performance implications from pursuing a digital business strategy. The four themes are (1) the scope of digital business strategy, (2) the scale of digital business strategy, (3) the speed of digital business strategy, and (4) the sources of business value creation and capture in digital business strategy.

Loebbecke and Picot (2015) reviewed the previous literature about digital transformation from the perspective of employment. The authors revealed the mechanism underlying how digital technology changed the operating law of business and society and outlined the impact of this evolution on human capital in enterprises, especially knowledge workers.

Matt et al. (2015) built a digital transformation framework that contains four key elements: use of technologies, changes in value creation, structural changes, and financial aspects. Both changes in value creation and structural changes are mutually casual to the use of technology.

Considering financial aspects can transform the former three dimensions. Besides, the authors also emphasized the importance of some procedural aspects such as leadership and assessment in digital transformation.

Gust et al. (2017) took a Swiss electricity utility as a case study. By analyzing a bottle-up initiative that aims to build an analytics ecosystem from technological capabilities, organizational and business, this study refined four key lessons. The first lesson is making more stakeholders involved in the digital transformation to cultivate the nascent analytics capabilities. Breaking boundaries in departments to encourage information exchange is the second lesson. The third lesson is applying agile development practices. Finally, the authors suggested managers move from using isolated tools to open platforms. To avoid local optimum, leaders may even reject the best tool for a given task to put a tool with better integration potential in their place.

Pagani (2013) conducted a field study in the European and U.S. broadcasting industry using primary and secondary data sources. The first part of the data comes from interviews with 45 industry leaders. The authors also searched the articles in two leading industry journals from 2000 to 2008 and constructed the metrics to measure each technology generation's core and edge capabilities. Finally, this study also combined longitudinal data that covered 792 firms between April 2000 and May 2008. The result revealed that incremental innovations drive the mechanism behind value networks and cause disruptions to shift those to two-sided markets.

Svahn et al. (2017) conducted a longitudinal case study based on Volvo Cars' connected car initiative. This study identified four competitive issues in digital innovation and the conceptual origin of these issues in digital innovation, focusing on incumbent companies.

Kohli and Johnson (2011) took Encana Oil & Gas (USA) Inc as a case study. This study described how Encana Oil & Gas (USA) Inc, as a latecomer to digital transformation, responds to the challenges of market fluctuations caused by the sharp decline in natural gas prices and demand using IS. In this case, the role of leaders, such as the CEO and CIO, is critical. Therefore, the article concludes with lessons for CIOs and CEOs. This successful case provides a substantial reference value for companies who want to become frontrunners in the latecomer industry.

Chief information officers are usually regarded as an exclusive position responsible for the IT technology of enterprises in the early stage of digital transformation. However, with the development of digital transformation, companies need people who can be in charge of both digital and business. Therefore, a Chief Digital Officers (CDO) is born at the right moment. A CDO is a leader who combines business intelligence with digital expertise to help organizations drive digital transformation through an organization's smart digital vision and strategy. To clarify the definition and responsibility of CDO, Singh and Hess (2017) described the experiences of six companies that employ a CDO. These six companies belong to six industries respectively, including the retail industry, the tourism industry, the education industry, the market research industry, the financial service industry, and the publishing industry.

Customers proficient in digital technology are more demanding, and new entrants are increasing. Aware of the increasing competition, Sia et al. (2016) took DBS, a large Asian bank as a case study. From its response to digital threats and opportunities by adopting a digital business strategy, this study refined requirements for enterprises. The four key lessons learned from the case are: (1) a digital business strategy demands strong leadership; (2) an agile and scalable “core” is critical; (3) a digital business strategy exploits information abundance to create new value for customers; (4) a digital business strategy requires the continuous navigation of the dynamic and emerging digital landscape.

Dery et al. (2017) emphasized the importance of the digital workplace underlying responsive leadership and employee connectedness based on the transformational journeys of three established companies. The four key lessons learned from the case are (1) ensure the organization appoints a digital workplace or employee experience leader (2) define customer experience and employee experience and use them as the basis for digital workplace design (3) develop an evidence-based approach to managing employee experience (4) distinguish between systems that improve employee experience and employee wellbeing.

Sebastian et al. (2020) indicated the results of their research on 25 companies undergoing digital transformation. This study has identified two digital strategies: customer engagement and digitized solutions. Two technology-enabled assets are critical for leveraging those strategies: an operational backbone and a digital services platform.

Coreynen et al. (2017) performed a multiple-case study based on four manufacturing small and medium enterprises from the perspective of service offering. There are three service pathways due to specific digital options mentioned in this paper, including industrial, commercial, and value servitization. Each path has its own competitive benefits, dynamic resource configurations, the barriers from a dynamic resource-based lens.

Hansen and Sia (2015) took Hummel, a European sports fashion company, as a case study. This study elaborated how to overcome challenges in building various online and offline channels to deliver a seamless customer experience.

Svahn et al. (2017) found that intensive customer involvement (ICI) and product-focused customer involvement (PCI) practices will positively contribute to the increase of innovations in firms. The authors examine the moderating role of “relational information processing capability” (RIPC) and “analytical information processing capability” (AIPC) in this relationship. The result showed that RIPC positively moderates the relationship between PCI and the amount of firm innovation and that AIPC positively moderates the relationship between ICI and the amount of firm innovation.

Saldanha et al. (2017) found that intensive customer involvement (ICI) and product-focused customer involvement (PCI) practices will positively contribute to the increase of innovations in firms. The authors examine the moderating role of “relational information processing capability” (RIPC) and “analytical information processing capability” (AIPC) in this relationship. The result showed that RIPC positively moderates the relationship between PCI and the amount of firm innovation and that AIPC positively moderates the relationship between ICI and the amount of firm innovation.

Karimi and Walter (2015) studied the relationship between first-order dynamic capabilities created by leveraging existing resources and building digital platform capabilities. These capabilities, to some extent, determine the performance of response to digital disruption. The result revealed a positive correlation between the dependent and independent variables.

Oestreicher-Singer and Zalmanson (2013) emphasized the role of the social experience in the content website’s digital business strategy. By collecting data from Last.FM, a site offering both music consumption and online community features, authors found that willingness to pay for premium services is strongly associated with the level of community participation of the user.

Dorfleitner et al. (2021) found the factors that are associated with the digital transformation of microfinance institutions (MFIs) and proved that the adoption of digital transformation will not damage the interests of enterprises as expected. Compared with using some tiny digital tools, a wide scoop to apply digital solutions leads to a better result for the profitability of the institutions and their home country development. However, this study also had some limitations, including not longitudinal data, not enough MFIs, and the absence of supply-side factors.

Bertani et al. (2020) explored the benefits of digital transformation on the empirical and the modelling sides. They indicated that tangible and intangible investments, including information and communication technologies and software and databases, positively correlate with both labor and total factor productivity. Computational experiments show the emergence of technological unemployment in the long run with a high pace of intangible digital investments.

Llopis-Albert et al. (2021) applied the method of fuzzy set qualitative comparative analysis (fsQCA), proposed a model of digital transformation on the performance and participant satisfaction of the automotive industry, and analyzed its impact. The research results revealed the impact and adaptation strategies of the digital transformation of the automotive industry.

Feroz et al. (2021) used the research method of systematic literature review (SLR) to classify the impact of digital transformation on environmental sustainability into four areas: waste management, pollution control, sustainable production and urban sustainability. The author discussed the agenda of digital transformation strategy, organizational capacity, performance and environmental sustainability.

F. Li (2020) proposed some methods to guide digital transformation by studying the world's leading enterprises in digital transformation, including: (1) innovation through experiments, (2) complete transformation through continuous incremental change, and (3) dynamic sustainable advantage through evolving temporary advantage combination.

Nasiri et al. (2020) collected the data of 280 Finnish small and medium-sized enterprises and used the method of confirmatory factor analysis (CFA), it was confirmed that the digital transformation of enterprises alone could not improve the relationship performance, which needed to be combined with intelligent technology to achieve this goal. The company's digital transformation improves relationship performance by promoting intelligent technology.

Soto-Acosta (2020) proposed that the Covid-19 pandemic has accelerated the digital transformation and digital transformation of enterprises. Under the influence of covid-19 pandemic, the business model of enterprises has undergone significant changes. Digital transformation opens up new business model opportunities for enterprises. Digital transformation projects are usually a supplement to the existing traditional business model. Covid-19 pandemic and digital transformation have had a far-reaching impact on the work organization of enterprises, including changing the competition rules among enterprises in the industry and creating new jobs.

Fischer et al. (2020) conducted semi-structured interviews with the heads of case enterprises using qualitative methods to solve the problems that most enterprises have vague understanding of digital transformation and are difficult to design and implement. Based on the interview, six core elements of BPM framework are introduced, namely strategic consistency, governance, method, IT, personnel and culture. The model of enterprise digital transformation is established, and three strategies of communication / learning, unification / optimization and certification / automation are put forward.

Wrede et al. (2020) discussed the role and promotion actions of senior managers in coping with digital transformation. The author found that senior managers respond to digital transformation by participating in three key actions, namely, understanding digitization, setting a formal environment for digitization and leading change. In addition, the survey results emphasize that the decisions made by senior managers play an important role in defining the company's digital transformation path.

Gurbaxani and Dunkle (2019) proposed a framework for evaluating digital transformation at the enterprise level. The framework includes six dimensions, namely, the company's strategic vision, the consistency between the vision and digital transformation investment, the applicability of innovation culture, having sufficient intellectual property assets and proprietary technology, the advantages of its digital capability and the use of digital technology. The framework can help enterprise executives assess the progress of enterprise digital transformation and compare the status of other enterprises, so as to identify the gaps existing in enterprises.

C. L. Chen et al. (2021) revealed four major obstacles to the digital transformation of small service enterprises: lack of capital, lack of digital ability, lack of human resources and technical obstacles. The research explained the relationship between drivers, obstacles and government roles in the digital transformation of small service enterprises. The government can support the digital transformation of enterprises by building a digital platform for small service enterprises, promoting mobile / digital payment, providing digital training and building a digital collaboration ecosystem.

Van Veldhoven and Vanthienen (2022) proposed an interactive digital transformation framework, which contains three axes to represent the main entities: digital technology, business and society. For each entity, the author summarized its elements in the digital transformation into five categories. Digital transformation interaction referred to the interaction between the above three entities. The author classifies 23 drivers of digital transformation.

Sjödin et al. (2021) conceptualized three interdependent AI capabilities in the digital transformation of industrial manufacturing: data pipeline capability, algorithm development capability and AI democratization capability. In addition, the author emphasized three important principles of business model: CO creation with agile customers, data-driven delivery operation and scalable ecosystem integration. Finally, the author explained how to support business model innovation through interdependence, feedback cycle and coevolution process.

Zhang et al. (2021) selected 116 manufacturing companies that have disclosed the information of digital transformation, took whether to carry out digital transformation as an independent variable and the return on net assets as a dependent variable to build a model. Through the method of did, compared with not implementing digital transformation, enterprises implementing digital transformation can significantly promote economic benefits, which has nothing to do with industry and region.

Zhang et al. (2021) used the partial least squares path modeling or partial least squares structural equation modeling (PLS-PM, PLS-SEM) to find that the digital transformation of enterprises has a direct and positive impact on organizational elasticity. The impact was mediated by exploitative innovation and exploratory innovation. Exploitative innovation and exploratory innovation of enterprises had a positive impact on Organizational Resilience, and exploitative innovation and exploratory innovation complement each other.

Hsu et al. (2018) identified the role of digital transformation and the role of the Department in digital transformation. Perception-acquisition-transformation provided help for this process. It department played an important and positive role in the initial stage of organizational transformation and played a leading role in developing ICT capability, but it will not be able to play a leading role in the organization after the transformation is completed.

Ziółkowska (2021) aimed to understand how digital transformation affects the marketing activities of small and medium-sized enterprises (SMEs). IT technology and digital tools affected marketing, help build relationships with customers and create value for each organization. The digital transformation of enterprises affected the relevance of content marketing. The digital technology budget of small and medium-sized enterprises also affected marketing activities.

H. Liu et al. (2021) used the data of China's A-share agricultural listed companies from 2015 to 2020, through empirical research, it is concluded that the digital transformation of agricultural enterprises only promotes the number of technological innovation, but it does not affect the innovation efficiency. The period cost rate is the reason why the digital transformation has different effects on the quantity and efficiency of technological innovation of agricultural enterprises. Digital transformation plays a positive role in the development of enterprise technological innovation quality.

Chu et al. (2019) conducted a questionnaire survey on 138 enterprises, using the methods of fsQCA and SEM, and obtained that IT capability has a positive impact on process innovation performance and digital transformation, and digital transformation has a positive impact on process innovation performance and product innovation performance. Digital transformation plays a partial intermediary role between enterprise IT capability and process innovation performance, while it plays a complete intermediary role between enterprise IT capability and product innovation performance.

Pflaum and Golzer (2018) put forward a reference process of digital transformation of the company, which is divided into four steps. First, create a strategic business vision for the enterprise and decompose it into data-driven use cases. Secondly, create and develop a model containing use case information through knowledge. Then, in the knowledge application step, the company uses artificial intelligence technology to obtain new insights and knowledge from these data. Finally, the company integrates the solution into the organizational decision-making process.

C. Wang et al. (2020) confirmed that the implementation of digital transformation was conducive to improving short-term and long-term financial performance. In addition, the cognitive conflict of senior leadership team has an inverted U-shaped regulatory role in the relationship between digital transformation and short-term financial performance, while it has a positive regulatory role in the relationship between digital transformation and long-term financial performance.

Zeng and Lei (2021) verified that digital transformation has a positive impact on total factor productivity through empirical research, based on the data of A-share listed enterprises in Shanghai and Shenzhen. In the heterogeneity analysis, the author found that digital transformation only significantly promoted the total factor productivity of high-tech enterprises. In addition, only in small and medium-sized high-tech enterprises, digital transformation would have a positive impact on total factor productivity. This showed that small and medium-sized enterprises could save management costs and improve efficiency through digital transformation.

X. Guo et al. (2022) revealed that the digital transformation of enterprises was conducive to enterprises to jump out of the pattern of industrial monopoly and regional monopoly through empirical analysis. Heterogeneity analysis showed that digital transformation had a more obvious impact on the performance improvement of enterprises with high industry concentration. Under the high industry concentration, it was more conducive to the development of small enterprises. In addition, the impact of digital transformation on the performance improvement of enterprises with low regional competitiveness was more obvious.

J. Yu and Moon (2021) constructed the concept of digital capability under the background of enterprise digital transformation, and pointed out that digital capability included three core elements: digital infrastructure, digital integration and digital management. In addition, the author collected 160 questionnaires from Chinese enterprises, and confirmed that customer orientation and technology orientation had a positive impact on digital capability through the construction of structural equation model. Customer orientation was more important than technology orientation, and digital capability had a positive impact on organizational performance.

By adopting a phenomenon-based approach, Chanias and Hess (2016) conducted a multiple-case study in three European car manufacturers from the process perspective. This article creatively integrated Mintzberg's strategy typology with the concept of IS strategizing to draw on an activity-based process model. The result showed that the deliberate strategy of senior managers seeks to achieve the subsequent consistency between the pre-existing emergency strategy content and its intention while increasing the share of deliberate content.

Ganju et al. (2016) indicated that information and communication technology represented by the number of fixed telephones, internet, mobile phones could improve well-being at the national level. The authors use a fixed-effects model and an instrumental variable approach to test the relationship between ICT and a country's well-being. In addition, the authors also identified the countries with similar patterns by using an exploratory method (biclustering). The result showed that not all countries improve their well-being levels by using ICT in the same pattern. Developing countries increased their well-being by using mobile primarily, while developed countries improved their well-being with any ICT system.

To address how e-leadership in SMEs drives successful alignment between business strategy and digital technology, fostering longevity and growth, W. Li et al. (2016) interviewed 42 successful European SME leaders. The resulting diagnostic model will help managers to fully leverage the potential offered by these technologies.

To meet the challenges brought by digital transformation and systematically deal with the various impacts of digital change on the internal and external environment of the organization, top management is increasingly formulating and implementing a digital transformation strategy (DTS). Chanias and Hess (2016) adopted the explanatory case study method to study DTS formation from the perspective of process/activity. An in-depth case study was conducted in a large financial service provider. The results showed that various emergency strategy-making activities mainly form this DTS through the bottom-up process before senior management introduced the overall approach. Then, top management attempts to formalize the emergency strategic content by developing and implementing DTS, including a shared goal map, unique digital transformation governance, and measures to increase the share of intentional, strategic content.

2.2 Digital technology

2.2.1 Concept and connotation

Digital technology is an electronic and digital tool for acquiring, storing and analyzing data.

Through the use of digital technologies, many research areas can integrate disparate technologies to maximize data access, thereby reducing research costs and improving operational efficiency (Fuentes et al., 2021). Similarly, some scholars indicated that digital technology is to express the information in the form of bits and encode, compress and decode the information with the help of computer, so as to reduce and save the cost of storing, calculating and transmitting data (Goldfarb & Tucker, 2019). A key feature of digital technology is that it enables users to customize and generate personal content through digital tools, and carry out high-level information interaction with other users. Users can access digital technology whenever and wherever possible, they are common participants in the process of content creation and communication (Shawky et al., 2019).

Today's digital technologies such as social media, business analytics, Internet of Things, big data, advanced manufacturing, 3D printing, cloud and web solutions, and MOOCs permeate every private and public organization (Paschou et al., 2020; Rippa & Secundo, 2019). The advantages of technology and digital connectivity have revolutionized every aspect of human social life.

The rapid development of digital technologies has dramatically changed the business environment and injected new vitality into traditional industries, allowing them to survive and adapt. In this new competitive landscape, companies' digital activities need to rely on the entire entrepreneurial ecosystem. Against this background, Zahra et al. (2022) analyzed and highlighted the close links between ecosystem development, digital technologies, and the positive role played by new businesses, and describe a complex evolutionary process. For example, with the development of the digital twin ecosystem, different types of startups have emerged, playing complementary strategic roles.

H. Li et al. (2021) believed that digital technology will have an impact on market agility. External relationship management based on digital technology and business strategy coordination had a direct positive impact on market agility, while internal relationship management based on digital technology had a positive impact on market agility by affecting digital technology infrastructure management.

Urbinati et al. (2020) considered that digital technology can more easily obtain, share and use the knowledge and information flow in the process of creation and transmission, so as to realize the management of open innovation process. Therefore, digital technology can be used to carry out enterprise innovation activities, such as augmented reality and virtual reality, artificial intelligence and network physical systems.

Elia et al. (2020) believed that digital technology is the promoter of entrepreneurial activities. Digital technology could help create new commercial enterprises and digital start-ups, and as an integral part of their business model and operation. Digital technology could be embodied through digital products or services, digital platforms, digital infrastructure, Internet service innovation and other forms.

Anthony Jnr (2021) considered that digital technology has been applied in many new fields of enterprise development and innovation, which has created new value for enterprises. In order to successfully and effectively apply digital technology in the process of enterprise development, enterprises need to combine information technologies such as big data, cloud computing and social media to adapt to the changing external environment. With the help of digital technology, enterprises can improve productivity and income, reduce product costs, and finally reflect the improvement of customer service level.

Likewise, the architecture, engineering and construction industries are embracing the digital age. The processes involved in the design, construction and operation of building assets are increasingly influenced by technologies that involve value-added monitoring of sensor network data, management of this data in secure and resilient storage systems supported by semantic models, and engineering System simulation and optimization.

Ardolino et al. (2018) believed that digital technology can promote manufacturers' service innovation, change the supply chain structure and reshape industry competition by providing innovative products or services. With the three digital technologies of Internet of things, cloud computing and predictive analysis positioned according to the level of data information knowledge intelligence, many products or services can be transformed through a higher level of information and communication.

Ardolino et al. (2018) were particularly concerned with the role of digital technologies in service transformation as it addresses how the three DTs of IoT, cloud computing and predictive analytics can support service transformation for manufacturing companies. Through the Data-Information-Knowledge-Intelligence model, the authors discuss how the aforementioned technologies can transform low-level entities such as data into information and knowledge to support service transformation for manufacturers. A set of digital features is proposed based on the existing literature and findings from four case studies. It then discusses how these capabilities support manufacturers' service transformation trajectories. In the end, the study found that IoT is fundamental to any service transformation, although it is primarily required to become an availability provider.

To date, the spread of digital technologies has rapidly increased in brick-and-mortar stores due to continuous technological advancements and consumer expectations for new technologies.

Pantano and Vannucci (2019) investigated the actual level of dissemination of these techniques to understand effective responses from retailers. Based on theory of innovation diffusion, this study was based on direct observations of 208 stores in Oxford Street, London, UK, in October and November 2017. Analyzing the data using qualitative research methods revealed that few stores have more than three different types of digital technologies, and the number of digital technologies adopted increases with the size of the store.

Likewise, digital technologies are making academic entrepreneurship activities, processes and outcomes more flexible and sustaining the development of a new concept: digital academic entrepreneurship. Rippa and Secundo (2019) claimed that this novel conceptualization is characterized by a high degree of utilization of new digital technologies to improve emerging forms of academic entrepreneurship, which develops the academic entrepreneurial process through the use of digital technologies, with the ultimate goal of enabling the university ecosystem democratized, thereby attracting more stakeholders.

In the field of education, digital technologies also play an important role. Research byGan et al. (2015) shows that digital media can enhance students' learning process. The educational experience of students and their collaborative learning is enhanced by the integration of several digital technologies into teaching using iPad learning, using network technology to achieve various connection points, and solving real-world business problems through capstone courses. There are three reasons for this: first, as part of a student's blended learning experience, they support groups of learners to master collaborative project tasks and achieve course objectives; second, they help students harness the power of collaborative learning scenarios and develop further with the help of their peers key competencies; finally, they allow students to seek out and gain more knowledge.

As a convenient tool for teaching and learning, digital technology can take students or teachers as the center of the learning process and help them obtain new teaching information in time. At the same time, in the field of physical education, digital technology has always been a hot topic discussed by many scholars. Many professionals focus on how to make better use of digital technology to provide support and help for young people's learning. Teachers' experience and proficiency in using digital technology tools vary from person to person, which is a very interesting feature of research in this field.

In the field of health care, digital technology has become an indispensable part. Using digital technology tools, case acquisition, patient information and doctor reply can be carried out online in digital form, such as video consultation. In the process of fighting against COVID-19, digital form of non-contact medical care played an irreplaceable role. In addition, with the deepening of the combination of digital technology and medical treatment, telemedicine technology will have a greater and greater impact on visceral diagnosis (Naumann et al., 2021).

The simultaneous maturation of multiple digital and telecommunications technologies has created unprecedented opportunities for ophthalmology to create new models of care using telemedicine enabled by digital innovation. H. Li et al. (2021) reviewed how countries around the world are using these digital innovations to address eye diseases such as diabetic retinopathy, retinopathy of prematurity, age-related macular degeneration, and more. Additionally, to reduce the risk of infection in healthcare settings during the COVID-19 pandemic, real-time telemedicine has been rapidly incorporated into routine care services. The patient groups that telemedicine was designed to serve are no longer focused on targeting remote areas. Instead, it's fast becoming a new standard of care.

In mental health research, J. Li and Brar (2022) defined digital technology as electronic tools, such as smartphones, laptops and tablets, that can access digital media. They examined the impact of indigenous peoples' interactions with digital media on their mental health and well-being by conducting a systematic literature review. Numerous studies have shown that high rates of suicide, depression, substance abuse and violence are common among Indigenous people globally, especially among young people. However, Indigenous communities, especially Indigenous youth, can overcome the digital divide through advances in mobile technology and actively adopt digital technologies compared to older Indigenous generations.

On the question of whether digital technology can enable green development, L. Wang et al. (2021) gave the answer. They conducted an empirical study on the relationship between digital technology innovation, technology spillovers and national carbon emission intensity from three aspects: direct and indirect impact, mechanism identification, and permanent path. The research results show that technological innovation in the information industry increases carbon emission intensity, and cross-industry technology spillover effects continue to reduce domestic carbon emission intensity. Digital technology will empower domestic green development, and the emission reduction effect of technology spillovers is greater than that of technological innovation. Increasing the proportion of non-fossil energy utilization and industrial structure optimization are effective mechanisms for digital innovation to reduce carbon emission intensity.

While digital technology brings a series of benefits to people, it also brings a series of dark sides, especially people's mental health. Marsh et al. (2022) claimed that they've uncovered a wealth of insights into certain dark side effects, especially stress associated with email and smartphones. They identified a range of techniques associated with dark side effects. The objective requirements and perceived requirements that these technologies impose on employees, which were often conflated in the past, are differentiated. Five dark side effects have been identified in the literature: technology-related stress, overload, anxiety, interruptions and distractions, addiction, and overuse.

2.2.2 Categories of digital technologies

With the advancement of digital technology, it has been injected into all aspects of society and has existed in various forms. Nambisan and Satish (2017) claimed that Digital technology consists of three related but different elements: digital artifacts, digital platforms and digital infrastructure.

Digital artifacts refer to new products, applications and media content that provide specific value to users as part of services (Kallinikos et al., 2013). In the field of information systems, there are many researchers who claim that digital artifacts are different from physical artifacts. They have been embedded into ever-changing and broader systems, so they have become increasingly reprogrammable and distributable, as well as having stronger interaction terms. This constant deformation makes the value and utility of these artifacts more dependent on changes in the network of functional relationships with other artifacts in a given environment and organization. For the same reason, control of the development and use of these artifacts is assigned to a series of decentralized stakeholders, and its management becomes a complex technological and social enterprise (Kallinikos et al., 2013). Additionally, digital artifacts include Digital storytelling, Virtual and augmented reality, Blockchain, and more.

Digital storytelling is claimed a research method, which is based on many art forms, such as synthetic images, video, audio and text in a few minutes. Digital storytelling can accurately and deeply mine users' life experience, improve users' or participants' understanding of the research process, and explain the research findings in a highly participatory way (Rieger et al., 2018). Gurrieri and Drenten (2019) considered that digital storytelling is to tell stories around certain themes through the combination of some digital media tools, such as text, image, audio, video files and so on. The length of a digital story is 3 to 10 minutes, usually in digital format. Users can use Internet browsers to view a variety of digital stories on any tool that can play videos. In addition, digital storytelling can help students practice oral English. It is very friendly to the language learning process and can improve users' oral skills efficiently and accurately (Mirza, 2020).

Virtual reality refers to a complete analog reality based on a computer system based on digital format. Augmented reality is an image that superimposes multiple elements (3D objects, multimedia, text information, etc.) onto the real world. Virtual and augmented reality are hot technologies, which have been applied in many fields, such as education, geography, medicine, media communication and so on (Martín-Gutiérrez et al., 2017). Virtual reality is generally regarded as a 3D virtual environment generated by computer. Users can interact and operate with it through sensors and other devices. The three key elements of virtual reality are visualization, immersion and interactivity. Users can immerse themselves in the virtual environment for real experience. Augmented reality usually refers to the use of computer-generated image layers to enhance the real-world environment. VR and Ar are highly correlated and are applied in various fields (Yung & Khoo-Lattimore, 2019).

Conversation system is usually expressed in the form of chat robot for background reply. At present, the research focus in this field has changed from randomly generating reply to pursuing more targeted and accurate interaction. The traditional dialogue system is based on database search, which will be limited by the needs of users, and most of them are based on heuristics and manual rules, which can’t be accurately processed and popularized in case of accidents. This technology includes the endpoints of human-computer interaction and is applied in many fields, such as restaurant reservation engine and travel reservation assistant (Gunasekara et al., 2019).

In recent years, blockchain has attracted great research and attention from global innovators and scholars. The economist indicates that "blockchain will redefine the world". Blockchain combines computer technologies such as distributed data storage, automatic and intelligent consensus mechanism, dynamic encryption algorithm and decentralized and independent peer-to-peer transactions (Hawlitschek et al., 2018). It is an innovative application mode. At the same time, blockchain is widely used in many fields, such as helping to realize multi-party and bilateral transactions and deeply exploring network information sources (Lu, 2019). It is considered to be a revolutionary technology for building distributed energy system. Through the decentralized trust mechanism provided by the blockchain itself, many management bugs and problems in the distributed energy system can be solved (Q. Wang & Su, 2020).

Digital platform generally refers to a group of shared and common architectures, which provide a use environment for products that do not support each other. They can be defined as software-based platforms, created from an extensible codebase of software-based systems that provide core functionality shared with the modules they interoperate with and the interfaces through which they interoperate (Tiwana et al., 2010). Building on Tiwana et al. (2010), Ghazawneh and Henfridsson (2015) define digital platforms as: "A software-based external platform consisting of an extensible code base of a software-based system that provides. The core functionality shared by modules, and the interfaces to interoperate with them". De Reuver et al. (2018) argue that digital platforms are a challenging subject of study because of their distributed nature and strong institutional, market, and technological relevance. Specifically, the spread of digital platforms to many different industries, the exponential growth in the scale of platform innovation, and the increasing complexity of platform architectures have created new research challenges. It includes intelligent applications, big data and data analysis, cloud computing, social media, Mesh app and service architecture etc.

Intelligent applications are digital technologies that perform some of the functions of a human assistant, making everyday tasks easier and more efficient (Hoyer et al., 2020). For example, a chatbot is a virtual assistant software program that talks to users via audio or text. They are designed to simulate human conversation chatbots are often used in customer service environments. The AI behind the chatbot uses natural language processing (NLP) algorithms. Virtual assistants, chatbots and bots are the result of frameworks based on different combinations of task types (repetitive vs non-repetitive) and activity types (behavioral vs cognitive). Intelligent voice assistant is also a kind of intelligent application. Its main technologies include voice activation, automatic voice recognition, voice teaching, dialogue management, natural language understanding and named entity recognition. For example, "Alice" is a smart assistant for smartphones and personal computers. It can help users search for information on the Internet, find locations on maps, report weather forecasts, and provide dialogue and entertainment for users.

About big data and data analytics, a large number of fields and disciplines, ranging from everyday life to traditional research fields (i.e., medicine and rehabilitation, geography and transportation, government affairs and national security), involve big data problems (Lv et al., 2017). Researchers and practitioners are trying to study the future of big data to extract more benefits. As data and interactions are generated in various forms of human behavior, big data is used in almost every aspect of life. Big data is increasingly benefiting research and industrial fields such as healthcare, financial services, and business recommendations. Big data is mainly used to predict certain news such as transient power and stock prices. At the same time, big data and analysis are also applied to other fields, such as medical and social networks. In the medical field, doctors can process and query medical data with the help of big data technology, so as to analyze the treatment characteristics of patients and prescribe the right medicine. In the field of social networks, enterprises can extract users' social behavior rules from unstructured data by analyzing online social networks and shared spaces (Zhu et al., 2018).

Many applications in smartphones require ever-increasing computing power. However, smartphones are resource-constrained devices with limited computing power, memory, storage, and energy. Fortunately, cloud computing technology provides almost unlimited dynamic resources for computing, storage and services (A. U. R. Khan et al., 2014). Cloud computing is Internet-based computing that provides computers and other devices with shared computer processing resources and data on demand. It is a model for enabling ubiquitous on-demand access to a shared pool of configurable computing resources (Rippa & Secundo, 2019). In addition, cloud computing is also defined as a new computing paradigm, which has the characteristics of resource sharing, automatic service and instant payment. These characteristics of cloud computing enable it to provide services for infrastructure, data platform and software. In terms of application, cloud computing can provide technical support for problems in Earth Science, social science, astronomy, commerce and other fields by combining with big data (C. Yang et al., 2017).

Social media refers to the technology or tool with computer as the medium. It can realize information interaction, information sharing and output of other forms of expression through virtual community and network. In the process of using social media, a large amount of data will be generated. These data contain many dimensions of information. Reasonable mining and analysis of these data can bring benefits to enterprises or individuals (Bhimani et al., 2019). From this perspective, social media can be used in many fields.In the medical field, social media can provide convenience and help for patients. For example, it can supplement the information provided by medical personnel and provide psychological and social support for patients, which has prompted more and more patients to use social media tools to communicate with medical professionals on weekdays (Smailhodzic et al., 2016). In addition, social media also refers to platforms and websites that allow users to fill in personal information and use information to communicate and interact with other users. Research shows that social media platforms can recruit a large number of experimental participants through the Internet. With the increase of social media usage, it has become the main source to find research participants, such as Facebook or other crowdsourcing platforms (Topolovec-Vranic & Natarajan, 2016).

Mesh app and service architecture (Masa) refers to things that are regarded as applications by people, such as mobile applications, web applications, desktop and Internet of things applications. Masa can connect with many back-end servers, including connection to cloud computing or serverless computing in the form of API. From the perspective of transformation between different systems, Masa can provide services quickly and conveniently. Users can use clients, laptops, smartphones and other devices to connect with Masa. The service state is very stable and allows users to access information in real time (Sangkhapan et al., 2020).

Digital infrastructure refers to digital technology tools and systems that provide computing and information interaction capabilities. The use of digital infrastructure is a socio-technical process defined by Tilson et al. (2010) as digitization, which has important implications for concomitant changes at cognitive, social and institutional levels. In fact, the study of them covers different contexts (such as health, telecommunications, natural resources, government, and manufacturing), levels of analysis (such as organizations, groups, industries, and societies) and technologies (such as standards, the Internet, and platforms). Artificial Intelligence (AI) and advanced machine learning, Internet of Things, 3D printing, Drone Technology, etc. all belong to digital infrastructure.

Artificial intelligence (AI) and advanced machine learning are made up of many technologies and techniques to enable a range of intelligence, including physical devices as well as applications and services (Rippa & Secundo, 2019). AI is currently permeating many organizational processes, leading to growing fears that intelligent machines will soon replace decision-making for many people. Jarrahi (2018) argued for complementarities between humans and AI, and examine how each individual plays to his or her strengths in organizational decision-making processes often characterized by uncertainty, complexity, and ambiguity. With greater computational information processing power and analytical methods, AI can expand human cognition when addressing complexity, while humans can still provide a more comprehensive and intuitive approach to dealing with uncertainty and ambiguity in organizational decision-making.

Similar to how humans use the Internet, different devices will be the main users in the Internet of Things ecosystem. Devices will communicate with each other autonomously without any centralized control and collaborate to collect, share and forward information in a multi-hop fashion. The ability to gather relevant information in real time is key to harnessing the value of IoT as this information is translated into a level of intelligence that contributes to a smart environment. The quality of the information collected depends on the level of intelligence of the device.

Things that connect "things" to the internet include, but are not limited to, wearables, newly purchased cars, and smart home devices like smart speakers and smart TVs. Additionally, the Internet of Things now makes certain forms of private information, such as location and health, easier to collect than before. In these situations, these new forms of information collection are more sensitive to individual privacy concerns, and individuals will exhibit higher privacy preferences and be willing to pay more to address privacy concerns in these situations.

Furthermore, the degree of individual awareness of how their private information is used will attenuate privacy preferences and valuations within IoT, but the perceived benefits of control will in turn moderate knowledge of privacy regulations (Goad et al., 2021).

3D printing (also known as "Additive Manufacturing" or "Rapid Prototyping") enables the transformation of computer-aided and designed virtual 3D models into 3D tangible structures/objects through layer-by-layer deposition methods (Chang et al., 2019). Compared to traditional methods, 3D printing enables rapid prototyping, custom design and one-step fabrication of actuators and sensors with complex structures and high resolution. As an advanced technology, 3D printing has been used to manufacture complex and high-precision objects in many fields. For example, 3D printing can definitely benefit the field of micro-robotics, and the representative applications of 3D-printed micro-robots with rational designs to date demonstrate how these printed micro-robots can be utilized in medical, environmental, and other related fields (J. Li & Pumera, 2021).

Drone technology is an aircraft without a human pilot, known as an unmanned autonomous vehicle. ICT tools and technologies such as embedded systems, GPS and sensors are used to control drones. Drones were originally invented for military applications and it can be used to monitor very dangerous situations/missions. Gradually, drones were successfully used in several civilian applications such as agriculture, policing, surveillance, entertainment purposes, and inspired a new wave of entrepreneurs (Reddy Maddikunta et al., 2021; Rippa & Secundo, 2019).

Reddy Maddikunta et al. (2021) argued that the application of drones to agriculture has greatly promoted the development of smart agriculture. Drones can observe unnoticed farmland under cloud cover in detail, speed up deployment, and capture high-resolution images at minimal cost, while performing all activities similar to flying high-altitude aircraft, ensuring high safety. These images contribute to a better understanding of agricultural resources and livestock, leading to more accurate and consistent data for better decision-making. While the rapid population growth has put a lot of pressure on crop production, the use of drones in the agricultural sector has alleviated this to some extent, and at the same time, advances in drone technology have become extremely important. Currently, there are multiple agricultural drone applications such as soil and field analysis, planting, crop spraying, crop monitoring, health assessment, etc.

These disruptive digital technologies are critical to the development of Industry 4.0, which can be applied to many disciplines. Especially during the COVID-19 pandemic, the use of disruptive digital technologies has eased the burden on healthcare teams, safeguarded the physical and mental health of patients, and provided governments with effective oversight programmes on how technology can be adopted to reduce the impact of the outbreak (Abdel-Basset et al., 2021).

2.2.3 Application in various fields

Many studies have discussed the application of major digital technologies (IoT, cloud computing, big data, AI) in manufacturing, agriculture, and IT industries.

The Internet of Things (IoT) is regarded as the technological and economic wave of the global information industry after the Internet. The Internet of Things, an intelligent network, connects all things to the Internet to exchange and communicate information through information sensing devices according to agreed protocols. It realizes the goal of intelligently identifying, locating, tracking, monitoring and managing things. It is an extension and expansion of the Internet-based network, extending the communication between people to people and things or things and things.

In the field of manufacturing, technological progress has continuously supported the development of industrialization. The introduction of digital technology and its integration with operational technology is one of the core elements of the digital transformation of manufacturing companies. This shift is reshaping industry competition, and technologies such as the Internet of Things (IoT), cloud computing or big data and analytics are enabling companies to enhance their product service offerings, both of which provide advanced infrastructure to deliver services and create scaling the potential of service. The servitization trend can be defined as the combined paradigm of providing goods, services, supporting self-service and knowledge to customers, and this trend is not new (Cavalieri et al., 2012; Opresnik & Taisch, 2015; Porter & Heppelmann, 2014).

In the era of Industry 4.0, intelligent manufacturing system uses Service Oriented Architecture (SOA) to provide end users with collaborative, customizable, flexible and reconfigurable services over the Internet, enabling highly integrated human-machine manufacturing systems. This high integration of human-machine collaboration aims to establish an ecosystem of various manufacturing elements involved in IMS, so that organizational, management and technical levels can be seamlessly integrated. Artificial intelligence plays an important role in IMS by providing typical characteristics such as learning, reasoning and action. By using artificial intelligence technology, human involvement in IMS can be minimized. With the continuous deepening of Industry 4.0, autonomous perception, intelligent interconnection, intelligent learning and analysis, and intelligent decision-making will be finally realized. For example, an intelligent scheduling system can schedule jobs based on artificial intelligence technology and problem solvers, and can be provided to other users as a service in an Internet platform (Feeney et al., 2015).

Meanwhile, B. Chen et al. (2017) proposed that due to the current structure of the digital factory, it is necessary to build a smart factory to upgrade the manufacturing industry. Smart factories use a combination of physical and cyber technologies to deeply integrate previously separate discrete systems, making the technologies involved more complex and precise than they are today. The production methods of manufacturing enterprises are changing from digital to intelligent.

The Internet of Things is also an important digital technology that promotes the development of the manufacturing industry. W. Liu et al. (2012) used an RFID-enabled real-time production management system to collect real-time production data from raw materials, work-in-process (WIP) items, and employeed to improve visibility, traceability, and traceability of items of interest. Another example is provided by the case study of Dai et al. (2012). This SME engine valve manufacturer uses an RFID-enabled workshop manufacturing solution throughout its operations. Expands the integration of manufacturing execution systems and enterprise resource planning systems based on RFID-enabled real-time data.

Similarly, Jin et al. (2018) proposed a content-based cross-layer scheduling method named CONCISE for industrial IoT applications, which proposed a novel model to guide and collect data in a content-centric manner via Time Synchronized Channel Hopping (TSCH) scheduling. The advantage of this study was to balance the traffic load. Furthermore, experimental results showed that, according to the proposed scheduling method, network traffic congestion was reduced, communication reliability was improved and end-to-end delay is reduced.

Cimini et al. (2021) discussed the role of digital technologies in the implementation of mid- and high-level services. The application of digital technologies can further advance servitization by providing complex and novel services. The adoption of technologies such as Internet of Things (IoT) analytics and artificial intelligence can enhance or completely change the characteristics of delivered services and enable new service-oriented business models, thereby reshaping industry competition. In fact, product-centric companies introduced digital technologies to improve service delivery efficiency and the value of product-service offerings, while changing processes and business models.

Servitization is one of the main business models in the era of Industry 4.0 (Cimini et al., 2021). Rapidly evolving digital technologies offer opportunities to realize novel product service offerings, develop customized value propositions, higher quality services, and deeper customer relationships. The adoption of new technologies is critical for the shift to more service-oriented business models and the acceleration of servitization: manufacturers introduce digital technologies to improve the efficiency of their service delivery and increase the value.

Alhayani et al. (2021) studied artificial intelligence applied in IT industry, especially the effectiveness of artificial intelligence techniques against cyber security risks. The authors suggested artificial intelligence had become one of the main assets for businesses to improve their cybersecurity performance, and cyber security was a important aspect that every organization must ensure. The results revealed neural nets, intelligent agents had a significant impact on artificial intelligence and cybersecurity, except for expert systems. The findings provided the importance of artificial intelligence technology in IT professionals to take preventive measures to prevent cyber attacks.

Pylianidis et al. (2021) proposed information technology can be used to design and implement next-generation data, models and decision support tools for agricultural production systems. The application of digital twins provided an unprecedented level of control over physical entities and helped manage complex systems. The authors reviewed related literature on digital twins in agriculture in 2017-2020, and compared reported benefits, service categories, and technology readiness levels to assess the level of adoption of digital twins in agriculture. The results identified digital twin features that can provide added value to agriculture from digital twin applications in agriculture and other disciplines.

In the field of commerce industry, Alodib (2016) studied a model-driven approach to automate QoS-aware service composition, including real-time monitoring. As described, violating defined SLAs in multiple locations by different users was a significant problem. Therefore, the SLA proposed by users of different sites was mapped into the Petri net, thereby combining the Petri net model with the UML QoS model. The diagnostic theory of discrete event systems (DES) motivates the proposed algorithm, applied to Petri nets to generate composite services. Introducing a cost-effective survey to evaluate the performance of objects in IoT environments to meet QoS requirements is the main strength.

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The results identified digital twin features that can provide added value to agriculture from digital twin applications in agriculture and other disciplines.

In the field of healthcare and medical industry, Y. Liu et al. (2016) considered the application of 3D printing technology in the medical and health industry had several advantages. 3D printing technology can be used to replace, restore, maintain or improve tissue function. The replacement tissue produced by 3D printing technology had an interconnected pore network, biocompatibility, appropriate surface chemistry, and good mechanical properties. Shahrubudin et al. (2019) proposed 3D printing technology can also be used to print similar organ failures caused by critical issues such as disease, accidents and birth defects. 3D printing technology enabled the formation of highly controllable cancer tissue models, showing great potential in accelerating cancer research. By using 3D printing technology, patients can obtain more reliable and accurate data. The 3D printed output model can be used in the learning process to help neurosurgeons practice surgical techniques. By using 3D models, it also improved accuracy.

Meanwhile, IoT healthcare is a technical solution for networking things and devices. Consumer wearable devices currently on the market, such as the Apple Watch health app and the Nike Fuel bracelet, belong to the former IoT healthcare application. The technical scenarios of medical IoT healthcare show a wide range of applications. S. Kim and Kim (2018) examined key factors that influenced user acceptance of IoT lifestyle disease management services. Information about the service provider's specialization, scope of tasks, equipment, expert support and a range of shared personal medical data were considered important attributes.

Baloch et al. (2018) studied a hierarchical context-aware data composition method for IoT healthcare applications, and the proposed method includes context acquisition, conditional structure, and meaning. The authors explained body sensor networks (BSNs) or wireless body area networks (WBANs), typically placed on patients' bodies, to collect physiological data for IoT healthcare applications. Since data was collected from multiple heterogeneous sources, a technique for combining these datasets is required, known as "data fusion". This new approach facilitates presenting the collected data in a way that facilitates timely and precise decisions, addressing challenges such as sensor deficiencies, limited coverage, irregularities, and ambiguity.

Besides, Damis et al. (2018) analyzed theoretically and experimentally three epidermal loop antennas for measuring biological factors for application in healthcare IoT applications. In this study, Error Vector Magnitude (EVM) checks and BER factors are displayed and evaluated accordingly to verify the authenticity of GSM and BLE communications with QL antennas. The experimental results showed an appropriate reliability between the radiation form and the reflection coefficient. Datacom evaluations indicated that the obtained BER may be suitable for this antenna technology to operate in a 4-QAM wireless connection.

In the marketing industry, Nöjd et al. (2020) proposed that digitization changed the way customers search for relevant information, evaluate competing products, make purchases, and interacting with retailers and service providers. Service providers have applied digital in-store technology to their physical service environments, changing the way people were positioned in the brick-and-mortar retail space, transforming it into a psychological place that customers (consciously or unconsciously) empowered managers to see meaning and value. As a result, technological advancements made customers increasingly autonomous and changed the way they collaborated and integrated resources in the value creation process.

3D printing technology was related to fashion and plays an important role in corporate customization services of retail industry. 3D printed shoes, jewelry, consumer goods and clothing can effectively attract consumers' attention. In the clothing industry, through 3D printing technology, it can use grid systems to design and produce clothing, as well as print ornaments for traditional textiles. In addition, the application of 3D printing technology was not limited to the fashion industry, but can also print leather goods and accessories. For example, jewelry, watches, accessories, etc. In addition, 3D printing technology can provide creative ideas for marketing communications (Attaran, 2017; Vanderploeg et al., 2017).

proposed the application of artificial intelligence (AI) in social media and digital advertising promoted a better return on investment and increase the productivity, efficiency and profitability of an organization. Artificial intelligence technology was mostly applied in trend model, artificial intelligence application and machine learning technology. Machine learning was the use of algorithms to generate propensity models based on lessons learned from historical datasets. Applying propensity models was the application of these models in predicting a given event. Artificial intelligence applications referred to all other forms of artificial intelligence suitable for roles that are primarily used by humans.

Also, Ishfaq et al. (2021) found companies applying digital supply chain technologies and analytics can benefit from increasing the speed and agility of their internal processes. The authors proposed a conceptual framework to study the key elements of digital supply chains and their potential interactions. The results revealed that digital awareness of businesses help to transform into an ecosystem that iteratively guided the digital transformation process. Omnichannel retailing should be restructured, driven by digital technologies, and implementing ecosystem logic can provide businesses deliver digital capabilities.

In the field of electric and electronic industry, 3D printing technology offers advantages for the processing of products and their electronics. 3D fabrication techniques provide a low-cost and efficient method for mass production of electrode materials, and the 3D printing process of the 3D electrodes is fully automated with a high degree of precision. Besides, with multi-material printing technology, the efficiency of electronic systems may be adopted by Industrial Revolution 4.0, creating more innovative designs in one process. The development of green electronic devices with low manufacturing cost, good safety, high reliability and fast production speed is an urgent need in society to solve environmental pollution (Foo et al., 2018).

The applications of digitization in different industries benefit customers, providers, and the environment and society.

In terms of customer benefits, digital applications can replace on-site personal service, reduce costs, increase flexibility, improve access and save time. For example, Wünderlich et al. (2013) developed a basic framework for intelligent interactive services. Customers are empowered when they are given a set of options, tools and resources to facilitate decision making, allowing them to tailor products to their specific needs and desires. Integration through product and service design and improved use of ICT can lead to improvements in areas such as sustainability, strategy, design and technology.

In terms of benefits to suppliers, the application of cloud computing in manufacturing is used to innovate mechanisms to create value. This value is achieved by improving customer experience, enhancing customer perceptions of the company (thereby increasing total customer lifetime value and profitability), increasing customer stickiness, and reducing acquisition costs (Weinman, 2016). For example, Eloranta and Turunen (2016) examined the case of a technology platform that supported service delivery and facilitated relationships with stakeholders. digital servitization reduced operating costs, delays and cancellations, and increased productivity.

In terms of benefits to Environment-related benefits, such as reduced energy consumption and environmental impact, are also enhanced through digital services. Bressanelli et al. (2018) examined how IoT, big data, and analytics can facilitate the transition to a circular economy, and how these technologies can improve resource efficiency, extend product life, and “close the loop.” In addition, the continuous development of digital technologies brought value to society. Lindström et al. (2018) explored how a multipurpose cloud service platform based on the IoT paradigm can effectively monitor and optimize glass, paper, metal and plastic recycling and consumer processes by improving customer knowledge.

2.2.4 Business and employee adoption behavior

Many studies have discussed the antecedents of business digital adoption behavior. From the perspective of external environment and internal environment, the influencing factors mainly include market factor, competitor factor, organizational factor, technical factors.

Kuan and Chau (2001) studied the predictors for electronic data interchange (EDI) of small enterprises. The authors constructed a model of EDI adoption based on the technology-organization-environment framework, then verified the model by collecting data from 575 small enterprises. The results of regression analysis revealed that perceived direct benefits, perceived financial cost, perceived technical competence, perceived industry pressure, and perceived government pressure influenced adoption decisions.

Alshamaila et al. (2013) research analyzed the driving determinants of adopting cloud services by applying the Technological-Organisational-Environmental (TOE) model. The authors conducted the semi-structured interviews to collect data on 15 different small and medium enterprises (SMEs) and service providers. The findings of qualitative exploratory study showed that the major factors playing an important role were: relative advantage, uncertainty, geo - restriction, compatibility, trialability, size, top management support, prior experience, innovativeness, industry, market scope, supplier efforts and external computing support.

Yoon and George (2013) investigated the antecedents of organizations' intention to adopt virtual worlds based on a Technology-Organization-Environment model. The authors used the questionnaire survey data and a secondary Database data to identify influencing factors. The findings indicated that imitation pressure and normative pressure affected strongly the intentions to adopt virtual worlds, while the technical factors, such as comparative advantage and compatibility were not significant.

Gutierrez et al. (2015) identified the predictors of adopt cloud computing of managers in the UK by applying the Technology-Organization-Environment (TOE) model. The findings indicated that competitive pressure, complexity, technology readiness and trading partner pressure positively affected the adoption decision of cloud computing services, and the most important predictor for the adoption of cloud services was trading partner pressure.

El Ouirdi et al. (2016) studied the significant predictors for social media adoption in human resource management. Based on the Unified Theory of Acceptance and Use of Technology (UTAUT), the authors mainly examined the effect of four core variables (performance expectancy, effort expectancy, social influence and facilitating conditions) and the moderated variables (recruiters' characteristics) on the recruiter's intention to use social media. The empirical analysis results showed that four core variables and the moderated variables influenced the intention to use social media. Besides, the recruiters' characteristics moderated the influence of performance expectancy, social influence and effort expectancy on behavioral intention.

Hassan (2017) emphasized organizational factors influencing an organization's adoption of cloud computing. The authors conducted a questionnaire survey to collect data and constructed a structural equation model to supported hypothesis. The results showed that information technology (IT) resources significantly affected cloud computing adoption, while top management support and employee knowledge were not the driving determinants of cloud computing adoption.

Dincă et al. (2019) discussed the factors affecting cloud computing adoption by Romanian small and medium sized enterprises (SMEs), and further proposed a conceptual model affecting the choice of the company's management to apply cloud computing technologies. The results of the regression analysis showed that managers' expertise in cloud computing and the perceived cost of implementing the technology were the main factors influencing the spread of cloud computing among Romanian SMEs.

Najib and Fahma (2020) investigated the antecedents of the digital payment system adoption for small and medium-sized enterprises. Based on the extended Technology Acceptance Model (TAM), the authors conducted a questionnaire survey, and used Structural Equation Modeling with Partial Least Square to test hypothesis. The result showed that the perceived ease of usage, perceived usefulness, attitude towards digital payment and trust significantly affected the intention to use digital payment.

Grover et al. (2020) research investigated the feasibility of leveraging artificial intelligence (AI) within an organization from six factors: job-fit, complexity, long-term consequences, affect towards use, social factors and facilitating conditions as different elements of operations management. The research results provided guidance for managers to apply AI in different components of operations management, improving product quality and reducing defect rates or enhancing employee judgment prompted the use of artificial intelligence of employees.

Won and Park (2020) explored the antecedents and implications of smart factory adoption by small and medium enterprises (SMEs). The authors conducted an analysis of SMEs in South Korea, the research findings revealed that experienced benefits of prior information and the unique characteristics of SMEs had no significant impact on smart factory adoption intentions. Instead, existing information investments and efforts appeared to affect negatively.

Shi et al. (2020) determined the factors influencing the adoption of smart manufacturing-related information and digital technologies (SMIDT) within manufacturing small and medium-sized enterprises (SMEs). The findings of a cross-sectional survey revealed that SMIDT adoption were influenced by technological, organizational, and environmental factors.

Ghobakhloo (2020) investigated the antecedents of the adoption of information and digital technologies for smart manufacturing. Through the literature review and consulting experts, the authors conducted an interpretive structural model. The findings indicated perceived benefits and management support were considered the driving factors of the implementation of information and digital technologies, and operational technology maturity and cybersecurity maturity were dependent determinants.

Henao-Ramírez and López-Zapata (2021) examined the factors that influence companies' willingness to adopt 3D Design Digital Technology (3DDT) from technical, organizational, and environmental perspectives. The results confirmed that five factors: perceived usefulness, technical ability, senior management support, competitive pressure, and competitive pressure significantly affected firms' intention to adopt 3DDT. In addition, the authors analyzed the mediating role of perceived usefulness, senior management support, and competitive pressure.

M. Yang et al. (2021) explored the reasons why manufacturing companies adopted digital technologies and the impact of adoption on supply chains. The study pointed out that the adoption of digital technology was influenced by corporate strategy, with manufacturing companies deploying digital as an important business to help better meet customer needs, predict inventory problems, rationalize the use of resources and maintain supplier relationships. The driving determinants for enterprises to adopt data technology included external driving and internal driving. Internal drivers related to operational issues and strategic direction, while external drivers referred to customers, suppliers or other supply chain partners, and competition.

Suroso and Rafinda (2021) study examined the antecedents of digital marketing adoption behavior in micro and small businesses. The findings showed that perceived ease of use, perceived usefulness, and perceived scale of economic benefits positively influenced a firm's intention to use digital marketing. Businesses' motivation for digital marketing was the expected economic benefits, while businesses believed that there was an option to inquire about digital marketing services when needed.

Dabas et al. (2021) compared the adoption of digital marketing and related tools by restaurant businesses in the UK and India, the authors understood the extent of adoption of digital marketing tools and how businesses accepted digital change in their operations based on qualitative research.The results revealed a clear gap between the restaurant space in India and the UK, with UK restaurateurs using selective digital tools such as personal social media accounts to create more personalised engagement to meet customer demand, while India of restaurants had not yet fully leveraged digital media as a strategic tool for marketing.

Meanwhile, some studies have explored the driving determinants of employee digital adoption behavior. From the perspective of external motivation and internal motivation, the influencing factors include employee characteristics, technical factors, organizational factors.

Yunus et al. (2016) focused on employee attitudes toward the use of mobile money in large nonprofit organizations, in particular considered the role of reliability, efficiency, and quality. Based on 11 focus group discussions and 50 in-depth interviews, the results found that most employees agreed that using mobile money reduced workload, saves time and money, and contributed to an easier life. However, a small number of employees expressed concern that mobile money posed a threat to their job security, which had hindered employees' willingness to adopt mobile money to some extent.

Gupta et al. (2017) identified the most significant factors influencing the adoption of e-government employee. The results showed there were eleven factors affecting on the adoption of e-government employee, which were mainly divided into four types: employee personal characteristics, technical factors, organizational factors and trust. Besides, organizational factors and technical factors were the two most significant factors influencing government employees’ intention to adopt e-government, and training, technical infrastructure, speed of access, technical support and trust were the top five sub-factors for employee adoption of e-government.

Sabi et al. (2018) investigated educators' attitudes towards the adoption of cloud computing in the education process. The authors constructed a research model based on innovation theory, and applied questionnaire data to verify the research hypothesis. The results indicated that sociocultural factors and the provability of results influenced employees' willingness to adopt cloud computing. Furthermore, gender had a moderating effect, there were statistical differences in male and female employees' perceptions of cloud computing adoption, and the relationship between cost and cloud computing adoption was significant among female employees, but not among males.

Anjum and Islam (2020) identified the factors influencing employee’s adoption of Electronic Human Resource Management (E-HRM) based on Technology Acceptance Model. The authors collected questionnaires data from 130 employees, and then conducted a regression analysis. The findings indicated that employee technical competency significantly affected perceived usefulness and perceived ease of use, organizational innovativeness significantly affected perceived ease of use and adoption intention, while organizational resources competency was a factor influencing perceived usefulness. Besides, perceived usefulness and perceived ease of use had effects on intentions of adopting E-HRM.

Brachten et al. (2021) studied how employees accepted and adopted enterprise bots. The authors constructed a research model based on decomposition of planned behavior theory. The findings of structural equation model revealed that the internal motivation of employees positively impacted on the intention to use enterprise bots, while the external motivation had less impact on the intention to use enterprise bots.

Chadee et al. (2021) research investigated how digital work connectivity impaired employee work behaviors. The results suggested that digital work connectivity led to a decline in self-control, affecting the disengagement from work. Additionally, relational energy was a necessary resource buffering the detrimental effects of digital work connections on hotel employees. The link between digital work connectivity and employee exit behavior underscored the urgent need for hospitality companies to develop clear guidelines governing the use of technology at home for work purposes.

Venkatesh (2022) considered that employee adoption of AI tools was a necessary step for organizations’ benefits, and investigated the antecedents of employee adoption and use of AI tools. Applying the unified theory of acceptance and use of technology, the authors proposed a model from the perspective of individual features, technology features, environmental features and interventions. The findings revealed incomplete information from stakeholders outside the organization, tolerance for uncertainty, a climate of innovation, and gamified training were considered as possible driving determinants.

Besides, other studies focus on individual motivation of adopting digital technology, From the perspective of hedonic and utilitarian motivations, the influencing factors include functional elements, social element and relational element.

Gao and Bai (2014) focused on consumer adoption of Internet of Things (IoT) technologies. Based on the technology acceptance model, the authors considered the role of social influence, enjoyment, and perceived behavioral control, and developed a research model from three perspectives: technical characteristics, social context, and user characteristics. The empirical analysis results showed that users' perceived usefulness, perceived ease of use, social influence, perceived enjoyment, and perceived behavioral control significantly affected users' willingness to adopt IoT technologies, however, the role of trust was not significant. Besides, the study found that perceived ease of use and trust were antecedents of perceived usefulness.

Ratten (2014) discussed cloud computing services, the author firstly pointed out that the use of cloud computing technology had advantages across time and space, and consumers could use computers to generate continuously expanding and merging information. Furthermore, the drivers of consumer adoption of cloud computing services were explored. Combining technology acceptance models and social cognition theories, the author constructed a research model that influenced cloud computing service adoption intentions, suggesting the facilitative roles of perceived usefulness, consumer innovation attitudes, social norms, performance expectations, and trust. In addition, the study also demonstrated differences in American and Chinese consumers’attitudes towards technological innovation.

Pham and Ho (2015) explored the factors that promoted consumers' intention to adopt NFC-based mobile payment from the dimensions of product characteristics, consumer personal characteristics, trust and attractiveness of alternatives. The findings revealed that the behavioral intention of NFC mobile payment was affected by perceived usefulness, compatibility, perceived risk, trialability, added value of NFC mobile payments, innovation of new technologies, absorptive capacity, and attractiveness of alternatives, however trust was not an antecedent of consumers’ willingness to adopt NFC-based mobile payments.

Chawla and Joshi (2019) explored the antecedents of consumer’s willingness to use mobile wallets. The authors developed a model based on the technology acceptance model and unified theory of acceptance and use of technology. The findings revealed that the importance of perceived ease of use, perceived usefulness, trust, security, facilitating conditions and lifestyle compatibility for the consumer willingness to use mobile wallets, while security didn’t significantly impact on willingness to use mobile wallets.

Belanche et al. (2019) focued on the application of artificial intelligence in financial technology and discussed the customer’s robo-advisor adoption. The results found consumers’ attitude to robo-advisors, mass media and interpersonal subjective norms were the significant factors affecting customer’s robo-advisor adoption. Besides, for the customers who were familiar with robots, perceived usefulness and attitude had a higher effect on adoption, while for the customers who were less familiar with robots, The effect of subjective norms was more significantly relevant.

Gursoy et al. (2019) explained customers’ intention to adopt artificially intelligent device in service process. The authors collected questionnaire data and verified the developed model. The results revealed three stages(primary appraisal, secondary appraisal and outcome stage) had effects on adoption of using artificially intelligent device. Specifically, social influence and hedonic motivation significantly impacted on performance expectancy, and anthropomorphism was antecedent of effort expectancy. Further, performance and effort expectancy positively affected customer emotions and adoption.

McLean and Osei-Frimpong (2019) proposed a research model to analyze the adoption of artificial intelligent in-home voice assistants. The authors interviewed 724 customers and conducted the analysis of structural equation model. The results suggested that utilitarian benefits, symbolic benefits and social benefits were driving determinants of adoption, and perceived privacy risks palyed a moderated role in the process of the adoption of artificial intelligent in-home voice assistants.

Nikou et al. (2020) studied that elderly people adopted digital healthcare technologies based on the capability approach framework. Combining qualitative and quantitative methods, the research found the willingness of using online healthcare website was influenced by the desire to use digital healthcare technologies to improve elderly people's ability to live independently. The findings suggested the availability of digital technology mediated the relationship between outcome expectations and willingness to use digital technology, and how digital technology enabled people to live in valuable ways to them should be considered.

Vishwakarma et al. (2020) investigated the antecedents of consumers' intent to adopt virtual reality (VR). the authors discussed factors about perceived benefits and perceived sacrifices based on the value-based adoption model. The findings indicated that perceived value was one of the most important predictors of VR adoption, perceived immersion and perceived physical risk significantly affected user adoption, while perceived cost did not significantly affect perceived value of VR use. In addition, the moderating effect of gender was not significant.

Shin and Jeong (2021) studied travelers' motivation of adopting augmented reality and the moderating effects of personal innovation. The authors constructed a conceptual model based on cognitive evaluation theory and self-presentation theory. The results showed that adopting augmented reality was influenced by hedonic and utilitarian motivations, and self-presentation motivation positively affected travelers' attitudes toward augmented reality for the highly innovative group.

Andrews et al. (2021) investigated the determinants of the willingness to adopt artificial intelligence. The findings showed that performance expectancy and attitude to use of artificial intelligence significantly affected on the willingness to adopt, while social influence and effort expectancy were not the determinants of the willingness to adopt artificial intelligence.

Erdmann et al. (2021) examined the use of augmented reality (AR) technology by businesses to drive consumers' willingness to buy online. Based on a cost-benefit analysis, the authors focused on consumers' value assessments and the impact of technological, experiential, and social AR value drivers, and constructed a model based on enhanced value adoption. Survey data results revealed that the technical dimension had an ambiguous impact, and technical complexity directly increased the perceived value of purchasing online, while reduced the net value of the consumer economic cost-benefit analysis. Besides, experiential and social AR dimensions significantly affect consumers' online purchase intention.

Fernandes and Oliveira (2021) confirmed the driving factors of the adoption of digital voice assistants. The authors developed a model from the perspective of functional elements, social element and relational element, and then used the questionnaire survey data to identify influencing factors. The results showed that adoption was drived by functional, social and relational elements, and experience and interpersonal Interaction needs had significant moderating effects.

Fazal-e-Hasan et al. (2021) identified antecedents of consumer intention to apply smart retail technology. The authors conducted a survey of 338 consumers with SRT experience, and the results of structural equation modeling indicated that SRT's perceived novelty, perceived efficacy, perceived compatibility and perceived risk were driving factors of customers' intention to use. In addition, the authors utilized fuzzy set qualitative comparative analysis to analyze the combined effects of various factors, the findings revealed the combination of perceived novelty and perceived compatibility increased the willingness to use.

More recently, the COVID-19 outbreak has changed life and office scenarios, and boosted the development of digital technologies, applications relying on digital technology become widely popular. For example, users adopt the Zoom video service to keep in touch with family and friends. At the same time, digital technology has promoted the rise of the online industry. In the education industry, teachers and students adopt Zoom to conduct remote classrooms, while in the medical industry, doctors provide virtual consultation services for patients, which brings great convenience (Sheth, 2020).

Similarly, due to the adverse impact of the epidemic, governments and businesses deploy a number of digital interventions. Akinnuwesi et al. (2022) focused on digital tackling techniques to explore the factors that influence users' behavioral intentions to accept and use digital tools. The results showed performance expectations, facilitation conditions, and social influences had a significant impact on an individual's willingness to accept and use digital tackling techniques. In addition, the moderator such as age, gender, and voluntary use had no effect on behavioral intention.

2.3 Digital technology-enabled business operational performance

In different industries, firms adopt various digital technologies, and consequently the mechanisms of digital technology-enabled business operational performance are different (Y. Li et al., 2020; W. Yu et al., 2021). Therefore, this part reviews related literatures according to different industries. First, we refer to the Global Industry Classification Standard (i.e., GICS), which includes 10 industry sectors (i.e., consumer discretionary / staples, energy, financials, health care, materials, telecommunication services, utilities, industrials, and information technology) (P. F. Chen et al., 2016). Second, we refer to the China Industry Classification Standard (i.e., CICS), which includes mining, foods and tobacco, textile, wood, paper and printing, processing of petroleum, coking, processing of nuclear fuel chemical products, metals and non-metal products, machinery, production and supply of electric power and gas, and so on (Fan & Wang, 2014). Finally, we integrate the two classification standards and review literatures according to the three industries: consumer staples (e.g., food, medicine, etc.), energy and manufacture, and service.

2.3.1 Digital technology-enabled business operational performance in consumer staples

The related literatures of digital technology-enabled business operational performance in consumer staples mainly investigate the enabled mechanism of big data analytics capability (BDAC), green supply chain management (GSCM), lean automation (LA) practices, employees' involvement (EI), and so on (De Giovanni & Cariola, 2021; G. Tortorella et al., 2021; G. L. Tortorella et al., 2021; J. Yu & Moon, 2021). The details are as follows.

W. Yu et al. (2021) explored the relationship between digital technologies orientation and operational performance in healthcare industry. Concretely, the digital technologies included artificial intelligence, machine learning, big data analytics, Internet of Things, and blockchain, and the operational performance include quality, delivery, and cost performance. Additionally, the study explored the mediate role of big data analytics capability, and controlled hospital age, size, and state-owned hospital type. The result showed that big data analytics capability fully mediates the digital technologies orientation and operational performance relationship.

Dubey et al. (2020) investigated the relationship between digital technologies (i.e., big data analytics and artificial intelligence, known as BDA-AI) and operational performance in eight different industries (mainly including food, consumer goods, chemicals, pharmaceuticals, electrical, equipment, pulp and paper, and so on). Specifically, the operational performance included revenue, profit to revenue ratio, market share, return on investment / capital employed, cash flow from operations, new product / service development. Additionally, the study controlled organizational size (OS), and industry type (IT). The result showed that the BDA-AI capabilities enables a business to achieve superior operational performance.

De Giovanni and Cariola (2021) explored the relationship between business leanness and operational performance, and the moderate role of a process innovation strategy based on digital technologies in various industries (mainly including pharmaceuticals, agriculture, and others). Concretely, the digital technologies in this study included robotics, automated guided vehicles (AGV), 3d printing, smart sensors, industrial internet of things, and advanced human-machine interface, and the operational performance included total cost, lead time, time to market, quality standards, level of service. Additionally, the study explored the mediate role of green supply chain management (GSCM), and the moderate role of digital technologies adoption (i.e., investing in process innovation through digital technologies). The result showed that a process innovation strategy based on digital technologies improved the effect of business leanness on operational performance, which led to higher economic outcomes of business.

G. L. Tortorella et al. (2021) investigated the relationship between lean automation (LA) principles (i.e., sociocultural-oriented and technology-oriented) and the firm's operational performance mainly in food, textile, and chemical industries. Specifically, the digital technology-oriented included digitally interconnected machines / devices / sensors, digital twins, cyber-physical systems, and the operational performance included safety (work accidents), quality (scrap and rework), delivery service, productivity, inventory. Additionally, the study explored the mediate role of lean automation (LA) practices (mainly oriented to workplace level, known as micro-level, value stream, known as meso level), extended value stream or supply chain, known as macro level), and controlled tier level, company size. The result showed that lean automation practices positively mediate the relationship between lean automation principles and the firm's operational performance.

G. Tortorella et al. (2021)explored the relationship between digital technologies adoption and operational performance improvement in various companies (mainly including food, chemical, and textile). Concretely, the digital technologies in this study included digital automation, remote monitoring of production control, big data, cloud services, and the operational performance included productivity, delivery service level, inventory level, quality (scrap and rework). Additionally, the study explored the mediate role of employees' involvement (EI), and controlled company size, technology intensity. The result showed that employees' involvement indeed has a positive mediating effect on the relationship between digital technologies adoption and operational performance.

2.3.2 Digital technology-enabled business operational performance in energy and manufacture

The literatures of digital technology-enabled business operational performance in energy and manufacture mainly investigate the enabled or empowered mechanism of integration, collaboration, efficiency, transparency, and responsiveness in supply chain (SC), organizational learning (OL) capabilities at different contextualization levels (i.e., individual, team, organization), digital supply chain platforms, supply chain capability, lean automation (LA), circular economy (i.e., resource output rate, resource consumption rate, integrated resource utilization rate, waste disposal and pollution emission rate, dynamic remanufacturing capability) (Bag et al., 2021; Frederico et al., 2021; Y. Li et al., 2020; Rossini et al., 2019; G. L. Tortorella et al., 2020; W. Yu et al., 2021). Szász et al. (2020) summarized related literatures and found that digital technologies had a positive impact on operational performance (mainly including quality, delivery, cost, and flexibility), which indicated that larger companies invested more in implementing digital technologies, and manufacturing companies in less competitive regions invested more effort than competitive regions, as well as multinational firms have no advantage over local firms. The review mainly explored 3D printing, augmented, virtual reality, Internet to Things, and adaptive manufacturing system, which summarized as digital technologies. However, the review not mentioned the specifically enabled or empowered mechanism. The literatures of specifically enabled or empowered mechanism are summarized as follows.

Buer et al. (2021) investigated the relationship between company digitalization and improved operational performance in manufacturing industry. Specifically, the digital technologies (i.e., digital sensors, Internet to Things, digital monitoring, control, optimization, and automation), and the operational performance included throughput time, product quality, production cost per unit, process flexibility / uptime. Additionally, the study explored the moderate role of lean manufacturing, and controlled production repetitiveness, length of lean implementation, company size. The result showed that the company digitalization contribute to improved operational performance, and there is a complementary effect when combined company digitalization and lean manufacturing.

Gillani et al. (2020) explored the relationship between digital technologies and company performance in manufacturing industries. Concretely, the digital technologies in this study included 3D printing and high precision technologies, smart / digital factory, reconfigurable manufacturing systems, automation, robotics and automated guided vehicles, and RFID, and the operational performance included flexibility, design, delivery, quality performance. Additionally, the study controlled the company size, high / low-tech industry. The result showed that the adoption of digital technologies had a significant impact on company operational performance.

Ahmad et al. (2021) investigated the relationship between artificial intelligence technologies and operational performance and efficiency in energy industry. Specifically, the AI technologies, which belonged to digital technologies, mainly included machine learning, deep learning, IoT, big data, cloud data storage, and analytics, etc., and the operational performance included time, productivity, and optimization performance. The result showed that artificial intelligence technologies outperformed traditional models in big data handling, controllability, cyberattack prevention, Internet to Things, robotics, smart grid, predictive maintenance control, energy efficiency optimization, and computational efficiency in energy market, and artificial intelligence was becoming a key enabler of a new, complex, and data-related energy industry, providing a key tool to increase operational performance and efficiency in an increasingly cutthroat environment.

Frederico et al. (2021) explored the relationship between digital technologies and supply chains processes (SCPs) performance in operations and supply chain management (SCM) fields. Concretely, the digital technologies in this study included Internet of Things (IoT), cloud technology (CT), cyber-physical system (CPS), big data analytics (BDA), and cyber security systems (CSS), and the profitability, which included sales and costs. Additionally, the study explored the mediate role of integration, collaboration, efficiency, transparency, and responsiveness in supply chain (SC), and the moderate role of interoperability in supply chain (SC). The result showed that digital technologies significantly impacted supply chains processes (SCPs) performance (i.e., integration, collaboration, transparency, and responsiveness), and the integration of digital technologies and their interoperability had a positive impact on supply chains processes profitability.

G. L. Tortorella et al. (2020) investigated the relationship between digital technologies and achieving higher operational performance in manufacturing firms. Specifically, the digital technologies mainly included Internet to Things, cloud computing, big data, data analytics (e.g., machine learning and data mining), and the operational performance included safety (work accidents), delivery service level, quality (scrap and rework), productivity, inventory level. Additionally, the study explored the mediate role of organizational learning (OL) capabilities at different contextualization levels (i.e., individual, team, and organization), and controlled the company size. The result showed that learning capabilities at an organization level positively mediated the effect of digital technologies on achieving higher operational performance, but learning capabilities at an individual and a team level may not present a significant effect on such mediation.

Y. Li et al. (2020) explored the relationship between digital technologies and both economic and environmental performance in manufacturing firms. Concretely, the digital technologies in this study included Internet of Things (IoT), cloud computing (CC), big data and analytics (BDA), and the economic performance included return on sales / investment, profit, sales, market share and the environmental performance included air emission, waste water, solid wastes, firm’s environmental situation. Besides, the study explored the mediate role of digital supply chain platforms, and the moderation role of environmental dynamism, and controlled the ownership type, number of employees, sales. The result showed that digital supply chain platforms mediated the effects of digital technologies on both economic and environmental performance, and the mediating effects was enhanced under a high degree of environmental dynamism.

Chauhan et al. (2021) investigated the relationship between digital technologies adoption and operational performance in manufacturing companies. Specifically, the digital technologies mainly included digital automation, sensors, remote monitoring, integrated engineering systems, big data, cloud services, IoT, and the operational performance included operating costs, time required for creating and delivery, quality, product innovativeness, product capability and performance. Additionally, the study explored the moderation role of extrinsic and intrinsic barriers to digital technologies adoption. The result showed that intrinsic and extrinsic barriers was negatively linked with the digitalization, and digital technologies adoption improved operational performance and supply chain competency.

W. Yu et al. (2021) explored the relationship between digital technologies and business operations in automobile industry. Concretely, the digital technologies in this study included cloud computing, artificial intelligence (AI), Internet of Things (IoT), and blockchain technology (BCT), and the operational performance included quality, new products. Besides, the study explored the mediate role of circular economy and supply chain capability. The result showed that digital technologies had the potential to make significant improvements in business operational performance, and digital technologies played a positive role in implementation of circular economy practices and supply chain capability, and the circular economy practices provided evidence to have positive relationship with operational performance, as well as supply chain capability.

G. L. Tortorella et al. (2019) investigated the relationship between lean production practices on operational performance improvement in manufacturing industry. Specifically, the digital technologies mainly included digital automation, sensors, manufacturing execution system, virtual models, Internet to Things, 3D printing, simulation, big data, cloud services, and the operational performance included productivity, delivery service, inventory, quality (scrap and rework), safety (accidents). Additionally, the study explored the moderation role of digital technologies, and controlled technological intensity, tier level, company size, duration of lean production (LP) implementation. The result showed that digital technologies moderated the effect of lean production practices on operational performance improvement, but in different directions. Besides, the process-related technologies negatively moderated the effect of low setup practices on operational performance, whereas product / service-related technologies positively moderate the effect of flow practices on operational performance.

Rossini et al. (2019) investigated the relationship between lean automation (LA) and operational performance in manufacturing industry. Specifically, the digital technologies mainly included digital automation with(out) sensors, digital automation with process control sensors, manufacturing execution system, supervisory control, data acquisition, flexible lines integrated engineering systems, additive manufacturing, rapid prototyping or 3d printing, finite elements, computational fluid dynamics, big data, cloud services, internet-of-things, product service systems, and the operational performance included productivity, delivery service level, inventory level, and quality (scrap and rework). Additionally, the study explored the mediation role of lean automation (LA), and controlled the company size, lean implementation time. The result demonstrated that there was the positive correlation between lean automation and operational performance, and that lean automation implementation generated a competitive advantage, probably because it integrated simultaneously so many elements of Lean Production (LP) and digital technologies.

Bag et al. (2021) explored the relationship between digital technologies and sustainable supply chain operations in manufacturing industries (i.e., automotive, mining, steel, and engineering industries). Concretely, the digital technologies in this study included internet of things, big data, and the operational performance meant sustainable supply chain operations (i.e., supply chain resilience, cost savings, customer retention). Besides, the study explored the mediate role of circular economy (i.e., resource output rate, resource consumption rate, integrated resource utilization rate, waste disposal and pollution emission rate, dynamic remanufacturing capability), and the moderation role of control orientation (i.e., coordination, discipline, communication), flexible orientation (flexible production line, supplier flexibility).

The result showed that using digital technologies to improve resource consumption rate and reduce waste and pollution was most likely to enhance sustainable supply chain operations, and both the control orientation and flexible orientation of the production team enhance their ability to generate positive sustainable outcomes from digital technologies use, which should generalize to developing nations. The study found that there were viable pathways to sustainable supply chain operations, driven by digital technologies applications, through reducing waste and pollution and improving resource consumption.

G. Li et al. (2021) explored the relationship between corporate social responsibility and idiosyncratic risk mainly in manufacturing industry. Concretely, the digital technologies included Artificial Intelligence, Machine Learning, Neural Network, Genetic Algorithm, Support Vector Machine, SVM, Bayesian, Decision Tree, and so on, and the operational performance referred to firms' capability to transform their resources into outcomes and is also referred to as operational productivity or operations capability. Additionally, the study explored the moderation role of AI innovation, operational efficiency, and controlled Firm-level variables, which included return-on-assets, cash flow, financial leverage, firm size, firm age, R&D intensity, dividend pay, profits volatility, market-to-book ratio, and Industry-level variables, which included Herfindahl-Hirschman Index, industry growth, industry risk. The result showed that 1) corporate social responsibility (CSR) can negatively affect idiosyncratic risk (IR), exhibiting a U-shaped relationship; 2) firms with high operational efficiency can obtain a higher optimal benefit by improving their corporate social responsibility (CSR); 3) AI innovation weakened corporate social responsibility's (CSR) positive impact on idiosyncratic risk (IR).

Rossini et al. (2019) investigated the interrelation between digital technologies and lean production practices on operational performance in manufacturing industry. Specifically, the digital technologies included robotic, RFID, cloud computing system, Artificial intelligence, machine learning, additive manufacturing, rapid prototyping, 3D printing, Big data, Internet of Things, and the operational performance included productivity, delivery service level, inventory level, workplace safety (accidents), quality (scrap and rework). Additionally, the study explored the moderation role of lean production implementation, company size, type of ownership, business operating model, technological intensity. The result showed that digital technologies are highly related to lean production practices.

Ghobakhloo and Fathi (2019) explored the relationship between digital technologies and operational performance in manufacturing firm. Concretely, the digital technologies included Industrial Internet of Things (IIoT), Internet of Services, Blockchain, cloud/big data, and so on, and the operational performance included operational excellence, revenue growth, product innovation performance, customer relationship effectiveness, marketing agility, customer satisfaction, waste avoidance and minimization. Additionally, the study explored the mediation role of IT-enabled capabilities, which included lean-digitized manufacturing, knowledge ambidexterity, leagile manufacturing, proactive corporate environmental strategy, supply chain integration capabilities, market sensing capability, new product development effectiveness, improvisational capabilities. The result showed that 1) transition requires the integration of many digital technologies; 2) smaller firms can begin with digitization of operations in support of core strategies; 3) the lean-digitized manufacturing system is a business strategy for survivability.

S. Khan et al. (2021) investigated the relationship between digital technologies and operational performance in manufacturing companies. Specifically, the digital technologies referred to blockchain technology, and the operational performance included product quality, performance, on-time delivery, entire cost. Additionally, the study explored the mediation role of green information system, green supply chain practices. The result showed that 1) BT (blockchain technology) and GIS (green information systems) positively influence SSCP (sustainable supply chain practices); 2) GIS (green information systems) positively influence SSCP (sustainable supply chain Practices); 3) SSCP (sustainable supply chain practices) have a positive and significant relationship with operational performance; 4) operational performance have a significant effect on organizational performance.

Bag et al. (2020) explored the relationship between digital technologies and operational performance in mining industry. Concretely, the digital technologies referred to Big data, and the operational performance included visibility of supply chain dynamics, risks managed, costs, supply timely, respond in volatile environment, and so on. Additionally, the study explored the mediation role of innovative green product development, employee development, innovation and learning performance, and the moderation role of supply chain innovativeness. The result showed that 1) BDA-MC (big data analytics management capabilities) have a significant effect on IGPD (innovative green product development) and SSCO (sustainable supply chain outcomes); 2) BDA-TC (big data analytics talent capabilities) have a significant effect on ED (employee development) and SSCO (sustainable supply chain outcomes); 3) ILP (innovation and learning performance) affect SSCP (sustainable supply chain performance), and SCI (supply chain innovativeness) has an important moderating role.

Cadden et al. (2022) explored the relationship between digital technologies and operational performance in manufacturing sector. Concretely, the digital technologies included machine learning, expert systems, robotics, natural language processing, machine vision, speech recognition, and the operational performance included operating cost, inventory costs, flexibility, delivery performance. Additionally, the study explored the mediation role of SCCE (supply chain cultural enablers, e.g., process, relationships, information sharing, autonomy, data driven, customer focused), and controlled sales turnover, industry sector, organizational size, length of relationship. The result showed that CE (cultural enablers) have on the successful integration of digital technologies in supply chains performance.

W. Yu et al. (2020) explored the relationship between digital technologies and operational performance mainly in automobile, electronics and electrical industries. Concretely, the digital technologies included lean techniques (e.g., pull-production systems, variability reduction, continuous improvement, quality management, people involvement), and the operational performance included financial, environmental, social performance. Additionally, the study explored the mediation and moderation role of lean practices, and controlled firm size. The result showed that 1) innovativeness was positively associated with LPs (lean practices); 2) innovativeness indirectly affected operational performance through the mediation of LPs (lean practices), and LPs (lean practices) did not moderate the effects of innovativeness; 3) the integrating innovation and LPs (lean practices) achieved improved operational performance.

Raut et al. (2019) investigated the relationship between digital technologies and operational performance in manufacturing industry. Specifically, the digital technologies included IoT, big data, cyber-physical system (e.g., CPS), additive manufacturing, cloud manufacturing, and the operational performance included environment technology / improvement in relevant knowledge, air pollution control / carbon footprint / eco-packaging / reduction in solid and water waste / recycling efficiency, environment / responsiveness / supply chain cost, customer satisfaction. Additionally, the study explored the mediation role of big data analytics (BDA). The result showed that digital technologies enabled sustainable practices have a significant influence on BDA (big data analytics) and SBP (sustainability business practices / performance).

2.3.3 Digital technology-enabled business operational performance in service industries

Relevant literature on the operational performance of digital technology business in services mainly studied the impact of digital technology in industrial services, healthcare services and tourism services on related operating performance. Among them, industrial services mainly studied product and service systems, such as product-service systems (PSS)(Lerch & Gotsch, 2015; Pirola et al., 2020), operational services (DOS) and other platforms, and digital technology in the service process (Blichfeldt & Faullant, 2021; Zhou et al., 2021), medical services mainly focuses on the impact of technology on operational efficiency and value creation(K. S. Hong & Lee, 2017; Laurenza et al., 2018; Mazor et al., 2016; Russo et al., 2019), and tourism services mainly study the impact of digital technology on its competitiveness and agility (Hadjielias et al., 2022; Melián-Alzola et al., 2020). The details are as follows.

In recent years, global manufacturing was undergoing major changes, and industries must respond to competitive pressure through automation and digital technologies based on the utilization of intelligent data systems and technology. Product manufacturers were increasingly shifting from simply selling products to providing suitable supporting services. These services ranged from traditional product-related services such as maintenance, repair, and training to advanced customer-oriented services. Advanced services were often in the form of product-service systems (PSS), or were bundled with intangible services in a customized manner to meet highly personalized customer needs. These innovative, personalized product-service bundles increased the value delivered to customers and thus increased vendor competitiveness.

The term smart PSS mainly referred to a PSS based on “networked smart products and service systems for providing new functionalities” Pirola et al. (2020), thus leveraging on digital architectures, Internet of Things, cloud computing and analytics. Research found that manufacturers provide innovative PSS, such as availability guarantees or build–operate–transfer (BOT) models, which increased customer value on the one hand and created competitive advantage for the provider on the other. For the pure digital service section, companies offered novel services enabled by ICT systems, including software-based simulations, virtual or augmented reality applications, and digital technical analyses. Lerch and Gotsch (2015) found that these services both extended the company’s service offerings and significantly enhanced the performance of the product or service that is the core offering.

The operational services (DOS) presented were the key part of a novel digital platform called DigiPrime, whose aimed is to provide SME with a federated service infrastructure that help overcome the current information asymmetry and explore the possibility to access and transit towards a CE cross-sectorial value-chain. Pedone et al. (2021) found that by using the DOS platform, SME could enjoy highlighting thefinancial advantages of resource and energy efficiency, the access to innovative manufacturing services, as well as mentioning the potential for improving competitiveness in a cross-sectorial environment. In other words, SME could integrate operation services through digital platforms, so as to promote cross-industry and circular economy transformation.

Blichfeldt and Faullant (2021) analyzed the relation between product and service innovation and competitive advantage as measured by return on sales (ROS). The results showed that, for service innovation in process industries, in the low-tech sectors, digital technologies were used to generate product and services innovations which then translated into higher performance. In contrast, in the high-tech sectors, digital technologies had a direct impact on performance and are thus rather accustomed to realizing the efficiency gains not primarily used for innovation.

Zhou et al. (2021) explained how digitalization and servicing mutually affect corporate performance. By adopting the service-dominant logic, the study examined how two types of servitization—basic and advanced—interact with two types of digitalization—internal and external—in influencing the market performance of a manufacturer. The results indicated a mismatch between advanced services and internal digitalization. Because internal digitization was more focused on the operation of the company, it was usually driven by new methods and management concepts, which also required most employees to absorb new knowledge. The increasing improvement of internal digitization might dilute the resources required to provide advanced services, thus inhibiting the positive impact of advanced services on enterprise market performance.

Healthcare (HC) refers to all the services provided by medical professionals to protect people's physical and mental health, and it has been one of the major industries where the digital transformation takes place. Research in HC focuses on the impact of technology on operational efficiency and value creation.

Based on the scientific research of design, examples of HC related to operational efficiency through the hospital emergency department were provided by Mazor et al. (2016). The researchers studied its impact on patient duration of hospital stay by developing digital dashboard prototypes. Their findings suggested that the average patient stay time may decrease by 34%, this will relieve overcrowding and improve productivity.

K. S. Hong and Lee (2017) investigated the impact of operational innovations such as advanced information technology (IT) systems and applications of supportive knowledge and skills (SKS) on the quality of care and customer loyalty. The results suggested that the use of IT systems and SKS which provided quality care in operational innovation increased customer intimacy, thereby enhancing patient satisfaction and customer loyalty.

Laurenza et al. (2018) examined that how IT impacts business process improvements in the healthcare industry through an illustrative case. The results showed that the adoption of digital technology can improve the performance of major medical business processes, especially those that can be simplified through the adoption of information technology. More specifically, digital technology can improve efficiency while providing shorter response times and better quality.

Health information systems (HIS) can significantly improve health care, and Ker investigated the possibility of using HIS to reduce outpatient flow delays by focusing on improvement. The results suggest that adoption of HIS can not only minimize confusion in the outpatient operating room but also the time and costs associated with patient flow.

Furthermore, among stakeholders in digital-enabled operations, Russo et al. (2019) focused on patient empowerment, which defined as "the patient's health education, responsibility, and active participation in medical management". Empowerment meant that patients shift from passive guidance and treatment to subjects able to collect and analyze information related to their condition and manage their own health status. In the long term, for the healthcare system, patient empowerment means better management of resources, improved quality of service and patient satisfaction, thus reducing the cost of healthcare services.

Travel organizations used different digital technologies to facilitate services, interacted with actual and potential customers, facilitated online booking and sales, provided more non-contact services, and communicated and coordinated with supply chain partners. These technologies included social media, networking facilities and resources, online booking platforms, email and conferencing facilities, and smart devices. In addition, due to digital technology in reducing labor costs and improve service efficiency, digital technology in the Internet of things (IoT), big data, cloud computing, voice recognition and other basic technologies, as well as face recognition, such as social media, virtual reality (VR) / augmented reality (AR), intelligent service desk and service robot technologies have been used in the hotel industry and tourism.

Capriello and Riboldazzi (2020) explored how tourism through one case studies uses the Internet and new technologies to maintain and develop its competitiveness in the context of evolving digital technology. The results suggested that tourism uses rapidly updated digital technology to improve its competitiveness and take the collaborative management actions of many new channels, thus enhancing the customer experience while improving the overall performance.

Because information technology (IT) had operational and strategic advantages, it was an important organizational resource in hotel management, such as the use of Internet to promote the relationship with users; tourism industry and hospitality industry improve management by using management software, thus identifying market opportunities and optimizing the utilization of organizational resources. Melián-Alzola et al. (2020) further investigated that the use of IT not only directly affects organizational agility, but also indirectly by improving the ability of technology to manage technical resources. Empirical data suggested that technical capabilities played a mediating role in the relationship between IT use and hotel agility. In other words, it represented a key tool for developing technical capabilities, which in turn improved the hotel's ability to respond to environmental changes. Therefore, hotel managers should strengthen the effective management of technical assets, and let technology assets play a more active role in business strategy design when new technologies created new competitive scenarios.

Hadjielias et al. (2022) explored the support of operational agility in the digitalization of tourism and customer value results. "Operational agility" through digital technology included three specific operational capabilities: a) the ability to pursue targeted promotions; b) the ability to automate booking, trading, and sales; and c) the ability to build contactless services and processes. The results suggested that, operational agility leveraged digital technologies to achieve effectiveness and speed in value creation and delivery.

2.4 Summary

In this Chapter, we comprehensively review some important literature that is relevant to this thesis. Specifically, the study discusses the literature concerning business digital transformation, digital technology, and digital technology-enabled business operational performance. Firstly, we review the research on business digital transformation including the concept of digital transformation, the motivations and factors facilitating digital transformation, the promotion mechanisms and boundary conditions in coping with digital transformation, challenges and impediments to digital transformation, the process of advancing digital transformation and the role of stakeholders in the process, and the role and evaluation of digital transformation. Because digital transformation research is just emerging, most of the studies have used qualitative research methods, including senior leadership research and interviews, case studies, and grounded theory, etc. In recent years, scholars have begun to use quantitative methods such as structural equation modeling to study the impact of digital transformation on firms. However, to the best of our knowledge, no studies have yet addressed the study of the mechanism of the impact of digital transformation on firms' operational performance.

Secondly, an overview of digital technology is provided, including concept and connotation, categories of digital technologies, digital technology application in various fields, and firms and employee digital technology adoption behavior. The literature review shows that various digital technologies such as Big Data, Internet of Things, Cloud Computing, Social Media, Artificial Intelligence, Blockchain, Drones, 3D Printing, Virtual Reality, Augmented Reality, Digital artifacts are used by businesses to support their operations. Specifically, big data, cloud computing, Internet of Things (IOT), machine learning and data mining are the most frequently used digital technologies in enterprises. These technologies are applied to the management of corporate supply chain partners, business enhancement of various departments within the company such as R&D, purchasing, sales, marketing, operations, HR management, finance, after-sales customer service, etc. Also, a large number of studies have explored antecedents of business digital adoption behavior. From the perspective of external environment and internal environment, the influencing factors can be broadly categorized into market factor, competitor factor, organizational factor, technical factors. Meanwhile, some studies have explored the driving determinants of employee digital adoption behavior. From the perspective of external motivation and internal motivation, the influencing factors include employee characteristics, technical factors, organizational factors. Besides, some studies focus on individual motivation of adopting digital technology, From the perspective of hedonic and utilitarian motivations, the influencing factors include functional elements, social element and relational element.

In the last part of the Chapter, the study presents some important works studied on the mechanism of how digital technology influences business operational performance. We, in particular, focus on the influence of digital technology on operational performance in consumer staples such as agriculture products, food, consumer goods, textile, chemicals, medicine, and healthcare, energy and manufacturing industries, and service industries. We also reviewed the moderation conditions and control variables of the effect. The results suggest that these digital technologies play an important role in driving the digital transformation process in enterprises and their timely deployment and proper utilization can determine the success or failure of digital transformation. But the rather limited existing research explores exactly what kind of mechanisms digital technology uses to influence the operational performance of firms. An extensive analysis of the extant studies reveals the shortcomings and the gap needed for urgent attention in this study.

Chapter 3: Application of Digital Technologies in Sichuan Fishery-PV Wulian Technology Co., Ltd.

It is widely accepted that digital technology is the lifeblood of organizations, and that IT and digital systems have traditionally worked in the background to improve efficiency, increase coordination and communication, and enable strategy. The digital transformation of the enterprise has facilitated the adoption of digital technology in the business. Digital transformation as a company-wide phenomenon leverages new-age technologies such as artificial intelligence (AI), machine learning (ML), Internet of Things (IoTs) and blockchain to redefine value propositions and transform company identities. Digital transformation is seen as helping organizations achieve operational excellence and better respond to market demands. This chapter will provide a systematic introduction of the application of digital technologies in the operational business of Sichuan Fishery-PV Wulian Technology Co., Ltd. The investigation will help to understand how digital technology is integrated into the operational aspects of the business. The research in this chapter will provide the research motivation for the next chapter on using grounded theory to reveal the underlying mechanisms by which digital technologies affect the operational performance of the business.

3.1 Profile of Sichuan Fishery-PV Wulian Technology Co., Ltd

Sichuan Fishery-PV IOT Technology Co., Ltd. (hereinafter referred to as Fishery-PV) is a science and technology innovative service company of Tongwei Group, which was formally established in June 2016, and its core team consists of core members of Tongwei's information technology construction team with over 10 years of experience. These team members have experienced the whole process of Fishery-PV's information technology, built Fishery-PV's information technology into a benchmark in the agriculture and animal husbandry industry, focused on the research of intelligent equipment systems for aquaculture, and have many years of experience in IOT product development and operation, as well as many years of experience in Internet product design and development. In agricultural operation and management, the company's main business directions are IoT agricultural information solutions, IoT agricultural operation and management information solutions. IoT agriculture includes intelligent farming solutions, intelligent planting solutions, intelligent photovoltaic solutions and integrated fishing photovoltaic hybrid solutions, providing end-to-end, integrated, software and hardware integrated comprehensive solutions. IOT agricultural operation management includes farming operation, photovoltaics operation, and fishing photovoltaic operation. In photovoltaic power generation, the company mainly serves the back-end market of power plants, and is committed to providing customers with solutions for planning, design, implementation and operation of the whole ecological cycle to maximize the efficiency and benefits of fishing photovoltaic hybrid model, and to realize a new "intelligent + operation" management mode supported by information technology as the core. With its own farming technology advantage, the company innovates and develops the fishery and photovoltaic base operation mode of "intelligent power generation on top and intelligent fish farming on the bottom", which reduces the cost for customers in both directions and truly realizes the efficient synergistic development of agriculture and photovoltaics.

3.1.1 Main business

Fishery-PV's main business includes three major segments: intelligent operation of fishing photovoltaic hybrid project, intelligent agriculture, and information services. Intelligent operation adheres to the basic idea of "people-oriented, safe operation and maintenance, efficient cooperation", relying on independent research and development of new energy cloud management system, fishery and photovoltaic integrated intelligent cloud platform, intelligent aquaculture system, integration of various power station resources such as video monitoring, forming the five core capabilities of the power station's fishery and photovoltaics integrated industrialization, safe production model, standardization of power station production, intelligent operation and management, and maximization of power generation targets. The company uses Internet of Things technology to solve problems in modern agricultural production, combines modern intelligent agriculture and photovoltaic industry scientifically, professionally and organically, promotes the transformation and upgrading of agricultural production, agricultural product management and agricultural information services, creates a refined, efficient and green intelligent agricultural park, and realizes efficient and sustainable development of agricultural industry. Relying on 20 years of experience in information technology, fishing photovoltaic hybrid IOT provides overall information solutions for enterprises, uses Internet of Things, big data, cloud computing, artificial intelligence and other technologies to realize the integration of information technology with traditional industries, creating platform, multi-industry, and one-stop information services.

3.1.2 Company achievements

Fishery-PV as a national high-tech enterprise, the national leader in intelligent fisheries, Sichuan Province Enterprise Technology Center, with two integration management system assessment and other qualifications, and passed the quality and safety, environmental safety, occupational health and safety system certification. After more than 5 years of technology research and innovation, it has formed 3 domestic leading achievements, 22 patents and 15 software copyrights, participated in the "Blue Granary Science and Technology Innovation Project" of the Ministry of Science and Technology, and many provincial and municipal level science and technology projects, and was awarded as "Excellent Enterprise in IOT Industry Application", "Single Top PV Intelligent Operation and Maintenance Brand", "2020 Light Energy Cup Most Influential Operation and Maintenance Enterprise", "Outstanding Contribution Award in Aquaculture Intelligence", "National Agriculture and Animal Husbandry Industry Annual Innovation Brand", etc. The project of "Intelligent PV Centralized Operation and Maintenance Platform Practice Case" was evaluated as "2020 Chengdu Industrial Internet Excellent Application Case". By 2022, 50 photovoltaic power plants have been using the intelligent operation and maintenance management solution, with a total installed capacity of 3,019 MW, covering fishery, ground, agricultural and distributed types. Since the adoption of the intelligent operation and maintenance management solution, the operation and maintenance efficiency has been significantly improved, with inspection efficiency increased by nearly 60%, inspection frequency reduced by nearly 50%, fault location accuracy increased by nearly 80%, and the average annual power generation loss recovered by 1-2% of the total, achieving cost reduction and efficiency increase.

3.1.3 Organizational structure

Fishery-PV adopts a functional organizational structure and organizes the division of labor according to its functions, setting up five major departments: operation center, technology center, marketing center, finance department and human resources department, which are responsible for the management of operations, technical, technological and quality verification of new products after they are put into production, collection, collation and analysis of various technical information and data, product marketing, financial management and the responsibilities of human resources, labor and administration office, respectively.

3.2 Fishery and photovoltaic integrated operational model

3.2.1 Introduction to the hybrid operational model

The integrated fishing and photovoltaic operation model is based on the integrated fishing and photovoltaic big data and operation center platform as the decision-making and management center, and realizes a three-level management model. The first level is the integrated fishing and photovoltaic park, which is mainly engaged in specific projects, the second level is the operation center, and the third level the experts in related industries. At the same time, there are also three basic business service models, the self-operated model supported by Fishery-PV, the cooperation model of entrusted operation, and the joint venture model of cooperative operation between the two parties. The integrated fishing and photovoltaic service platform can access fishery projects, photovoltaic projects, and integrated fishing and photovoltaic hybrid projects. The project is based on various digital systems as the basic support, the headquarters provides operational support through the integrated fishing and photovoltaic service platform, and industry experts collaborate and support through the service platform.

The intelligent fishing and photovoltaic integrated park and fishing and photovoltaic integrated service platform can provide intelligent breeding, procurement and sales, cultural tourism and other services for fishery users, power users, and tourism users. As such, the model realizes the organic integration of the three industries. That is, the primary industry is based on fishery farming, the secondary industry is based on photovoltaic power generation, and the tertiary industry is based on scientific and technological research and development + rural tourism", facilitating Fishery-PV's “integrated fishing and photovoltaic” two-wheel drive model. The integrated operation model of fishery and photovoltaics is illustrated in Figure 3.1.

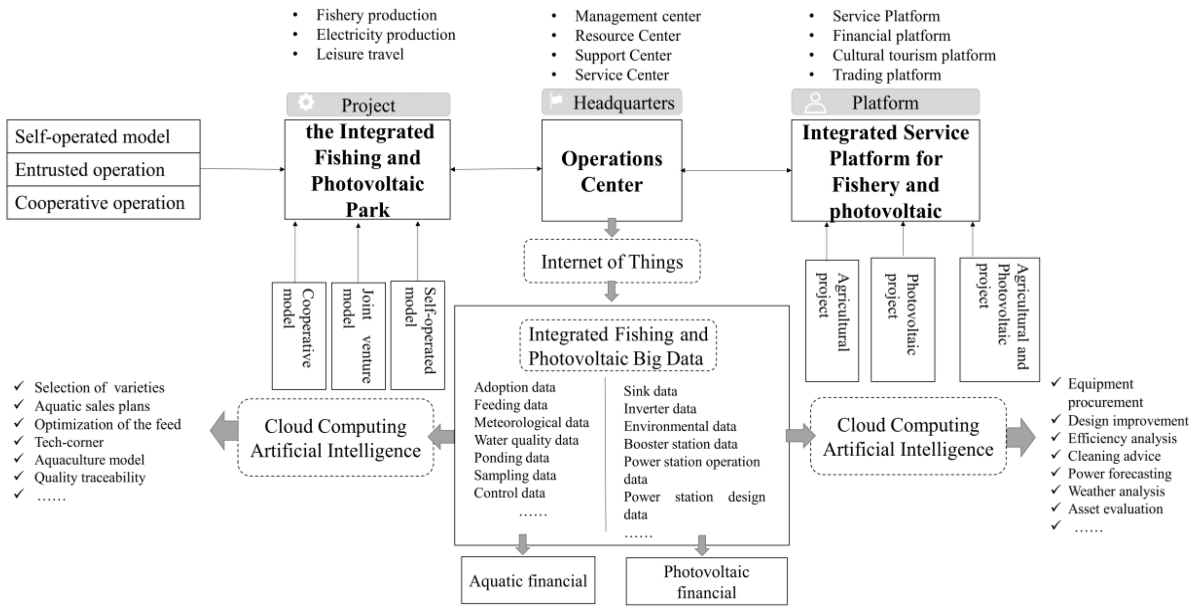

Figure 3.1 Integrated operation model of fishery and photovoltaics

Source: SFPV Co., Ltd. internal information

3.2.2 Operations center

The operation center, as the headquarters of the enterprise, is not only the decision and management center, but also the resource center, support center and service center of the enterprise. The big data output from the operation center is used to monitor and optimize the status of fish farming and photovoltaic power generation in order to more accurately provide the resources, support and services needed for fishery and photovoltaic operations. The fishery and photovoltaic big data include two types of data: fishery farming and photovoltaic power generation. In the fishery operation, the operation center can provide adoption data, feeding data, meteorological data, water quality data, ponding data, sampling data and control data for aquaculture and sales, so as to provide a reliable basis for selecting aquatic animal species with high production and sales volume, making reasonable aquatic sales plans, optimizing feed for aquaculture, improving farming technology and more accurate quality tracing, etc., which can provide better support for the development of aquatic finance of enterprises. In PV development, for better equipment procurement, design improvement, efficiency analysis, cleaning advice, power forecasting, weather analysis and asset evaluation, the big data will provide enterprises with sink data, inverter data, environmental data, booster station data, power station operation data and power station design data, etc., so as to provide more targeted management of PV power generation in fishery and photovoltaic operations, deliver the required resources, support and services in a timely and accurate manner, and realize the scale, standardization, modernization and intelligence of operations, thus also enabling the financialization of business.

3.2.3 The integrated fishing and photovoltaic park

3.2.3.1 Introduction to the integrated park

The integrated fishing and photovoltaic park is a new business model with one base, three industries, and the integration of three industries to achieve a great composite use of land.

The first industry is the new fishery, with new technology, new facilities and new operation of modern fishery, producing safe and reliable aquatic products and data services that can be traced throughout the whole process. The second industry is the new energy, with new technology, new mode and new operation of intelligent photovoltaic, producing green, zero carbon and economic new energy. the third industry is the new cultural tourism, with new products, new services and new mode, producing a new service experience presented by the beautiful countryside. The integrated fishing and photovoltaic park is illustrated in Figure 3.2.

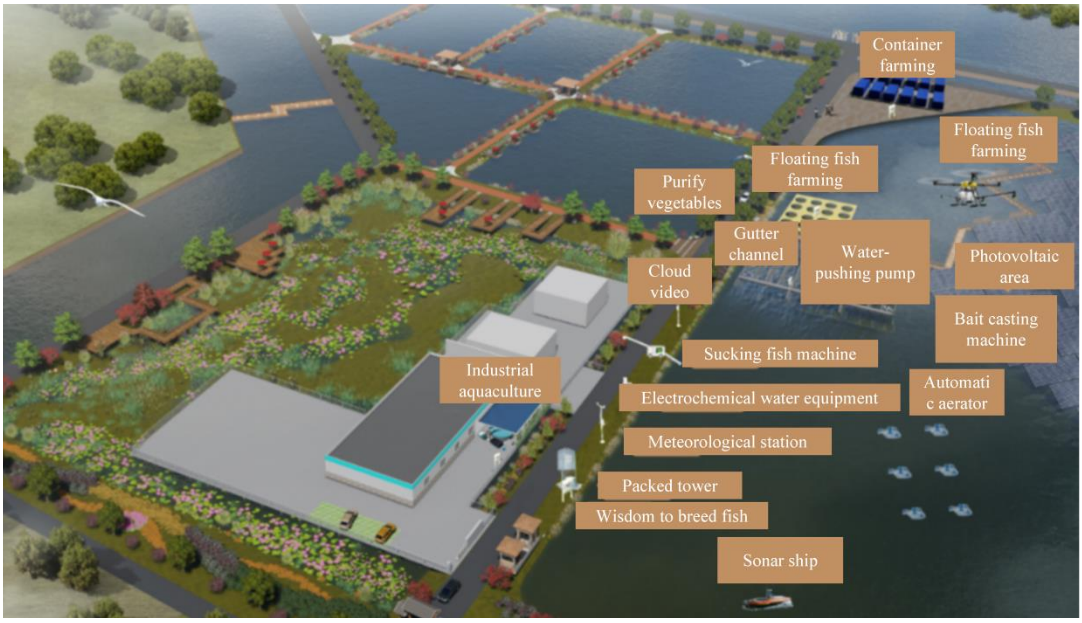

Figure 3.2 The integrated fishing and photovoltaic park

Source: SFPV Co., Ltd. internal information

3.2.3.2 Modern fisheries model in the park

"Fishery and photovoltaic" has become a new term in the industry in recent years, is a production method that combines aquaculture and photovoltaic industry, that is, in the pond water body to carry out aquaculture at the same time, on the water surface to erect photovoltaic modules, solar power generation. It has been proved that "fishery and photovoltaic" can make full use of land and space resources, realize fish, electricity and environmental protection, effectively prevent atmospheric pollution, make full use of space, save land resources, and use photovoltaic power stations to regulate the breeding environment, optimize the regional energy structure, improve the environment, and increase the output of fish ponds per unit, increase production and income, and realize the sharing of fields in aquaculture and photovoltaic industry. The organic combination of the two has changed the status quo of the traditional photovoltaic industry and aquaculture, which not only significantly improves the efficiency and reduces the cost of production, but also changes the structure of the industrial chain of both, which is a further extension of the value chain of the photovoltaic industry and aquaculture, and is a new model of energy saving and emission reduction and healthy farming.

The modern fishery in the "fishery and photovoltaic" project is to make full use of the Internet of Things, big data, cloud computing and other information technology combined with farming technology to promote the transformation and upgrading of traditional aquaculture, from precision feeding, balanced feeding, drones patrolling the pond, drones spraying, intelligent bottom drainage, intelligent residual bait fish excrement excretion, to achieve zero pollution, zero emissions, energy saving, environmental protection, to achieve the entire traceability of the farming process, to provide safe and reliable aquatic products, to achieve the integration of agriculture, industrialization and information technology, and to promote the supply-side reform of aquaculture.

(1) Pond culture model

The pond culture model is combined with Fishery-PV's "365" aquaculture model, and uses six critical technologies at the same time. Subvert the problems of internal, exogenous and non-point source pollution that cannot be solved by traditional pond decentralized culture affecting the quality and safety of aquatic products, provide high-quality animal protein for human beings, and ensure food safety. The pond culture mode also includes intelligent breeding system, water storage and sedimentation to ensure high-quality water supply, bottom sewage system, oxygenation system and feeding system. The pond culture model is illustrated in Figure 3.3.

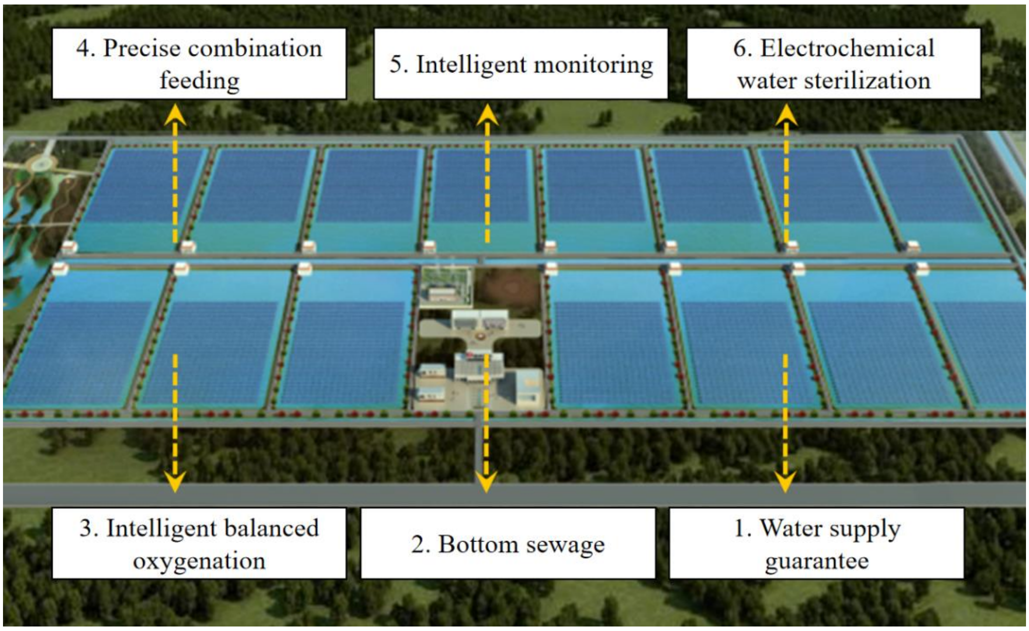

Figure 3.3 Pond culture model

Source: SFPV Co., Ltd. internal information

Fishery-PV aquaculture system integrates water quality online monitoring, aquaculture equipment control, and video monitoring. It can realize real-time monitoring of pond dissolved oxygen, water temperature, pH, ammonia nitrogen, etc. Greatly save labor costs and improve breeding efficiency. Water storage and sedimentation ensure high-quality water supply, and 5%-10% water storage and sewage purification ponds are built in the breeding area, with a water depth of 4 to 5 meters. By means of stepped oxygenation, slow flow into the pool, sedimentation of sediments, and aquaponic symbiosis, the pesticide residues are degraded, and the functions of water storage, drought prevention, and drying water are enhanced. At the same time, the middle layer water of the cistern is discharged into the pond, which can save energy and increase temperature in winter, and can save energy and cool down in summer.

The bottom drainage system can move the fish excrement and residual bait produced in the breeding process out of the breeding water body to improve the environment of the breeding water; the breeding wastewater moved out of the pond into the solid-liquid separation tank for treatment, the supernatant enters the wetland purification and then recycled to the breeding pond for secondary use, and the solid sediment goes to the drying pond for organic fertilizer to achieve zero pollution and zero emission. Oxygenation system adopts microporous oxygenator, water cart oxygenator, impeller oxygenator, surge machine, etc. to form a compound oxygenation mode, according to the water temperature and dissolved oxygen situation, turn on different types of oxygenators to ensure that the dissolved oxygen in the breeding water is above 5.0mg/L for 24 hours, which effectively promotes the growth of breeding fish.

In the feeding system, the feeding equipment uses Fishery-PV's self-developed wind feed baiting system, which can flexibly master the feed species, specifications, feeding amount and feeding time according to the breeding species, specifications, and density to achieve precise feeding and reduce labor costs.

(2) Surface facility farming model

The flow tank model is a standardized recirculation tank for about 2% of the pond area, and the remaining 98% of the pond area is used as a water purification area. This model adopts gas lifting technology, pollution collection technology, etc., which has the advantages of water and land saving, simple control, stable production, safe aquatic products, low energy consumption per unit output, high output per unit input, etc.

(3) Land-based farming model

Intelligent FRP recirculating aquaculture is a way to apply FRP equipment to aquaculture, through ponds, reservoirs (lakes) or rice fields and other aquaculture modes, integrating the technical system of recirculating aquaculture supporting facilities construction, bottom drainage, water treatment, aquaculture and disease prevention and control, so as to carry out aquatic animal breeding.

(4) Factory farming model

Factory aquaculture is a method of aquaculture in a small body of water, using a high degree of mechanization, electrification, and computerized automatic control technology to enable aquatic organisms to grow under optimal conditions of water temperature, water quality, dissolved oxygen, light, and feed. Factory recirculating water breeding system is the active control of water environment by industrial means,. It consumes less water resources, occupies less land, has less environmental pollution, has high-quality and safe products, has fewer diseases, has high density, and aquaculture production is not restricted and affected by geography or climate. High resource utilization rate is an important way to achieve sustainable development of aquaculture industry with high input and high output and low risk. In addition, photovoltaic panels can be erected on the roof to generate electricity to provide the electricity needed by the park and reduce the overall cost of breeding.

3.2.3.3 Integration of three industries

Based on the accumulation and exploration in the development and construction of modern agriculture, Fishery-PV has explored a long-term development model of green photovoltaic combined with aquaculture and plant cultivation. in the planning stage of agricultural production, it fully considers the refinement of breeding, scientific operation and management, harmless emission and diversified income, adopts advanced IOT and big data technology, supports intelligent facilities and equipment, relies on Fishery-PV's many years of experience and many research results in the agriculture and animal husbandry sector, and plans and builds modern agricultural parks. The fishing photovoltaic hybrid project uses intelligent operation and maintenance and farming management integrated information platform to form an intensive development model of "power generation on top and fish farming on the bottom" and "one resource, two industries", realizing a bumper harvest in five fields: fish, electricity, tourism, environmental protection and taxation.

Under the construction goals of high value-added aquaculture and green energy manufacturing, Fishery-PV continues to develop modern agricultural leisure and tourism, devoting itself to water fishing, leisure and tourism, study trips and other functions, building leisure fishing islands, comprehensive display centers, sightseeing towers, etc., interspersed with fishing spots, science hitches, stacks and other leisure infrastructure to create an integrated fishery and light industrial park. Fishery-PV New Energy Jiangsu Provincial Fishery Excellence Park covers an area of about 1930 mu, the construction and sightseeing area is divided into water greenery area, recreation and entertainment area, water recreation area, water science gallery, etc. It is a comprehensive industrial park with recreation and entertainment including fishing, water boating, science education, hairy crab DIY experience, mystery picking and special dining. Various themed cultural activities are carried out with the help of aquatic products cultivated in the park, and they are used as sightseeing tours, so that people can get up close and personal with, understand, and inherit food culture. At the same time, with the theme of “solar energy”, the park runs through the history, geography, popular science and industry of “photovoltaic + fishery”, forming a research and general education base integrating exhibitions, science education, interactive experience, learning exchanges, leisure and entertainment, and creating a comprehensive tourism park that organically combines “fishery + photovoltaic + tourism”. The tourism development model of photovoltaic combined with culture has abandoned the tedious promotion methods such as scientific popularization in the past, combined with local culture, used its own characteristics, attracted the public, and developed tourism. At the same time, it popularized photovoltaic knowledge to the public, and truly realized the integration and development of the three industries.

3.2.3.4 Fishery operation business model

The business model of the integration of fishery and photovoltaic includes three basic types, which are cooperative model, joint venture model and self-operated model. In the cooperation model, Fishery-PV provides solutions and services for the partners, implements strategic control over the partners, and the partners operate and sell through traditional channels, Fishery-PV is responsible for providing feed, intelligent facilities and equipment, breeding technology and breeding services for the operators, and supervising the production process, and the final product obtained through the cooperation model is common aquatic products. The joint venture model has the characteristics of WEN's model, mostly "company + farmer or family farm", Fishery-PV and the partner jointly operate the business, Fishery-PV is responsible for the operation control, capital, fry, feed, animal protection, facilities and equipment, management system, breeding technology, breeding service and maintenance service input in the pre-production and production process, planning and supervision of the production process, and finally Fishery-PV sells the products through online platforms (Fishery-PV fish platform, brand platform, e-commerce platform), through these platforms consumers can get two types of products: safe and reliable aquatic products and the whole traceability data. The self-operated model is similar to the animal husbandry model, which is different from the “company + farmer or family farm” model. The business model is integrated farming, adopting a full-process self-cultivation method, and the Fishery-PV is completely responsible for it. This model can reduce the transaction costs of intermediate links, make the entire production process controllable, and enhance the company's ability to resist market risks. Under this model, based on comprehensive planning, management, implementation and supervision of the production process, the platform (Fishery-PV fish platform, brand platform, e-commerce platform) provides consumers with safe and secure aquatic products and traceable data throughout the process.

3.2.4 Integrated service platform for fishery and photovoltaic

Fishery-PV's planning and construction of photovoltaic agricultural park is to combine solar photovoltaic power generation system, modern agricultural planting and high-efficiency agricultural facilities, and then widely used in modern agricultural planting and agricultural machinery power supply, so as to realize power generation on the shed, planting under the shed and sightseeing in the shed, and realize diversified income of agricultural industry. Through the two-level operation system of "park site - operation center", with the help of Internet of Things technology and big data, park operation without time and space restrictions is realized, real-time monitoring of the environment, timely detection of abnormalities, artificial control of environmental conditions, avoidance of farming risks, and the best sharing model of aquaculture and photovoltaic power generation is realized.

Fishery-PV's intelligent power station cloud platform is an important tool for intelligent operation and maintenance, covering daily production, operation and maintenance, remote real-time monitoring, data-driven decision analysis and power station asset management, realizing the efficient combination of online and offline to achieve the fundamental purpose of reducing costs and increasing efficiency and improving power generation.

It eventually forms a platform of ecological chain where production (including electricity production, fishery production, carbon sink production, etc.), trading (including agricultural products trading, green electricity trading, carbon trading, virtual products trading, etc.), finance (including agricultural finance, photovoltaic finance, personal finance, crowdfunding, etc.), cultural tourism (including online, offline, games, science popularization, research, experience, etc.), demonstration (including three new demonstrations, i.e. new agriculture, new energy, new rural demonstration, demonstration of integration of three industries), demonstration of integration of agriculturalization, industrialization and informationization, are integrated, forming a meta-universe of this industry. The integrated service platform for fishery and photovoltaic is illustrated in Figure 3.4.

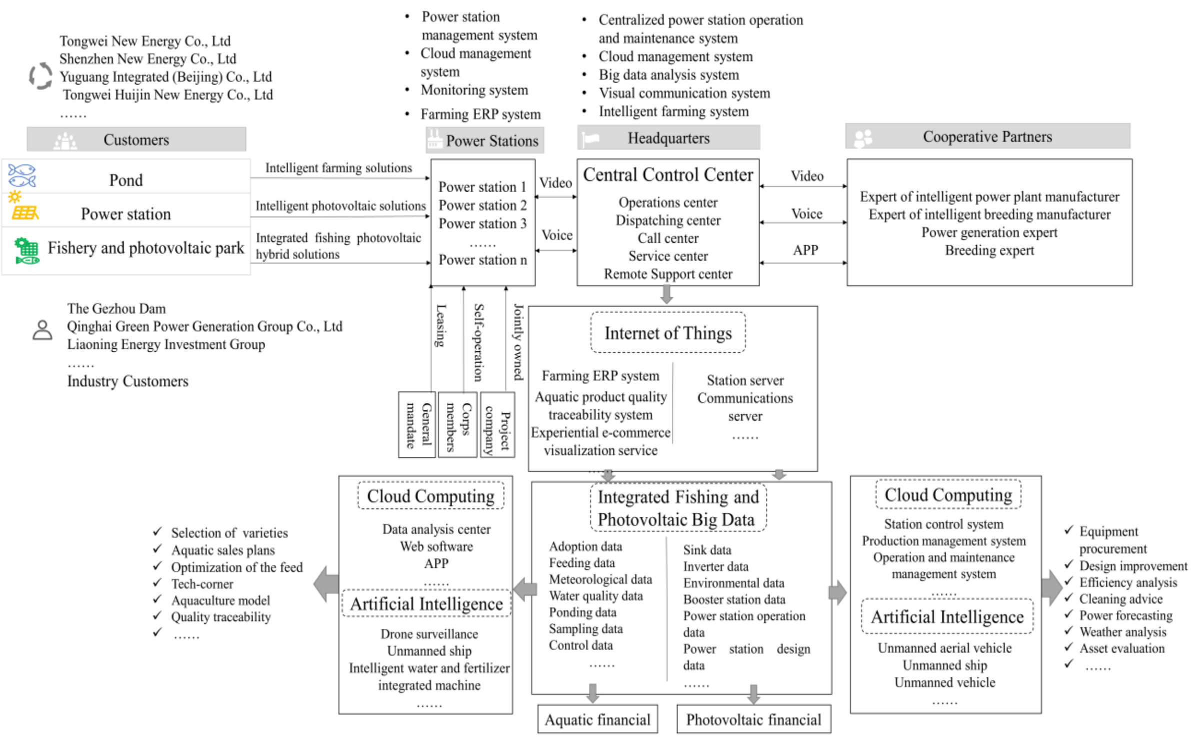

Figure 3.4 Integrated service platform for fishery and photovoltaic

Source: SFPV Co., Ltd. internal information

There are four stages in the operation planning of the integration fishery and photovoltaic. The first stage is the establishment, that is, the industrial forms of the park are all transformed into facilities and industrialization, and digital management is formed. The second stage is intellectualization. Through digital operation, a large amount of data is collected and accumulated. Through the understanding of the industry, business insight, and the summary of production and operation, based on artificial intelligence, multiple business models are abstracted and refined to form intelligent operation. The third stage is integration, based on the industrialization and intelligent operation of each industry, integrated operation is carried out, i.e. one team carries out unified operation and management of the three industries, weakening the dependence on industries and professions, greatly improving production efficiency and greatly reducing the demand for labor. The fourth stage is platformization, which means doing ecology, taking the integrated service platform of fishery and photovoltaic as the carrier and middle platform, forming an ecological chain of production, trading, finance, cultural tourism and demonstration.

3.3 The use of digital technology in operational processes

3.3.1 Digital technology usage in production operations processes

In the production and operation process of Fishery-PV, by integrating a number of IOT software and hardware equipment, using IOT transmission technology, sensor technology, software development technology, etc., develop a software system suitable for the whole process of production management, break the time and space constraints of the traditional breeding mode, solve the problems of low intelligence and informatization of breeding, and assist in the realization of agricultural modernization. Smart breeding, management and monitoring systems based on big data, Internet of things and other digital technologies play an important role in planning, management, implementation and supervision.

1. Smart aquaculture system

The intelligent aquaculture system is mainly through monitoring the various data of the park, through network transmission, real-time feedback to the management center, PC terminal, mobile phone terminal. and through the self-developed management system, to send control commands to a variety of farming equipment to achieve intelligent control. The architecture of smart aquaculture system is illustrated in Figure 3.5. The system mainly contains the following functions:

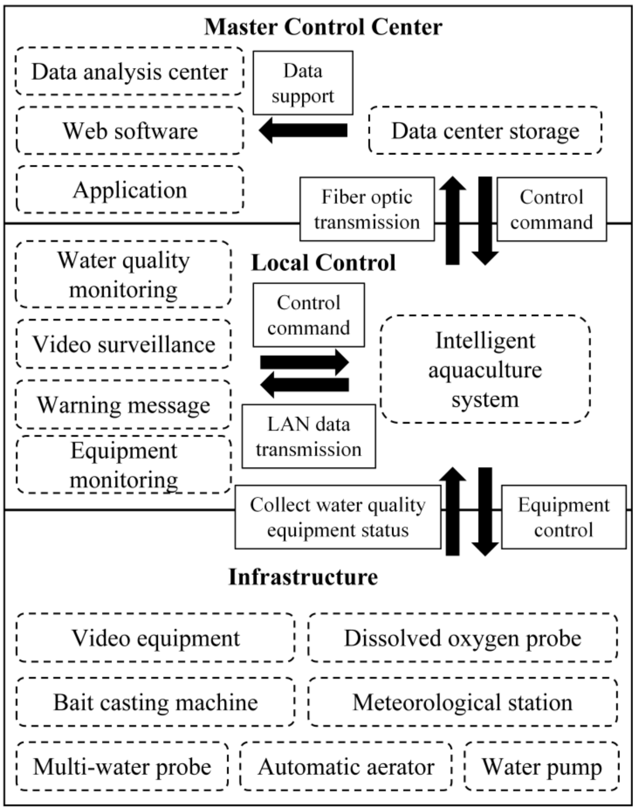

Figure 3.5 The architecture of smart aquaculture system

Source: SFPV Co., Ltd. internal information

(1) Water quality management system

Water quality management system is mainly through the deployment of water quality monitoring sensor terminal on PH value, chemical oxygen consumption (COD), suspended solids (SS), ammonia nitrogen, total nitrogen, total phosphorus and other water quality indicators for remote online monitoring, while through the video monitoring equipment for real-time monitoring of the discharge site of the tailwater. through the collection of information for storage and visualization convergence display, through the important pollutants in the water source for data analysis, threshold settings and early warning response, etc., to achieve monitoring and management of water quality.

(2) Intelligent feeding system

Intelligent feeding system is a combination of silo, weighing system, feeding system, control cabinet, water quality monitoring system. reduce labor cost and labor intensity.

(3) Sonar detection system

The sonar detection system currently uses sonar technology to detect how many fish are feeding, which is used as an input factor for the feeding model; feed more if you are eating well, less if you are eating poorly, and turn off the feeding system if you are no longer eating.

(4) The UAV monitoring system

The UAV monitoring system is a drone mounted infrared imaging lens, not only in the daytime to inspect the water surface conditions, but also in the absence of light at night through infrared thermal imaging, and send voice warning messages to intruders. greatly save manpower and material resources。

(5)The multi-level operation and maintenance visualization platform

The multi-level operation and maintenance visualization platform can display the water quality indicators and video images of the breeding water bodies and production in real time, and any abnormal situation will automatically trigger an alarm, while the working status of the breeding equipment can be monitored. ensure that the whole breeding park is in a state of guardianship 24 hours a day to avoid property losses and protect personnel safety.

2. Farming ERP system

The farming ERP system effectively manages the "production, supply and marketing" supply chain and "human, financial and material" resources, solves the accounting of farming costs and expenses, accurately analyzes the problems in the farming process, and intelligently predicts the profitability of farming. long-term accumulated data can be analyzed and mined to form an effective farming model, which has an important role in guiding the decision making of farming. The system mainly solves the problem of inaccurate profit accounting according to the aquaculture cycle, and is a software system for managing materials, costs, the breeding process, automatic accounting of bait coefficients, and accounting of costs and revenues for each breeding cycle (ponds). Farming process informationization is a phased process, at the current stage, this system provides real and reliable farming data for managers at all levels of the enterprise by recording the daily business of the farming process and providing basic information query and statistical tools to assist the enterprise in optimizing the farming management process and improving the efficiency of bait utilization by scientific means.

In addition, through the vessel management system, the ship-using department, management department and dispatchers can manage expenses, dispatching, maintenance and travel trajectories, rationalize cruise plans and automatically generate statistical reports, thus better managing vessels and avoiding wasted manpower and material resources.

3. Intelligent agricultural production management system

The IoT software system covering the whole process of agricultural production helps to improve the degree of refinement and management capability of agricultural production, timely detection of problems in production, formulation of corresponding technical countermeasures, and promotion of agricultural production to increase production and income.

(1) Environmental Information Acquisition System

The sensors installed in the enclosure can display information such as ammonia concentration, CO2 concentration, hydrogen sulfide concentration, wind, light intensity and air temperature and humidity in data reports, change curves and real-time images。

(2) Environmental monitoring management system

In the breeding system, based on the collected environmental parameters and feed consumption and bin storage, alarm limits can be set through an intelligent decision management system, thus enabling SMS alarms, email alarms and remote control to ensure that the environmental conditions at the site are suitable for the growth of livestock and poultry.

(3) Intelligent control system

According to the demand curve of crop growth and real-time monitoring parameters of cultivation environment, soil and the physiological condition of vegetable crop itself, intelligent control of greenhouse equipment operation, water and fertilizer equipment operation, fine control of crop growth environment, maintaining the best growth environment for each growth stage of the crop.

3.3.2 Digital technology usage in the product operations process

The fishery and photovoltaic hybrid project uses an intelligent operation and maintenance and farming management integrated information platform to form an intensive development model of "power generation on top and fish farming on the bottom", "one resource, two industries", without occupying agricultural, industrial and residential land, and its products mainly cover three industries, including fisheries, photovoltaic industry and tourism based on the " fishery and photovoltaic" park.

1. Application of digital technology in fisheries production

The Fishery-PV provides users with safe and reliable aquatic products and traceable product data throughout the whole process by equipping with intelligent facility-based fishery system and big data technology, and the modern fishery model of Fishery-PV mainly includes intelligent pond farming model, intelligent surface facility-based farming model, intelligent factory farming model and intelligent land-based farming model.

(1) Intelligent pond farming system

The core of pond farming is feeding, which is solved by the intelligent feeding system. The problem of loading and unloading is solved by the bulk truck, and the packaging cost is saved. The problem of feed storage is solved by the material tower, thus reducing the cost of storage and management, no inventory, no in/out operation. The system comes with a weighing function, which can automatically measure. The system has a built-in feeding model, which can analyze and calculate how many times a day to feed according to the size of the fish. Meanwhile, each time the system can dynamically adjust the feeding amount according to the changes of the environment, such as water temperature, dissolved oxygen, air pressure, and the feeding situation of the fish, thus saving a lot of labor and replacing experienced farm workers. The system greatly reduces labor and labor intensity, and realizes intelligent management of pond farming.

(2) Intelligent aquatic facility farming system

Through the water quality online monitoring system to monitor the main water quality indicators of the breeding unit, and linkage with the oxygenation system and water pushing system; at the same time to monitor the operation status of the equipment, and alarm; through the intelligent sewage system intelligent control of sewage, can be based on the length of time or the concentration of sewage, intelligent sewage; and according to the intelligent feeding system as introduced above according to the breeding species intelligent feeding. to achieve intelligent management of water surface facilities breeding.

(3) Intelligent pond farming system

Intelligent pond culture system monitors the main water quality indicators of the culture unit through the water quality online monitoring system, and linkage with the oxygenation system, such as controlling the time of liquid oxygen increase, oxygen production time, mechanical oxygenation time, etc. The system solves the problem of intelligent water intake and drainage through solenoid valve and water level meter, and solves the problem of tail water discharge through intelligent sewage system. Intelligent feeding according to the species of fish fry cultured, monitoring and alarming of all operating equipment, to achieve intelligent management of pond culture.

(4) Intelligent factory breeding system

The functions of intelligent oxygenation, intelligent sewage discharge, intelligent intake and drainage in the intelligent factory breeding system are similar to those in the intelligent breeding system. In addition to the above functions, an intelligent energy management system has been added to ensure the constant temperature in the factory room and manage energy at the same time. For adult fish farming, an intelligent feeding system is used, and for seedling farming, a feeding robot is used. The feeding robot can walk intelligently according to the planned trajectory, and can realize functions such as autonomous obstacle avoidance, intelligent feeding, and intelligent charging. And generate an intelligent feeding model, intelligently adjust the feeding amount according to the variety and environmental changes, and finally realize the unmanned factory.

2. Application of digital technology in photovoltaic products

Through the use of digital technologies such as IoT and big data, photovoltaic power plants have built an intelligent operation and maintenance management platform for photovoltaic power plants to help users focus on the unified management of the whole process and life cycle of production processes, equipment assets, and data assets. With centralized control, operations, data centers, computers, and APPS as the main body, it realizes functions such as intensive management, digital decision-making, intelligent diagnosis, and integrated monitoring, thereby improving the level of operation and maintenance management, improving on-site operation and maintenance efficiency, and playing a role in corporate publicity, demonstration, and publicity. The overall architecture of intelligent operation and maintenance management platform for photovoltaic power plants is illustrated in Figure 3.6.

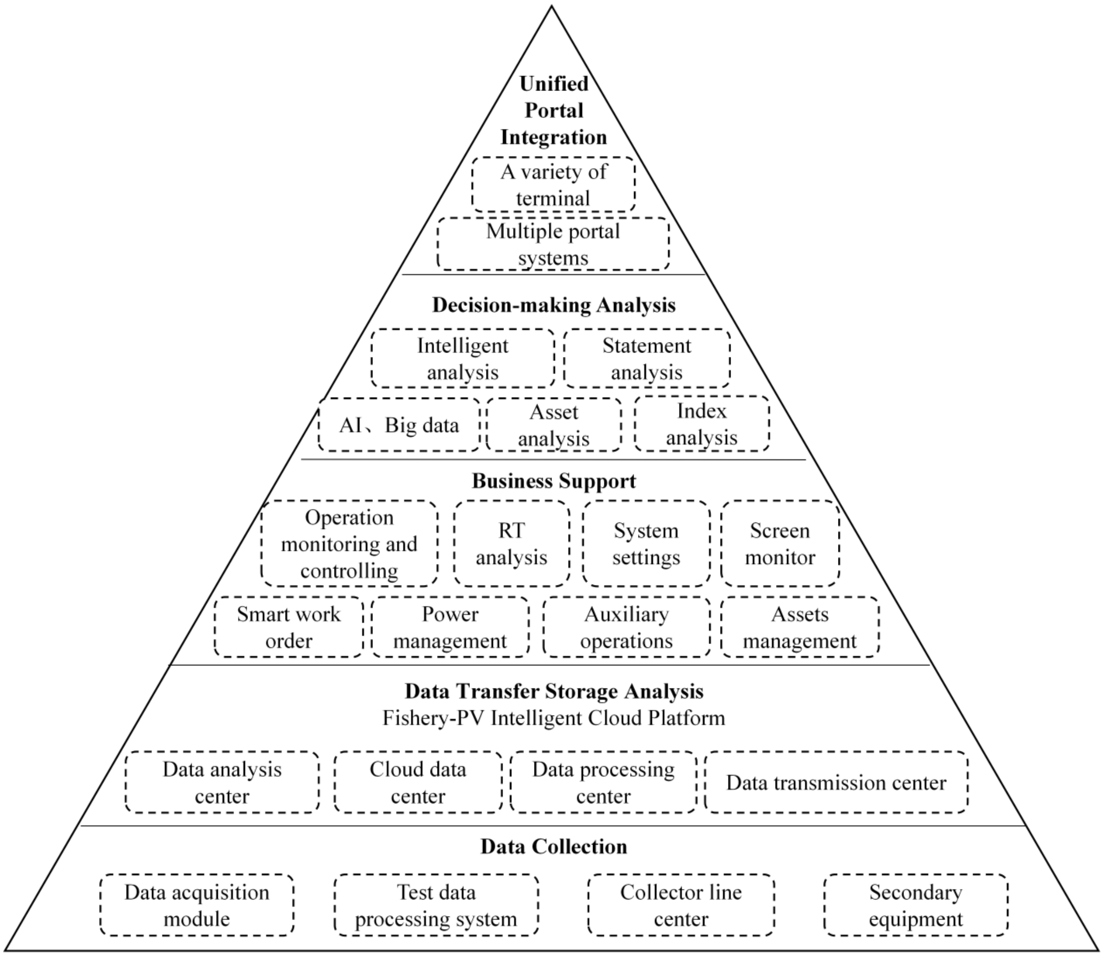

Figure 3.6 Overall architecture of intelligent operation and maintenance management platform for photovoltaic power plants

Source: SFPV Co., Ltd. internal information

The intelligent operation and maintenance management platform of photovoltaic power plants adopts a big data analysis architecture, which can easily cope with the collection, processing, calculation, analysis, storage and other applications of massive amounts of data. The platform uses cloud computing to build the corresponding system services and reduce the difficulty of operation and maintenance. The massive data storage resources on the platform are planned uniformly and used uniformly, which reduces the waste of storage resources and improves the efficiency of data use. The cloud application is updated promptly and quickly, which can be updated once and shared by all staff, eliminating the trouble of upgrading systems everywhere and huge travel costs. In addition, the platform adopts a unified deployment security policy and centralizes the management of data to ensure the security of data, the security and stability of the system and the continuous availability of operation and maintenance services.

The intelligent operation and maintenance management platform of PV power station realizes panoramic VR monitoring of the power station, monitoring equipment operation data and status, automatically locating faulty equipment and pre-judging alarms, intelligently analyzing daily operation data of the power station, various types of power comparison data, quantifying various production indicators such as quantitative assessment indicators of power station operation, realizing information management of the whole process of power station production, power station personnel management, equipment maintenance process management, equipment operation and maintenance process management, safety production management, power station assessment management, financial settlement management, etc.

Intelligent operation and maintenance management platform mainly contains five systems: basic capability system, production monitoring system, production management system, decision analysis system and intelligent inspection system, etc. The basic capability system establishes the basic information management framework according to the user's organizational structure, personnel structure, power station type, power station distribution, power station scale, etc. The production monitoring system helps the user to monitor the operation of power station production equipment in real time, fault alarm, visual management, etc., and also helps the user to track and manage the daily operation and maintenance work of operation and maintenance staff.

3.3.3 Digital technology usage in the sales operations process

The fishery sales mainly adopted the strategy of multi-platform sales channels for sales, mainly containing the Fishery-PV fish platform based on digital technology traceability service, brand platform and e-commerce platform.

Fishery-PV fish platform provides aquatic product quality traceability system and experiential e-commerce visualization service, users can claim online through online platform, using QR code can get corresponding data from public platform and intelligent farming system for quality traceability. in this process through intelligent IOT system, video monitoring system, RFID, barcode technology, GIS technology and other digital technology, by building platform and data center to provide quality traceability service to users.

The traceability unit is a farming unit, farming pond, farming species, and seeding time, and through the Internet of Things and big data technology, the farming process and water quality are linked to the traceability unit, and each traceability unit generates a QR code that can be scanned by WeChat to know the farming origin, species, specifications, seeding time, feeding records, medication records, sampling records, water quality, etc. Through the quality traceability system, real-time monitoring of the production base, farming management, and processing and transportation process is realized, creating a new business model for e-commerce and community management. The quality traceability inquiry process is illustrated in Figure 3.7.

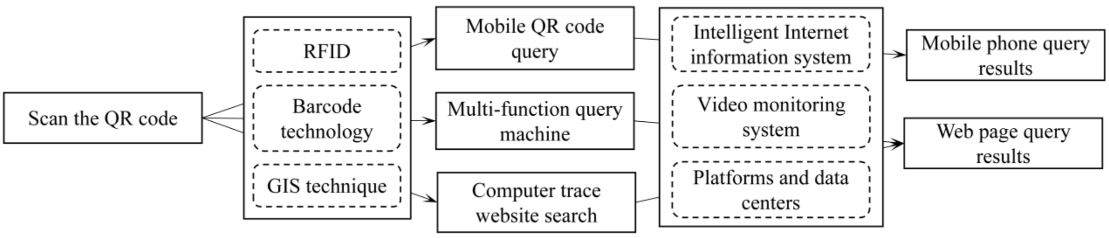

Figure 3.7 Quality traceability inquiry process

Source: SFPV Co., Ltd. internal information

3.3.4 Digital technology usage in service operation processes

Fishery-PV provides three models for corporate users: cooperative, joint venture and self-operated. In the service process, besides using the cloud service platform such as the intelligent farming system and management system developed by Tongwei, it also provides users with other intelligent services based on digital technology, such as fishery trade management platform and fish disease remote diagnosis system.

The fishery trade management platform provides a centralized, standardized and integrated trading platform for scattered fishery farming retail households in the region, integrating feed production equipment, inspection substances, animal protection drugs, aquatic seeds and other enterprises in the upstream of fishery farming to provide fishery farmers with a wide range of upstream products. at the same time, it integrates the product situation and sales information of fishery product farming retail households in the region, providing online consultation, supply and demand research, booking and purchase, and complaint feedback to downstream dealers and consumers, helping farmers to shorten their sales channels and grasp the market situation in time.

Fish disease remote diagnosis system consists of epidemic message sending, self-help intelligent diagnosis, expert remote guidance, and breeding forum. The system can push information to farmers in the first time when the epidemic occurs, to help customers take preventive measures in advance, when the fish disease, users can use the fish disease library for self-help diagnosis, if not solve, users can connect to the breeding experts for remote communication. Besides, users can post and exchange fish breeding experience and fish disease treatment methods on the breeding forum.

3.4 Summary

The top management of the organization recognizes the impact of digital technology in general and its ability to handle unexpected events and potentially enhance business performance to reduce business operating costs in particular. This chapter provides a systematic and comprehensive survey and overview of the application of digital technologies in the operational business of Sichuan Fishery-PV Wulian Technology Co., Ltd. As described in this chapter, companies have invested a lot of money and effort to embark on digital transformation and change, deploying digital technologies including IoT, big data, cloud computing, artificial intelligence, blockchain, etc. in many different operational aspects. However, are these investments worthwhile and how do digital technologies affect the capabilities and thus the operational performance of the enterprise? The existing literature does not provide an answer to this question, so an in-depth analysis of this issue is necessary. I will provide a systematic answer to this question through qualitative grounded theory method in the next chapter.

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Chapter 4: Mechanisms of the Impact of Digital Technology on Business Operational Performance

Chapter 4 proposes the mechanism model of digital technology on business operational performance. Specifically, this chapter first collects interview data through semi-structured interviews. Then, following the process and steps of the procedural grounded theory analysis pattern, that is, open coding, axial coding, and selective coding (Corbin & Strauss, 2008; Williams & Moser, 2019), this chapter puts forwards a model framework of digital technology-enabled operational performance. This chapter lays the foundation for subsequent empirical research and provides guidance on the model framework.

4.1 Research methodology and process

4.1.1 Interview outline

This chapter will start from the concept of "enterprise digital technology", focus on the question of "how the introduction and adoption of enterprise digital technology affects the operational performance of enterprises", and explore in depth the connotation and dimensional composition of the concepts of "enterprise digital technology" and "enterprise operational performance", and analyze the influencing mechanism and boundary conditions between them. Therefore, this chapter focuses on the research questions "What are the conceptual connotations and intrinsic dimensions of digital technologies and business operational performance?", "What is the mechanism of the digital technologies on firms' operational performance?", and "What factors moderate the impact of the digital technologies on firms' operational performance?"

In order to address the above questions, this study used grounded theory as I described in Chapter 1. This study embarked on an interview outline design. The outline of the interviews specifically focused on the conceptual components, antecedents and consequences, and mechanisms of formation of employees' perceptions of the impact of digital technology on the operational performance of the company and explored the factors that may have an impact on the process.

First, in the interview outline, the study added questions about the respondents' socio-statistical information, including their age, gender, years of work, work department, and job title, etc. In addition, the study added questions about the respondents' enterprises, including the region in which the enterprise is located, the industry in which the enterprise is located, the number of employees of the enterprise, the establishment date of the enterprise, the main business of the enterprise, the type of ownership of the enterprise, and the scale of the enterprise's business (sales), etc., so as to ensure the comprehensiveness and diversity of the study sample. The interviewer dynamically adjusted the questions to the researcher's different business backgrounds when asking questions, making the interview questions more targeted and relevant to the interviewee's practice experience.

Afterwards, the interview outline revolved around the impact of the introduction and adoption of digital technologies in the firm on the operational performance of the firm. In the first step, the interviewer asked the interviewees to recall when the firm started introducing digital technologies and what specific technologies were included. They were asked to give examples. After clarifying the scope of digital technologies, the interviewees were asked what were the problems faced by the company before the introduction of digital technologies and then asked to answer what were the goals or expectations of using the above technologies, whether the expected results were achieved by using the above technologies, and in what ways were these results reflected? And then, the researchers ask the interviewee what aspects of the organization are enhanced by the use of digital technology and, in turn, ask the interviewee what aspects have an impact on the effectiveness of the use of digital technology?

Finally, to ensure the effectiveness of the interview outline, this study combined expert opinions to adjust and revise the interview outline. A panel of experts consisting of a professor, two PhDs, four master's students, and a number of employees and managers who have worked for many years and have rich experience in the company, adjusted and revised the specific content, presentation format, and logical ideas of the interview outline as a whole. a complete interview outline was finally formed, as shown in the following Figure 4.1.

1.What are your enterprise name, region, time of establishment, industry, ownership type, number of employees, main business and business scale?
2. What is your position and department?
3. When did enterprises begin to introduce digital technology? What specific technologies are included? Please give an example.
4. What are the problems faced by enterprises before the introduction of digital technology? Please give an example.
5. What are the goals or expectations of using the above technologies? Did it meet expectations? Please give an example.
6. In the process of using digital technology, what aspects of the organization have been improved?
7. What aspects will have an impact on the use of digital technology?

Figure 4.1 Interview outline

4.1.2 Data collection

4.1.2.1 Data collection process

In recent years, qualitative research has received increasing attention from management scholars as a powerful complement to quantitative research, and grounded theory has been increasingly embraced by management researchers as an important and scientific methodology for qualitative research. With its origins in sociology and it has been applied to many other subjects in social science later. Grounded theory is favored for two main reasons: first, quantitative research is mainly applicable to examining relationships between the identified variables but lacks identification and explanatory power for phenomena that are not clearly defined or cannot be derived from established theory, which requires qualitative research to first define or give a theoretical framework for the phenomenon to be studied. Second, since its inception, the grounded theory has been valued for its more scientific operational process and its practice-oriented methodological features (Corbin & Strauss, 2008).

Grounded theory requires the researcher to build on existing theories and literature to capture new clues for constructing theories through data collection and analysis (Mohajan, 2018). Therefore, the quality of data collection determines the validity and innovativeness of the entire study. Question design, selection of research subjects, and training of the researcher are the three indispensable aspects of data collection preparation. In question design, the researcher needs to be flexible in the use of literature. First, using the relevant literature can provide the initial general direction for the study and avoid theoretical bias. Second, drawing on the scientific problem design process and methodology in the relevant literature can add to the normative nature of the study (Mills et al., 2006). However, researchers should avoid applying their own research to someone else's theory; the theory generated from the sources is actually a continuous process of interaction and integration between the sources and the researcher's personal interpretation. In addition to this, the researcher needs to continuously reflect on the way of asking questions during the data collection process and iterate on it in a circular manner so that the accuracy and richness of the data can be improved. In terms of the selection of research subjects, in-depth interviews rarely use random sampling, but rather flexible and non-random sampling. The common sampling methods for in-depth interviews include incidental sampling, quota sampling, snowball sampling, purposive sampling, and heterogeneous sampling (Morse, 1991). Open-ended sampling in the grounded theory involves selecting for research subjects, i.e., interviewees who can provide the greatest coverage of the research question according to the research question, thus covering all aspects of the research phenomenon and discovering from them the relevant concepts and categories needed to construct the theory, which usually occurs at the beginning of the in-depth interview (Draucker et al., 2007). For the training of the researcher, the researcher needs to select candidates with good presentation skills as an alternative for the researcher, and screen those who have a good understanding of the research topic as the final researcher by giving them a background knowledge related to the research topic. The data collection for this study consisted of three phases, which were conducted using open-ended interviews, in-depth interviews, and structured interviews, respectively, following the logic of "familiarity with the phenomenon-in-depth phenomenon - complementary phenomenon", as shown in Table 4.1.

Table 4.1 Research Process

Phase	Method	Time	Subjects	Purposes
Phase 1	Open-ended interviews, expert consultation (N=3), literature reading, secondary data collection (N=25)	2021.11-2022.02	Literature, Top Team members of SFPV, and social media Secondary Sources	Pre-research to become familiar with the phenomenon, identify possible mediating variables between digital transformation and operational performance, and refine the outline of the interview
Phase 2	In-depth interviews, semi-structured interviews (N=40)	2022.02-2022.04	Research subjects obtained by purposive sampling	Formal research, in-depth phenomenon

Phase 3	Structured interviews (N=6)	2022.04-2022.05	Convenience sampling of the research subjects obtained	Theoretical saturation check

Phase 1: Pre-research. As the CEO of SFPV, the research idea of this thesis comes from my personal work experience. In recent years, the company has included digital transformation in its planning, including fishery and aquaculture business. In the Tongwei "fishing light integration" ecological park located in the modern agricultural demonstration area of Dongying City, 20 modern intelligent fishponds are neatly arranged, and the water surface solar power generation array about to be put into aquaculture is continuously transmitting power to the State Grid every day. The supporting project of 220kV booster station complex building is in full swing. The biggest difference between this eco-industrial park, which is laid out with three functional areas of smart fishery, photovoltaic power generation and leisure tourism, and traditional fishery farming is that the organic combination of "fishery + photovoltaic + tourism" is realized on the basis of the original fishery farming method. Digitalization has also brought a lot of advantages to the employees of SFPV. The digital center allows employees to know the operation of all farming parks without having to go to the fishponds. At the same time, digitalization has also generated a large amount of farming data, and employees have moved from problem solving to proactive problem mining from the data, which has contributed to innovation in farming models while nip problems in the bud. Based on this, the author conducted exploratory interviews with three managers from the digital center of SFPV to obtain their views and attitudes on this research topic, and listened to their suggestions to adjust the specific methods of questioning. Further, this study continued to collect secondary sources on the web to summarize the possible mechanisms of digital transformation to empower business operational performance. In this stage, three open-ended investigations and expert consultation were completed, a large number of documents were read, 5 official reports and 20 UGC (User-generated content) were collected, and written materials and research notes were formed, which accumulated experience for the formal investigation in the next stage.

Phase 2: Formal research. Based on the experience gained in Stage 1, a combination of purposive and convenience sampling was used to obtain a total of 40 respondents. Specifically, in the research outline, respondents were first asked to recall when digital technologies were first introduced in their companies and what specific technologies were included. Then, from the perspective of company operations, respondents were asked to recall specific examples at work that reflected the relationship between digital technologies and digital technologies from the perspective of company operations. A total of 40 in-depth one-on-one interviews (N=15) and video telephone interviews (N=25) were conducted in one phase, with the locations of the in-depth one-on-one interviews mostly determined by the interviewees, mainly in shopping malls, cafes, companies, and private homes; each interview lasted about 30 minutes, with the longest interview lasting 79 minutes; and a total of 40 valid data were obtained, including a total of 230,500 words of written material.

Phase 3: Suppletory research. In order to meet the scientific and accuracy of the research results and achieve theoretical saturation, this study obtained several more research subjects as theoretical saturation tests, conducting a total of six one-on-one in-depth interviews (N=3) and video phone interviews (N=3), and supplementing the research with a total of 35523 words. During the supplementary research phase, no new constructs or categories emerged, nor were new elements or logical lines found. Therefore, the interview material can be considered to have reached saturation and can be coded for the next step of analysis.

4.1.2.2 Sample selection

Different from the sampling methods commonly used in empirical research, grounded theory adopts theoretical sampling, that is, select appropriate samples according to the needs of theoretical development. Sampling is not done all at once, but is a multi-stage, dynamic and iterative process. In this study, convenience sampling combined with purposive sampling was used to draw the sample. The overall profiles of the respondents are shown in Table 4.2 and Table 4.3.

Table 4.2 Profile of the respondents

Demographics	Items	Counts	Percentages	Demographics	Items	Counts	Percentages
Gender	male	26	56.5%	Region	Sichuan	15	32.6%
	female	20	43.5%		Guangdong	7	15.2%
Age	20-30	22	47.8%		Shanghai	5	10.9%
	30-40	19	41.3%		Beijing	5	10.9%
	40-50	5	10.9%		Jiangsu	3	6.5%
Position	General Manager	23	50.0%		Hubei	2	4.3%
	CIO	15	32.6%		Shenzhen	2	4.3%
	Department Manager	5	10.9%		Tianjin	2	4.3%
	CDO	2	4.3%		Guizhou	1	2.2%
	CFO	1	2.2%		Henan	1	2.2%
					Jilin	1	2.2%
					Shaanxi	1	2.2%
					Xinjiang	1	2.2%

Table 4.3 Industry profiles of the respondents

Demographics	Items	Counts	Percentages
Industry	Information transmission, computer services and software industry	16	34.8%
	Manufacture	7	15.2%
	Financial	6	13.0%
	Real estates	3	6.5%
	Education	3	6.5%
	Health, social security, and social welfare industry	3	6.5%
	Transport, storage, and postal services	2	4.3%
	Medical treatment	2	4.3%
	Scientific research, technical services and geological survey industry	1	2.2%
	Accommodation and catering	1	2.2%
	Wholesale and retailing	1	2.2%
	Agriculture, forestry, and fisheries	1	2.2%

Convenience sampling refers to the non-probability of the researcher selecting sampling units and researching the sample based on principles such as proximity. This study accomplished convenience sampling by inviting MBA classmates in business intelligence and data science course to recommend research subjects with the support of a professor in the School of Economics and Management, UESTC. The MBA classmates participating in the course recommended people they were relatively familiar with as potential research subjects based on the principle of convenience. This ensured that respondents were comfortable and truthful in expressing their views on the impact of the introduction and adoption of digital technology in the enterprise on the operational performance of the enterprise and avoided concealing their true thoughts and intentions due to unfamiliarity, fear of privacy disclosure, etc.

Purposive sampling is a non-probability sampling conducted by the researcher based on the typicality of the sample according to the research needs. In conjunction with the research purpose of this study, those who have applied or are applying digital technology in their companies are the research subjects needed for this study. Therefore, in terms of typicality, this study screened the typicality of the respondents based on a screening item: a pre-questionnaire was given to the respondents in advance, and only those who could accurately fill out the digital technologies applied in their companies in the questionnaire were continued to be interviewed. In terms of diversity, the respondents cover people aged 22 to 48, and are distributed in all age groups; in terms of gender distribution, there are 26 male respondents and 20 female respondents, which is a balanced ratio between men and women; in terms of position, the respondents include general managers (GMs), department managers, CIOs, CFOs, CDOs, and come from many different positions; in terms of regional distribution of companies, the respondents work in 13 provinces, municipalities and autonomous regions, including Sichuan, Guangdong, Shanghai and Beijing, covering all major administrative regions in China. In terms of business industry, the respondents come from 12 different industries, with complete coverage of the primary industry (agriculture, forestry, animal husbandry and fishery), secondary industry (manufacturing), and tertiary industry (information transmission, computer services and software, finance, etc.). Based on the above analysis, the age, gender, position, business location, and business industry of the respondents are rich and diverse, which meets the diversity requirement of the sample sampling.

Based on the theoretical sampling requirements of qualitative research and with reference to the sample size of similar studies, a total of 46 interviewees were recruited and in-depth interviews were completed in accordance with the principle of recruiting one interviewee from each company. Under the guidance of the purposive sampling method combined with convenience sampling, the sample selection of this study considered typicality and diversity, ensuring the availability of the interview content and, more importantly, the authenticity of the interview materials.

4.1.2.3 Quality assurance of data collection

Considering that the quality of interview data has a direct and important impact on the authenticity and robustness of the follow-up research of this study, in order to ensure the quality of interview data, we adopted the following measures in this study to ensure the quality of data collection process:

First, data collection is conducted according to academic process specifications to ensure a disciplined and valid data collection process. Before the interview, the interviewees were informed in advance of the purpose of the interview (data collection) and were explicitly promised that all content of the interview (data) would be used for academic research only, and that the interview would be desensitized to the parts involving personal privacy, so that the interviewees would feel less nervous and guarded about the interview and thus promote the truthfulness, completeness, and validity of their expressions during the interview. After the interview, the interview content is pre-processed, and the interview text is compared to ensure that the interviewees' expressions are indeed their true feelings, and the text is compared across paragraphs to uncover more clues to support a certain viewpoint, so that the authenticity and richness of the interview content can be guaranteed.

Second, the interview content was flexibly adjusted to the actual interview situation to ensure the efficiency and effectiveness of the data collection process. the interviewees themselves were different, so their responses to the same interview questions often differed significantly. We will make real-time adjustments to the content of the interviews during the interview process, depending on the actual situation of the interviews. For example, when the interviewee is unfamiliar with the question and finds it difficult to answer, we will further add the explanation of the question; or when the interviewee's statement exceeds the interview outline too much, we will make the content return to the core part of the interview outline through appropriate guidance, thus promoting the efficiency of the interview process and improving the effectiveness of the interview content.

Third, respondents were guided to conduct interviews objectively and truthfully to ensure the objectivity and validity of the data collection process. To avoid the influence of the interviewees' subjective emotions on the quality of the data, we used value-neutral questions and avoided leading questions in the interview process to ensure that the interviewees gave true and objective answers based on their personal experiences, thus ensuring the objectivity and validity of the interview.

4.1.2.4 Research ethics

As mentioned in previous studies, qualitative research emphasizes mutual trust between the researcher and the interviewee, only then the interviewee is likely to provide true and accurate information. Therefore, the researchers must clarify the relationship between themselves and the interviewees, in terms of normality, they need to ensure the reasonable normality of data collection and data use, and prohibit the use of relevant data for activities that violate laws and regulations or morality and ethics; In terms of objectivity, they need to detach themselves and conduct interviews from an objective and rational perspective to avoid affecting the objectivity of data collection.

In this thesis, the principles related to academic data collection were followed in the process of data collection to ensure that the data collection process was in line with research ethics. e.g. before the interview, the interviewees were clearly informed of the purpose of this interview (data collection) and were explicitly promised that all the contents of the interview (data) would be used for academic research only, and the subsequent interview (data collection) would only be conducted with the consent of the interviewees. In addition, for all the audio files, the interview texts were desensitized with personal information and strictly encrypted for preservation in order to ensure that the relevant rights and interests of the interviewees were not violated.

4.1.3 Data preparation and pre-processing

Typically, qualitative research mostly collects data through in-depth interviews, field observations, and focus group interviews. This study collected primary interview data primarily through face-to-face interviews (or online interviews due to the epidemic), as well as various publicly available data sources to supplement secondary data, for example, information on the interviewees' business profiles. These raw data are in the form of audio recordings, presentation materials and pictures, which are difficult to analyze directly and require pre-processing such as transcription, collation, and numbering to organize the information into textual material that can be analyzed, i.e., these unstructured data are pre-processed in preparation for the data coding and analysis below.

This study addressed the initial data as follows: (1) transcription of each interview recording into text, this step was done with the support of recording equipment and the Lark Converter application, and human correction of each textual material to reduce transcription errors, and the researchers tried to remain objective throughout the process and only addressed the accuracy of the material. (2) Following the ethical requirements of the study, all interviewees were anonymized, and data desensitized, and each respondent was given a specific number; (3) In addition to one-on-one interviews, this study made full use of existing sophisticated and convenient communication technologies, such as email, WeChat, and video conferencing, to communicate with interviewees in a timely manner. In short, the researchers maintained continuous communication and information sharing with interviewees throughout the data preparation and pre-processing period.

In accordance with the ethical requirements of the study, the interviewees were anonymized in this study mainly through the following methods: Using capital letters W or M for female and male interviewees and Arabic numerals for the first interviewee, e.g., W1 for the first female interviewee. other numbers have the same meaning and so on. In addition, keywords and industry-sensitive words were fuzzed during the interview process based on the interviewee's request and appeared as ellipses or superlatives in the coding as well as in the data examples.

4.1.4 Data analysis process and validity

This part follows the three-step coding method of procedural grounded theory to analyze the original data. This method can not only make up for the shortcomings of qualitative research in standardization and reliability, but also make up for the shortcomings of quantitative research in theoretical depth and validity. The coding process is divided into three steps: open-coding, axial coding, and selective coding. During the coding process, the researcher needs to remain sensitive to the theory and try to pave the way for the theory by categorizing the data into categories through constant comparison and trying to sort out the relationships between the different categories. By analyzing the research data in a specific research context, and then constructing a theoretical framework that can explain the context, ultimately deepening the understanding of the real world and phenomena and advancing the theory. Focusing on the research topic, by using this method, this section summarizes and refines a theoretical model of digital technology-enabled operational performance for transforming companies, with a view to providing theoretical support for technology investment and performance improvement in digitally transforming companies.

In addition, this section follows Yin (2009) case study design, i.e., multiple sources of data, information related to the interview outline, database creation, independent coders' discussions in response to inconsistencies, evidence chain building, and iterative discussions with the primary interviewees to safeguard reliability and validity. Reliability refers to the consistency, stability and reliability of the measurement results, and validity refers to the truthfulness, validity, and accuracy of the results, i.e., the extent to which the results reflect the researcher's intentions.

First, to ensure the reliability of this study, four main approaches were adopted: 1) During the actual interview, the interviewer would provide the interviewee with the purpose of the study, the topic, relevant information, etc., and explain the protection of private information, data desensitization, etc., and after obtaining the consent of the interviewee, the interview was recorded and transcribed. 2) After each interview, the initial coding was guaranteed to be completed within 24 hours, summarized in a timely manner, and repeatedly confirmed and discussed with interviewees for unclear or ambiguous points; 3) For each interview raw material, back-to-back coding and repeated iterations were conducted by at least two doctoral students in business administration who understood the main theories in the relevant fields, and the coding process tried to avoid the influence of personal bias on the coding results, discussed for inconsistent results, and conducted several internal discussions and corrections during the raw data analysis process; 4) During the process of database creation and presentation, this study showed the analysis process and specific paths of the raw data in steps while avoiding redundancy and taking into account representativeness.

Secondly, in order to ensure the validity of the study, i.e. that the findings do reflect theoretical concepts and real-world connotations, and to try to reduce the deviation between the "real world" as constructed by the researcher and the "real world" as described by the interviewees, three main approaches were adopted. 1) continuously ranking and eliminating potential disturbances in all aspects of the study according to the research questions, objectives, themes, relevant theories, etc.; 2) triangulating the data through multiple sources to test the stability of the findings and to verify their robustness and validity in different contexts; and 3) enhancing the diversity of the interviewees as much as possible based on ensuring the typicality of the sample, i.e., different genders, ages, education levels, years of work, types of industries to which they belong, and geographical areas to which they belong, etc., according to which the same research topic can be interpreted. The data analysis process of this study is shown in Figure 4.2.

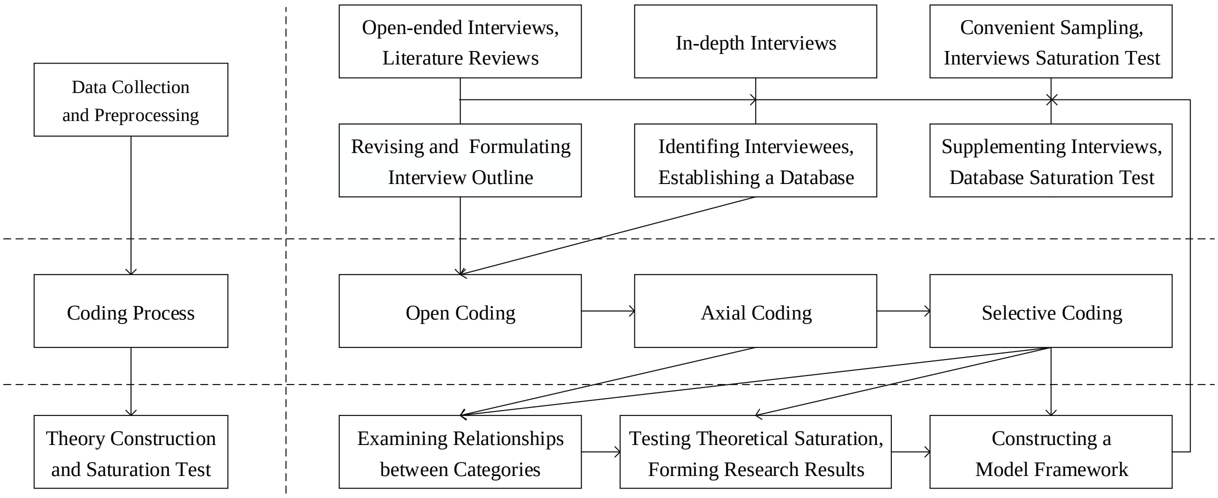

Figure 4.2 Data analysis process

4.2 Data analysis

The data analysis phase includes category extraction and saturation test. Category extraction is divided into open coding, axial coding, and selective coding. Open coding in the grounded theory approach is the analytical process of attaching concepts (codes) to observed data and phenomena in the process of qualitative data analysis, one of the "procedures" for dealing with texts proposed by and Corbin and Strauss (2008). Axial coding in grounded theory is the process of relating codes (categories and concepts) to each other, via a combination of inductive and deductive thinking. The final stage of data analysis is selective coding. Selective coding is the process of selecting central or core categories, systematically relating them to other categories, validating these relationships, and populating categories that require further refinement and development. Through selective coding, these categories are integrated and developed into theories. The coding process consisted of the following three main points: (1) breaking up the interview data of digital technology applications in enterprises, extracting meaningful and targeted raw data statements, and labeling them; (2) refining the initial concepts and initial categories by repeatedly comparing the similarities and differences of the initial labels; (3) inviting five experts and scholars in the field of business administration to discuss, analyze, and define the initial categories, and deriving the connections and relationships between the core categories and the main and secondary categories.

4.2.1 Open coding

4.2.1.1 Label data

In this study, the 40 interviews collected, totaling 230,500 words, were analyzed line by line, sentence by sentence, word by word, and meaningful and relevant raw statements were labelled, and as many labels as possible were generated inductively from the raw material, and statements indicating the same concept were given the same conceptual label. Due to the diversity, semantic complexity and certain intersectionality of the original data statements, by referring to existing literature and discussing with experts, the labels follow the following principles: (1) find statements related to the topic on digital technology empowering business operation performance; (2) the original statements should be complete in meaning and relatively independent from each other; (3) labeling uses raw data as much as possible to distill the meaning that the interviewees are trying to convey; and (4) focus on text that recurs in the raw material. Based on the above principles, the following will demonstrate the logical process of labeling by combining the interview data of 2 interviewees.

Interviewee W1 is a woman from the banking industry. in terms of the use of digital technology, it was mentioned several times that her company uses digital technology to varying degrees. For example, the scope, frequency, and functionality of digital use are the most visual manifestation of digital technology use, reflecting the popularity of digital technology.

For instance, she mentioned, "*Our branch is within the jurisdiction of the head office data center, and all the products used are also those of the head office. we do not have the authority and qualifications to innovate. starting from the branch, what the branch staff use is a unified working platform, and there are different platforms for different businesses. this is all unified nationwide, and there may be some codes in each region that will have some different differences. Some banks also have robots, but currently cover a relatively small range of outlets, generally in pilot operations. some outlets will have some robots to assist customers to handle* *some simple business or to help them line up. In addition some outlets in Shanghai, and some outlets in Guangzhou are currently open unmanned banks.*"

When assigning a specific label to the above interview content, a combination of interview questions and contextual context is required. After reading through the entire paragraph, it was found that this statement is able to reflect the application of intelligent robots in business operations and their interaction with customers. Therefore, the paragraph can be labeled as three: "pilot operation of intelligent robots"; "robots assist customers with their business"; and "unmanned banks opened in some branches".

As a further example, the interviewee mentioned that : "*Before the pandemic major banks mainly focused on offline services because people had more opportunities to go offline and did not expect the pandemic to occur later. Online business grew massively after the epidemic, and data centers also took advantage of the pandemic to massively develop many products and mobile online banking features. The bank's digital technology has become more mature during this period, so it can gain more competitive advantage, make the technology more perfect, more mature products, so it will be more attractive to customers. For small-size banks, during the pandemic, some business must still go offline, so it will have the problem of risk. But large banks it has completed the online mature business processing, so this is a particularly good opportunity to acquire customers. Such an example, I think, is able to show that the level of maturity of digital technology is able to help companies gain an edge over their competition at a certain level."*

After reading through the whole paragraph, it is possible to label the passage with five tags: "seize the opportunity to develop digital technology"; "continued development of digital technology can increase competitive advantage"; "technological and product improvements can attract customers"; "large companies can gain better access to customers"; "maturity of digital technology helps companies gain an advantage".

In addition, there is a paragraph about the characteristics of the employees of the enterprise: "*I can perceive, for example, ... I know this kind of state-owned bank, because it (the staff) is generally older, the staff aging situation is more serious, these older employees, very experienced, but they are more accustomed to offline business, not very accustomed to this kind of online business, there are a lot of business (may) have to countless times to tell him "this business can be handled through the kiosk", or "can let them (the customer) operate on mobile banking". Otherwise, once the customer comes, their first thought is "I can handle him (i.e. customer needs) manually". they have a mindset, so this kind of employee involvement has a certain impact on the digital use of the whole enterprise.*"

Based on the interview questions and the context, the above quote reflects the difference in the attitude of different employees towards digital technology and the impact of employee involvement on the digital technology in the company, while the interview notes show that the interviewees' speech slows down and becomes louder when referring to this part, and the use of digital technology is repeatedly described around the word "age", so it can be inferred that employees' personal characteristics are important for the use of digital technology. Therefore, we labeled the text content of this section with five tags: "employees in state-owned enterprises and banking are older"; "The aging of employees is serious"; "Experienced employees are more accustomed to offline business"; "Have the mindset of manually handling business"; "Employee participation affects the application of digital technology in enterprises".

Interviewee W5, a woman from the business services industry, repeatedly mentions that her company has been able to improve its work operations in terms of the use of digital technologies, for example, in customer relationship management, industry competition and productivity.

For example, she mentioned the role of digital technology in the relationship between companies and their customers: "*I think the digital technology used at that time was still not very mature, and in fact brands wanted to know what kind of people their customers were. Around 2018, the best platform on the market for consumer analytics was Taobao, but in Taobao they got three-party data, not primary data, and brands themselves wanted to know their own consumer profile, not the consumer profile analyzed by the data given by Taobao. So compared to other businesses, what we can offer to brands is: we can let brands get first-hand data, directly face their own members and customers, and then go to understand the information of these customers, this will be very accurate. This business is still relatively new at that time, not so many platforms are doing, so our volume is still relatively large. In addition, when we do this piece of business, it turns out to be more for brands to provide overall membership services, such as: the setting of membership mechanisms, membership activities, so we have a large customer base."*

This passage reflects the ability of companies to gain some advantages in competing in the industry. The author has tagged it with 5 labels: "Identifies the disadvantages of competitors"; "Defines the needs of customers"; "Provides first-hand data information"; "Has a relatively large business volume"; "Has a large customer base".

The interviewee also mentioned about the efficiency gains from the application of digital technology: "*For us internally, DT should save a lot of time and effort, that is, the efficiency has increased. For example, we were a little bit more traditional business, after we did it for* *the Party A, after they got those data back every day it was necessary to manually go through those reports and then to deal with those data. Now because of the system that is updated with them (synchronized), so the Party A hired our employees to help them to run the data to and use the data, I just need to click in the background, and can directly see what that report has (data), and then help him implement the analysis to come to a conclusion, very quickly.*"

This conversation reflects the themes related to efficiency in business operations. We have labelled it with 4 tags: "manual view of reports"; "synchronized and updated system"; "real-time view of reports in the background"; "rapid analysis of results".

Another example is, "*We did a New Year's campaign, and the feedback data from the campaign only showed the sales of the distributors and the number of orders, and it would take a long time to calculate the customer unit price and the number of units, but now our whole CRM system is directly connected to the customer's POS system, so I know which member, which person came to buy what and how many units. In the past, the feedback (data) came back, and the analysts went to Excel to process it based on the data they got, but now with this integration, especially after binding the whole membership data, we can do relatively deeper analysis to see the customer churn rate, whether the thing is doing well or not, which single products are selling well, which single products are not selling well, which single products can do activities, and how strong the discounts are."*

In this conversation, the keyword "customer" was mentioned several times, and the interviewees described in detail the acquisition and analysis of customer data in the course of their business operations, which were labeled as five tags: "connecting to CRM and POS systems", "specifying customer purchase lists", "viewing BI reports in real time in the background", "binding the entire membership data", and "doing detailed in-depth analysis".

Again, referring to the impact of digital technology on the day-to-day operations of companies: "*I'm not sure how to do it without digital technology, because I feel that large companies, especially finance, are using digital technology, for example, today this system is going to be online, I feel that this is similar to a strategic project, the company's leadership in the implementation of this (digital system), especially finance department. (and) if the general application in the company, finance department is the first to start, and then may go through many, many rounds of upgrading, is for financial compliance, forced to have to go with (digital technology).*"

Respondents in this conversation express the need for digital technology adoption, which is labeled in this paper under four tags: “indispensability of digital technology”; “strategic implementation by company leaders"; "digital technology undergoes multiple upgrades"; and "digital technology adoption can meet financial compliance".

Another example is, "*If we have access to digital technology in our daily life, if it can solve some unnecessary troubles, or bring me some convenience and solve my problems, I will be willing to use it. if it is at the level of the company, we may think more about the development of the company itself, its business, its efficiency, and its management, and may not think too much about the experience, but only to improve the experience in the process of use as much as possible. I think the existing internal management system, it is based on what business processes the company has first, for example, I have to draft a contract today, who to get to sign, who to get to stamp, who to get to review. The original process was to find a secretary to run through all these departments, drop it on the boss's desk, he reads it and signs it, and then hand it over to the next department. Now it is moving all these business processes online.*"

This conversation of the interviewees expresses the impact of digital technology application on the efficiency improvement of business processing innovations in the company's operations. Combining the interview questions and the contextual context, we label it with five tags: "digital technology facilitates business processing", "digital technology facilitates efficiency", "digital technology facilitates work management", "digital technology enhances the sense of experience of use", and "online business processes".

4.2.1.2 Conceptualize and categorizing data

After labeling all the original interview data, the subcategories, i.e., initial concepts, were refined by comparing the similarities and differences between the labels according to the guideline of "seeking common ground while preserving differences", which was different from the labeling stage where the original data were preserved as much as possible, but the initial concepts needed to be summarized in more academic language. 175 initial concepts were finally developed after repeated refinement. Further, the generated concepts are again compared and contrasted based on the attributes and dimensions given by the initial concepts, making them more abstract and categorized, and refining the categories that reflect the relationships between the concepts. At this stage, 38 initial categories are finally formed. The detailed initial categories are shown in Table 4.4 in terms of initial concepts.

Table 4.4 Categorization during open coding

Initial categories	Conversation texts (initial concepts)
A1 Widespread of digital	Companies are using different forms of digital technology (**a1 extensive use of digital technology**); App is very important for us, basically all customers should download one (**a2 download popular**); Our company started to introduce big

technology applications	data technology in instrument manufacturing, logging data acquisition, database application, etc. on a large scale. among them, instrument manufacturing mainly applies digital in instrument design, processing, quality inspection, storage, etc. (**a3 scale application of digital technology**)
A2 Intelligent diffusion of digital technology	robots assist customers to handle some simple business or help them to line up (**a4 machine to help line up**); some outlets in Shanghai, and some outlets in Guangzhou are currently opening unmanned banks (**a5 machine led business handling**); many of the company's businesses can be shunted to the machines (**a6 machine collaborative business handling**); the lobby is generally set up with many self-service machines, which are intelligent (**a7 a large number of intelligent machines are set up**); each room has an intelligent door lock system (**a8 popular intelligent door lock**). As my company is engaged in oil logging data acquisition and data processing business, digital acquisition and processing has been started since about 1995, mainly for processing and interpreting various data from underground stratigraphic measurements, evaluating geological characteristics such as porosity, permeability, oil (oil) and gas (natural gas) bearing properties of the strata, and providing supportiveness for later oil and gas extraction, such as the specific location and quantity of extraction (**a9 digital technology assisted business processing**); more automation in transferring materials and printing (**a10 assembly line intelligence**); CRM system solves the problem of customer relationship (**a11 digital technology assisted customer relationship management**)
A3 Rapid application of digital technology	Customers can download and use ICBC's mobile banking and online banking, which is currently used more frequently (**a12 technology is used frequently**); our company is always updating technology and then updating and replacing products based on this (**a13 technology is updated frequently**); the company performs online technology maintenance about every other quarter (**a14 technology is maintained frequently**); the system used by the company is iterated and optimized about every other year, and this system has been optimized about four or five times and is always being upgraded (**a15 system is continuously optimized**)
A4 Easy application of digital technology	Customers can handle a lot of business remotely online on mobile banking (**a16 cross time and space for business**); room door lock code distribution is also all the system directly through our client port to automatically send the password down to the customer's mobile phone (**a17 technical automation**); customers can report various supporting facilities to the room through the system, this operation is also very simple, for example: the water heater is broken, customers just need to open the app, and then according to the app prompts to report online repair (**a18 technical operation is simple**); the system has a search function, we use it more convenient (**a19 search convenience**). The teacher can add or subtract points based on the student's performance in the classroom. parents can receive their child's classroom grades on their mobile phones, which can help them understand their child's learning situation in school (**a20 timely information**); this technology can quickly help staff to manage the defense, manage the room, manage sales (**a21 fast management**); through this system to access the data of these vehicles, and then directly for the abnormal data of the vehicle repair is indeed much easier (**a22 fast access to data**); everyone can be on the platform of the document in real time, synchronous editing (**a23 real-time synchronous editing**).
A5 Rich functions of digital technology	In the context of digitalization, the head office has developed many products and many mobile (or) online banking functions on a large scale (**a24 scale development function**); on this platform you can pick up products, run cards, and do some simple business (**a25 rich business functions**); the XiaoPo Technology App includes various functions such as face recognition and alarms (**a26 diverse functions**); the SeeWo whiteboard has a full range of functions,

	such as digital presentation, Chinese character spelling, and English spelling (**a27 wide coverage of functions**). The pharmacy can automatically obtain the prescription prescribed by the doctor by scanning the QR code, to avoid mistaking due to the doctor's unclear handwriting (**a28 automatically obtain the prescription**); the information system of the repair shop can directly display which part of the front bar of the car I am repairing this time, the bumper it has a direct quote, and the reference price (**a29 the system automatically quotes**); we can retrieve the patient's previous cases from the system to make a comprehensive judgment (**a30 to increase data retrievability**)
A6 Discovering business opportunities	The technology is more perfect, the product is more mature, so then the attraction to customers will be greater (**a31 effectively attract customers**); the completion of a mature business processing online is a particularly good opportunity to acquire customers (**a32 effectively acquire customers**); with the help of these digital technologies, we will continue to find new business models, continue to try, and then continue to develop some new business opportunities (**a33 try to develop new business opportunities**)
A7 Identifying customer needs	All banks must improve digital technology so that they can better understand what customers want (**a34 better understanding of customer needs**); through this platform, we can market to customers accordingly, marketing some of our loan facilities, some preferential terms (**a35 accurate marketing strategy**); we will continue to maintain each port according to the needs of customers and the use of the housekeeper (**a36 continue to meet customer needs**); whether an employee leaves or say the employee is on temporary leave, his work is someone who can take over, and will not cause the loss of our customer information (**a37 ensure that customer information**)
A8 Optimizing resource allocation	The state of enterprise resource allocation when digital technology is thoroughly used will have a very big improvement compared to the state when digital technology is not thoroughly used (**a38 resource allocation comparison**); this system can integrate multiple resources well and can achieve a resource allocation maximization (**a39 resource allocation maximization**).
A9 Learning new knowledge	Learn something that can be used in their own work or life some knowledge (**a40 understand the new knowledge**); through such a learning, everyone can get points in this (**a41 get learning points**); they will be lazy to turn with their hands, now a little bit can see these things, learning motivation has been enhanced (**a42 enhance learning motivation**); the teacher will also use these digital technology, and then constantly go to learn and improve themselves (**a43 improve learning enthusiasm**); he is required to be proficient in the Internet system, and to establish data awareness (**a44 establish data awareness**); We are now training for an internal online course based on Taobao's nail app access (**a45 internal learning**)
A10 Streamlining of business processes	The use of this digital technology can enable all local drivers in Tianjin to use this card to pay fines directly online, as well as some appeal procedures (**a46 to enhance the convenience of business handling**); under the catalyst of digital technology, such a product derived for the convenience of customers (**a47 to provide convenience**); reduce the middle of many cumbersome processes, and then more regular (**a48 simplify the middle process**); his approval process is relatively more complete (**a49 improve the approval process**); compared to the previous, the entire organizational process is optimized (**a50 organizational process optimization**); between different levels of people, his information interoperability efficiency will be accelerated. digital progress brings the greatest effect is efficiency (**a51 enhance information interoperability**)
A11 Resource integration	This App directly carried out the online integration of data, which rooms are rented, which rooms have been rented out, rented out for how long and other information have a summary (**a52 data integration reporting**); documents are also classified all integrated together (**a53 document classification**

	integration); our monthly sales data summarized (**a54 summarized data**); later OA system all moved to Taobao DingDing, where some system things are included (**a55 system integration**); these software can provide a lot of convenience, including document sharing and meeting video, with this integrated software is very convenient (**a56 functional integration**)
A12 Identifying target customers	Innovations in technology can enable good use of this data so that customers can be acquired with great precision (**a57 precision customer acquisition**); customers in different regions can also be better connected together (**a58 optimizing customer relationships**)
A13 Improving the efficiency of innovation	The whole efficiency improvement should be a continuous innovation process (**a59 efficiency improvement**); special reform of some products, or special design of some products to make the whole business process become more rapid (**a60 business process change rapidly**); each month which sections or which market product sales have declined or improved, and if there is improvement, then where to get the improvement. These contents can be comprehensive and intuitive to reflect (**a61 visual display of market dynamics**); customers can more intuitively see the whole project duration is what kind of the project overall built out the effect is what kind of, which part is the use of what kind of engineering materials, so there is a more intuitive effect of the map, but also more conducive to our implementation of the project (**a62 visual display of engineering effect**)
A14 Expanding innovative forms	We will do some service-related innovation (**a63 enhance service innovation**); Children can feel it intuitively through videos or pictures. Then his class is no longer just a kind of sound transmission but will interact through more pictures and audio. What we do is include High Tech Expo, that is, the Expo of colleges and universities, which is to help the college publicize and make brands. These are relatively innovative (**a64 extended media model**); Such innovation can give customers better humanistic care and service (**a65 humanistic care innovation**); Innovation performance may be improved in some aspects of internal information communication (**a66 information communication innovation**)
A15 Boosting economic returns	The use of digital technology can improve some of the benefits of operations and can help companies achieve better profits (**a67 improve operating profits**); brings a very strong rise in revenue from 2017 to 2019 (**a68 improve revenue**); customers will also have greater stickiness to the bank as a whole (**a69 greater customer stickiness**); any decision will improve the overall business performance (**a70 improve operating performance**); for such a product, several major state-owned banks should hope to make the growth rate of loans to micro and small enterprises rise (**a71 improve business volume**); efficiency will increase, and then business processing will be more efficient, and the efficiency of the department will increase, and the company's performance will definitely increase (**a72 improve performance**).
A16 Reduction of solid waste	I think it reduces the use of paper, and the whole business process is gradually changing from a paper-based office to a paperless office (**a73 promote paperless office**); all contracts signed online are electronic contracts (**a74 popularize electronic contracts**); offline we also save a lot of materials (**a75 save materials**)
A17 Improving environmental performance	DT can help with carbon emissions (**a76 solve carbon emissions**)
A18 Cost reduction	It is beneficial for our hospital to have a cost control (**a77 strengthen cost control**); this piece is also a cost saving for the company (**a78 save cost**); for example, the credit system, uploading can be done without recording information every time and so on, the overall cost is definitely saved (**a79**

	reduce economic cost); as to whether they have sent the paper-based stuff to the middle office and so on, it should be no. So that they may still look at these information online, so it actually alleviates the mailing cost of the company (**a80 reduce mailing cost**). The most important cost should be the cost of time, so accordingly the cost will be reduced (**a81 reduce the cost of time**); found (machine appears) failure people cannot have to go, relatively improve the efficiency, it can reduce the company consumption (**a82 reduce manpower costs**); store manager to decide how much goods need to enter, predict the shortage will be how much, and artificial intelligence prediction may still have a certain gap, in this regard there may be a 5% to 10% improvement. For the loss rate of goods, that is, the accuracy of other forecasts in the middle is greatly improved, and the efficiency in this aspect is improved (**A83 reduce the cost of goods loss**); I think the larger the scale, the higher the cost and difficulty of human management will increase exponentially. At this time, it will be much easier to manage with one tool (**a84 reduce the cost and difficulty of human management**)
A19 Service satisfaction	We will give feedback to our customers in terms of the attitude of the staff on the app, the overall hygiene of the store, including the overall condition of this room, which means that there will be feedback on customer satisfaction (**a85 feedback on service satisfaction**); we will continuously improve our digital technology and make adjustments for the sake of customer satisfaction (**a86 improve customer satisfaction**); customers' trust in the hotel, or their expectations of the hotel, will be better (**a87 improve customer trust**); when we use digital technology to improve performance, it is those customers who really benefit (**a88 being customer friendly**)
A20 Personal safety	The core technology is to ensure the safety of all on-site construction personnel (**a89 staff personal safety**); there's a robot that puts it there when there's a possible fire and smoke, and it's able to do early warning (**a90 fire safety**); this technology also prevents outsiders from coming in, so it's actually quite safe (**a91 environmental safety**)
A21 Data Security	Digital technology is a very convenient and privacy-protective design, which I think is quite thoughtful (**a92 privacy design is very thoughtful**); this software of Air China also has a password, so it is also very secure (**a93 password security**); external personnel cannot directly enter our internal system to view this information (**a94 information viewing security**); the company has an intranet, which requires certified employees to log in and have a VPN before they can access individual data (**a95 set up an intranet to access data**). Another point is that for each business department there is a certain division of permissions, for example, my department, may not have permission to view the data of other departments ...... digital technology has made such a cut, even many internal permission groups we cannot see ourselves (**a96 division of permissions to access data**); our technical team is doing the whole server security and safety on a part-time basis, that is, its operation and maintenance. regarding the products we provide to users, we think our technology is on the upper side of the industry (**a97 data operation and maintenance security**). Take the confidentiality and management of documents and files within the company as an example, if the personnel is in a certain department, he has no permission to access some confidential documents in other departments. this technical staff will grade the documents, then the encryption level of the documents is different (**a98 document encryption grade processing**); document management is a more important thing, to protect the more confidential things for the company, it can protect part of the security of the company's internal data (**a99 protection of confidential data**)

A22 Improving operational capacity	When users book hotels, the best results are predicted by using our system (**a100 improve results accuracy**); digital technology can help our internal personnel attendance management, as well as the management of some meetings (**a101 strengthen internal management**); I think the development of digital technology is conducive to the control of the banking industry (**a102 improve the ability of corporate control**); our internal collaboration is this digital collaboration. in terms of workflow and work depth, far more than the same type of enterprises (**a103 improve the ability of corporate operations**). Digital technology will allow companies to master the entire business chain, as opposed to progressively separate processes, it can really bring an overall efficiency improvement (**a104 business efficiency improvement**); the performance aspect of the early company is still more of a humanistic management, but our boss was not very satisfied with the situation, so that's why we started to use Taobao's Dingding app for attendance (**a105 improve standardized management**)
A23 Enthusiastic work attitude	There will be a lot of employees with stronger enthusiasm to transform some of the current physical banking (business) to this direction of Internet finance (**a106 strong enthusiasm of employees**); within the company, you can know the strategy of the boss, because it is fully open (**a107 information openness**); and when other companies do not pay salaries and year-end awards on time, (we also) according to the highest specifications (**a108 ensure employee welfare**); this software system, very easy to communicate and collaborate between us, where this reminder meeting (function) is very good (**a109 improve employee satisfaction**)
A24 Work inertia	The older staff, who are experienced but more used to offline operations, are not very used to doing this online (**a110 operational habit**); their first thought is "I can handle him (i.e. the customer's needs) manually"; they already have a mindset (**a111 mindset**); if a developer completes a task, he is less inclined to update it because he finds it troublesome (**a112 work inertia**)
A25 Technical proficiency	A better mastery and understanding of emerging technologies will enable them to make better use of these emerging technologies throughout the bank's operations (**a113 degree of mastery of technologies**); like some older teachers may have some difficulties in using these modern technologies (**a114 difficulties in the operation of technologies**); irregular use of software, or although such software is available, it has some learning costs, which may lead to some problems (**a115 irregular use of technologies**). Because the system is actually still somewhat large and slightly complex, it may have some categorization links that not some employees who are new to the job can understand, for example, the more complex credit system. Now the system is still quite complex, it is necessary to be led by someone to use (**a116 technology exists threshold**)
A26 Reducing work stress	Digital technology can largely ease the workload (**a117 reduce workload**); I hope our technology can gradually improve, can gradually reduce the pressure of editing (**a118 ease the pressure of editing**); before applying digital technology to banking, you need to submit a lot of information (card), now directly on the mobile banking application, can help employees to reduce some pressure (**a119 reduce work pressure**); in the development process, business will also be cross-departmental. Through this platform, we have reduced the number of meetings (**a120 reduce the number of meetings**); in our opinion, in fact, digital solution is not a problem that cannot be solved by people, but can be solved by people (**a121 solve work problems**)
A27 Enhancing work capacity	Digital technology can improve employees' ability to a certain extent (**a122 improve employees' ability**); The participation of the broadcaster and the professionalism of the broadcaster will affect his ranking on this platform, as well as our exposure and the traffic given to us by the platform (**a123 employee**

	professionalism); Moreover, when using digital technology for analysis, he can also conduct a quality training for his company's employees to improve their quality (**a124 improve the quality of employees**); In the production process, for example, ERP or Devops, which are highly domain software, in terms of supply chain or operation and maintenance development, is actually an assistance to improve business capability (**a125 improve business capability**); I think this software is doing well. I believe its developers must also understand the needs. They know what the pain points we face, so they can do it well according to these pain points (**a126 solve the problem of work pain points**); Digital technology can cooperate with business to do logical combing. For example, we design experiments, how to prove its lifting power, how to prove its gain, and how to find intermediate causality and measurement relationship (**a127 help sort out logic**); The use of these tools can also stimulate the creativity of employees to a great extent, and help enterprises provide better products and services (**a128 improve the creativity of employees**).
A28 Improving efficiency	The use of this system can improve the efficiency of teachers' use of the classroom, and there will be no situation that everyone wants to use (**a129 improve job efficiency**); Contribute to the improvement of the internal operation efficiency of our company at ordinary times (**a130 improve the internal operation efficiency**); It will improve our communication efficiency in this work as a whole (**a131 improve communication efficiency**); Save a lot of time (**a132 save a lot of time**); At the same time, there is a workbench function in the system. After opening, you can process business through the mobile terminal and carry out mobile office (**a133 convenient for mobile office**); Through member interaction, the operation is easier, which actually improves the efficiency of employees (**a134 convenient for employees to deal with business**); For traditional state-owned enterprises, they rely on business departments for manual and manual data statistics. Now an information version of OA system and financial management system are online, which can greatly improve work efficiency. For a normal reimbursement process, the original labor takes at least one month... Now the financial management system and OA system are used. Through the connection of the two systems, each employee can initiate the reimbursement process online, and it takes only one week to financial audit (**a135 improve work efficiency**); Our pump house needs remote control, because people can't always stay next to the machine (a**136 help remote office**); Without this technology, hundreds of thousands of employees of the company need to work by hand (**a137 assist employees in working**)
A29 Improving service quality	Remote personnel will make a judgment according to the quality of some business documents photographed by the system (**a138 business service quality**); Whether it is to remotely check the service status or score of employees, there will be corresponding plus or minus points due to the quality of their service (**a139 improve service evaluation**)
A30 Mitigating job risks	Through digital technology, our company can predict many risks in the future (**a140 reduce risks**); The application of digital technology greatly reduces some losses caused by the untimely connection of funds (**a141 reduce losses**)
A31 Reducing operational errors	This system can count some error rates of business, and the degree of remote rejection will have corresponding bonus and deduction (**a142 evaluate the business error rate**); Engineers can build buildings one by one according to such three-dimensional animation. If such drawings enabled by digital technology are used to build houses, the error rate will be less (**a143 reduce the error rate**); At the same time, through such a model, they hope to better evaluate the risks of small and micro enterprises and reduce risks (**a144 reduce enterprise risks**)

A32 Digital engagement awareness	The data awareness of employees may have a great impact on the process of digital construction or its achievements (**a145 employee data awareness**); For employees, the degree of acceptance will gradually become stronger over time, and employees are also very willing to accept the use of some digital software (**a146 employees' willingness to accept**); Employees must be affected by this tool on how to better self-management and team management (**a147 employees' self-management**); The use intention of employees may have an impact on the use results of the tool itself (**a148 employees' use intention**); Achieve some benefits according to the specifications of the software. If the software is used but not standard, the benefits may be reduced (**a149 employee use specifications**); Relevant employees can actively participate in the practice (because it can greatly reduce their labor intensity and improve the timeliness) (**a150 employees actively participate**); When he doesn't really realize this value, they will think that these works are redundant, repetitive or meaningless; Let them see the significance of this process. When they see the significance of this process, they feel that using digital technology is more efficient. At the later stage, if employees feel that doing things in this way is more efficient, many things will be easier to do (**a151 change their attitude towards new technology**)
A33 Employee feedback	Employees' opinions are very important. We will collect employees' feedback on the system at the monthly meeting every month (**a152 employees' regular feedback**); If everyone can use this product in time, update the data in time, and then report the progress, other people using this technology in the project will get feedback immediately (**a153 employees get feedback in time**). The more they use it, the more convenient it will be for others; For example, if I want to send a file to the leader now, I will upload it to the system, and then give him a link. He can also comment on it. After I modify it, he can also see it directly (**a154 work transparency**)
A34 Technical competitiveness	If the development of digital technology is relatively mature, it can obtain more competitive advantages under such conditions (**a155 technology competitive advantage**); When digitalization is more suitable for the needs of enterprises, it will play a greater role in promoting enterprises (**a156 technology meets the needs**)
A35 DT system competitive capacity	These systems also form a very strong role of industry barriers in the future competition (**a157 system competitive potential**); The whole digital system will give your company an advantage in the highly competitive Internet Ecosystem (**a158 system competitive advantage**); Because this platform is customized, if this platform is suitable for your company, you will have advantages over other companies (**a159 platform applicability**)
A36 Hierarchy competitive capacity	If our digital technology and platform are more perfect, it means that our company hierarchical system is perfect, and it can prove that we are more competitive than competitive companies to a certain extent (**a160 improve the competitiveness of the company hierarchical system**); Using digital technology, it can be found that the company may be going downhill. For example, it may be found that there is a defect in the profit model (**a161 effectively identify the defect of the revenue model**)
A37 Product competitiveness	The competition of digital technology is largely the competition of the same industry. The same banks are also using some emerging technologies to make some products (**a162 product homogenization**); Enterprises will often visit to see where our products are different from those in the same industry (**a163 identify the differences between products in the same industry**); This technology can refine the number of visits to our website to a section or even an article, and there will be a very detailed data analysis, so we can pay attention to our information products. No matter which information products are not popular, there will be a very detailed data analysis, which will help to improve

	our products (**a164 improve product quality**). For this bank, with such a product, it can seize the market (**a165 better expand the business market**); Each warehouse has its own management system to facilitate storage (**a166 standardize product management process**)
A38 Comparative competitiveness	Through such a system, we can better understand where our problems are and what kind of gap we have with our competitors (**a167 competitive advantage comparison**); practices that their own school did not have before and felt good about when visiting competitors can be introduced (**a168 identify competitor strengths**); they can also better understand where their problems lie and what kind of gaps they have with their opponents (**a169 better understanding of their own strengths and weaknesses**). Consider learning from some competitors about their trends, and therefore go to reference to move in a similar direction (**a170 learn from competitors' strengths**); so that many news companies, who are now actually in the process of digital transformation, are paying attention to technology transformation, because without technology, it is difficult to compete with other companies (**a171 peer competitors' incentives**); the more intense the competition, the more demands companies will put forward, and this demand will be fed back to the designer of this technology product, which may also promote this product to become better (**a172 enhance competitive advantage**). Large firms are high-quality assets for banks, and competition from peers leads to a process of market capture (**a173 retain high-quality competitive resources**). Internal corporate information systems are not decisive for external markets ...... For example, the efficiency of management within different consulting firms determines the outcome of output solutions, and the more efficient they are, arguably they tend to achieve better results than their rivals (competing firms), ceteris paribus, because some traditional firms may not have been doing this, but with more competitors stepping in, it too is looking for cooperation and technical support (**a174 change in a competitive environment**); we also pay very close attention to how our competitors are doing it. How businesspeople are using digital technology, what the chain of their business looks like, and between this and the fact that it may involve multiple departments within our company doing this at the same time. A bit like the AB test, there are times when we also pay attention to the problems they are experiencing with their systems, which can be very informative for us (**a175 raise competitive awareness**)

Note: "a" for initial concept and "A" for initial category in the open coding process.

4.2.2 Axial coding

After the open-ended coding distilled the 175 initial concepts and 38 initial categories, the data remained relatively dispersed and relatively independent. In contrast to the open-ended coding, which decomposed the data into discrete parts, the second stage of coding was axial coding, which aimed to understand the relationship between categories and other categories and their subcategories in an attempt to make connections between the initial categories. In this stage, continuous comparisons continued to be made to discover similarities between categories until the subcategories were found with the main categories.

In the axial coding process, the distilled core categories or themes were validated by: in-depth analysis of the logical relationships between the initial categories based on phenomena, causality, parallelism, analogy, logical conditions and constraints, successive comparisons and cluster analysis of open-ended codes, which in turn grouped these categories together. Therefore, at this stage, this study analyzes sentence by sentence the view of possible intrinsic relationships between different initial categories in the open coding, and always pays attention to maintaining the rigor and mutual exclusivity of the relationships between the initial categories. By analyzing and combining the 38 initial categories obtained in the open coding and refining the subcategories and main categories that can cover the initial categories with similar concepts. Finally, 23 subcategories and 6 main categories are formed, and the results are shown in Table 4.5.

Table 4.5 Results of axial coding

Main categories	Subcategories	Initial categories
C1 Digital technology	B1 DT volume	A1 Widespread of DT applications A2 Intelligent diffusion of DT
	B2 DT application speed	A3 Rapid application of DT A4 Easy application of DT
	B3 DT type	A5 Rich functions of DT
C2 DT-enabled capabilities	B4 Sensing capacity	A6 Discover business opportunities A7 Identify customer needs
	B5 Coordinating capacity	A8 Optimize resource allocation A10 Learn new knowledge
	B6 Learning capacity	A9 Streamline of business processes
	B7 Integrating capacity	A11 Resource integration
C3 Innovative performance	B8 Innovation effectiveness	A12 Identify target customers A14 Expand innovative forms
	B9 Innovation efficiency	A13 Improve innovation efficiency
C4 Firm operational performance	B10 Financial performance	A15 Boost economic returns
	B11 Environmental Performance	A16 Reduction of solid waste A17Improve environmental performance
	B12Cost reduction	A18 Cost reduction
	B13 Upgrading service	A19 Service satisfaction
	B14 Upgrading security	A20 Personal safety A21 Data Security
	B15 Upgrading operations	A22 Improve operational capacity
C5 Employee engagement	B16 Job vitality	A23 Enthusiastic work attitude A26 Reduce work stress
	B17 Job performance	A32 Digital engagement awareness A33 Employee feedback A30 Mitigate job risks A31 Reduce operational errors
	B18 Duties fulfillment	A24 Work inertia A25 Technical proficiency
	B19 Professional effectiveness	A27 Enhance work capacity A28 Improve efficiency A29 Improve service quality
C6 Industry competition	B20 Technological competition	A34 Technical competitiveness A35 DT system competitive capacity
	B21 System competition	A36 Hierarchy competitive capacity

	B22 Market competitiveness	A37 Product competitiveness
	B23 Competitive consciousness	A38 Comparative competitiveness

Note: "B" represents the subcategory and "C" represents the main category

In order to intuitively display the analytical logic of the axial coding phase, the process of refining subcategory is illustrated by the example of "B4 Sensing capacity", where some interviewees described the use of digital technologies in their companies to acquire new customers, as reflected in "A6 Discover new business opportunities", the core ideas reflected in this initial category: "effectively attract customers", "effectively acquire customers" and "try to develop new business opportunities".

For example, "Compared to relatively small banks, they [large banks] have better technology and more mature products, which will be more attractive to customers. small banks did not lay out their digital business in advance during the epidemic and some of their business must need to go offline, which leads to the loss of customers. but such large banks have established more mature online business processing systems." This conversation texts reflect the fact that through the use of digital technology, firms can have a better chance of attracting new customers (a31 effectively attracting customers; A6 Discover new business opportunities).

Another example is, "We mainly advocate the idea of giving young people a warm home and forming a harbor to anchor. Nowadays, young people's renting has become an important social issue, especially for the female group. Young girls renting outside often comes with great safety hazards. Long term rental apartments like ours are flexible and convenient with a deposit of 1 to 1. The head office has developed an online app, so customers who may have searched for our apartments from WeChat public website or Meituan at the beginning can make reservations directly online by downloading the app." The text of this conversation reflects that through the application of digital technology, companies can have a better chance of attracting new customers (a32 effective customer acquisition; A6 Discover new business opportunities).

The company has been able to use this digital technology to show up in some encrypted system, so through some technological innovation, it can make these data to be well applied, and it can be very accurate to get the customer. At this stage, for example, a customer needs to buy a house, then it can go to him accordingly to carry out targeted and accurate marketing, marketing some of our loan products, some preferential terms. If the customer has a relatively large amount of money coming in during this period, the account manager can also use this way to manage this customer's money, that is, to help the customer to be able to better manage their property."

All three of these points reflect the ability of companies to effectively identify new customers and business opportunities when using digital technology. Therefore, the initial category "A6 Identifying new business opportunities" was extracted to describe and reflect this situation, and in a continuous comparison of the initial categories, it was found that "A7 Identifying customer needs" could also represent the phenomenon of customer acquisition and reflect the firm's ability to grasp the market in a business environment; however, the two differed in terms of specific concepts. "A6 Discover New Opportunities" focuses more on the ability of companies to identify potential customer opportunities, while "A7 Identify Customer Needs" focuses more on the ability to identify and meet customer needs, including "better understanding customer needs", "precise marketing strategies", "continuously meeting customer needs" and "securing customer information". For instance, Interviewee M11 mentioned, "*If we go to a TV ad, for example, you don't really know what yield that TV ad is going to bring you, how many people are coming because of the TV ad. Now because of the addition of some of the more detailed digital content, you can reach your members directly, and this is an extra piece of business that needs to be in the overall marketing budget and the overall organizational structure. The whole department originally had a person who was doing advertising placement, then a person who was doing some offline marketing activities, and another person he is now required to specialize in this piece of business of membership, knowing what the situation of their members is, how to use the system, how to get members to keep repurchasing or whatever, it changes throughout. "This passage reflects that through the application of digital technology, companies are able to better understand the needs of customers based on their shopping habits (a34 better understanding of customer needs; A7 Identify customer needs).*"

Also, for another instance, "*It is the same as having a whole set of operating system in the background, which can help offline shoppers to attract accurate potential customers more easily, because with such a system, for the party A, he can better manage these shoppers. For example, if I have a promotion and I want to send out some coupons, I can import these coupons into the system with one click and then send the coupons to the customers through the system, and then the whole process is smooth with all the verification in the backend, but originally it was very troublesome to do this. If you don't write off the voucher clearly, it will be very chaotic. Now we integrate these functions into the digital analysis system. For example, we all know what kind of coupons I have issued to what kind of customers, whether the customer has come to write off the coupons, what the coupon code is, and whether the corresponding person is appropriate. "* This conversation text reflects that through the application of digital technology, firms can precision marketing and attract potential customers (a35 precision marketing strategy; A7 Identify customer needs).

Again, “*Because there were many customer members, he (the employee) had to keep track of the whole complex process, the categories of business, how to do it, etc. But now it is basically done by clicking on the appropriate function module. For example, if a customer wants to withdraw money, I click on the option to withdraw money, and the customer's information will pop up; another example is a machine used to swipe the card, and after swiping the card, the customer's information will be displayed; if a customer wants to deposit money, enter 200, click on the confirmation, the system will automatically perform the background operation, and the customer will then deliver the money.*”

Moreover, "*At the same time, it will add a very convenient service. After we have this online system, through big data search and collection, we extracted the information about the customer's birthday. Then our head office will send the time of the customer's birthday to our store stewards and store managers in the background.*" This conversation text reflects that through the application of digital technology, companies are able to accurately obtain basic information about their customers and innovate customer needs (a37 ensure customer information; A7 Identify customer needs).

The above analysis shows that both "A6 Discover New Business Opportunities" and "A7 Identify Customer Needs" reflect that the application of digital technology contributes to the improvement of a company's market perception capabilities; "A6 Discover New Business Opportunities" focuses on the company's identification of market opportunities, while "A7 Identify Customer Needs" focuses on the identification and satisfaction of customer needs; therefore, the two concepts are juxtaposed and constitute important aspects of a company's sensing capabilities.

4.2.3 Selective coding

After extracting the main category and subcategory from axial coding, the third stage is selective coding. The purpose of selective coding is to uncover the central category from the main categories, discuss the relationships between the main categories and subcategories, and describe the overall phenomenon or event in the form of a storyline. Therefore, at this stage, the work of determining the central category and creating the storyline will be completed successively. Firstly, the central category of this study was defined as "*digital technology-enabled business performance mechanisms*" through in-depth analysis of each subcategory and the main category, repeated comparisons based on the original data records, and discussions with three professors in business administration and two PhD students. The reason for identifying this as the core category is that (1) the research topic of this study is an inquiry into digital technology-enabled business operational performance, which is fundamentally a discussion about the antecedents of business operational performance; (2) The core category must be overarching and closely linked to other main categories. The main categories of "digital technology", "digital technology-enabled capabilities", "innovation performance", "employee engagement" and "industry competition" are the influencing factors of "business performance" and are all covered in the core category of "digital technology-enabled business performance mechanisms".

Further, "storylines" are identified around the core category. The application of digital technologies can significantly affect the entire operational process of a firm: firstly, the application of digital technologies enhances the capacity of digital technology empowerment due to its different characteristics such as volume, speed as well as variety, which in turn is influenced by employee engagement. Secondly, once the firm's capacity is enhanced, it promotes the firm's innovation performance, with industry competition acting as a moderating factor in the impact process. Finally, the firm's innovation performance affects the firm's operational performance.

Finally, this "story line" is used as a clue to sort out the typical relationship structure of this study, as shown in Table 4.6: (1) in the context of digital transformation, the digital technology (volume, speed and type) of a firm directly affects the ability of digital technology empowerment; (2) the ability of digital technology empowerment has a direct effect on the innovation performance of a company; (3) the innovation performance of a company has a direct effect on the operational performance of a company; (4) Employee engagement moderates the impact of digital technology on DT-enabled capabilities; (5) Industry competition moderates the impact of digitally enabled capabilities on innovation performance.

Table 4.6 Typical relationship structure of the main categories

Typical relationship structure	Connotations of relationship structure
DT → DT-enabled capacity	Digital technology has an impact on the enabling ability of digital technology, that is, the application of digital technology in different degrees, such as volume, speed and type, will affect the enabling ability of firm digital technology.
DT-enabled capacity → Innovation performance	Digital technology-enabled capabilities have an impact on innovation performance, i.e., the ability to sense, coordinate, learn, and integrate directly affects innovation performance
Innovation performance → Operational performance	Innovation performance has an impact on operational performance, i.e., the firm's innovation effectiveness and innovation efficiency affect the performance of the firm's operational processes

DT → DT-enabled capacity Employee engagement ↑	Employee engagement plays a moderating role in the impact of digital technology on DT-enabled capabilities, i.e., employees' perceptions, feelings, and behaviors toward the enterprise enhance or diminish the effect of digital technology on DT-enabled capabilities
DT-enabled capacity → Innovation performance ↑ Industry competition	Industry competition plays a moderating role in the process of the effect of DT-enabled capabilities on innovation performance, i.e., the effect of DT-enabled capabilities on innovation performance is influenced by competition in terms of technology, systems, and markets.

4.2.4 Theory saturation test

After completing the three major coding steps, a theory saturation test is also required to demonstrate the adequacy of the sample and the reliability of the findings associated with the development of the theory. Theoretical saturation of categories occurs during coding and analysis if no new attributes appear, and the same attributes keep appearing throughout the range of the data. That is when the newly collected data can no longer yield new categories and make no new contribution to the theory building, theoretical saturation is reached, and the research is completed. When newly collected data contribute to theory building and new categories emerge, the study should return to the data collection and data analysis phase, requiring constant comparisons until theoretical saturation is reached. In this phase, this study focuses on three methods to achieve theory saturation based on:

(1) Triangular validation. On the one hand, using mixed methods (interviews, observations, memos) to collect data can reach data saturation faster than using only one qualitative data collection method. Secondly, the diversity of sample selection. Conduct research on different types of enterprises, such as banking, real estate and Internet industries。

(2) Expert experience. Five experts and scholars in the field of business administration are invited to participate in the coding process. They provide rich experience in qualitative analysis methods and can effectively supplement the tacit knowledge about the research results, such as when to reach data saturation and stop data collection.

(3) Supplementary information. This study conducted supplementary research to obtain 6 new original materials and ensured the stability of the research results through the constant comparative method. The goal is that these new data will not produce any new concepts, themes or knowledge. In the process of data analysis, constantly ask "what are the concepts not mentioned before in the new interview data? Can the existing concepts cover all the contents?". After repeated comparison, the research results show that the categories of open coding, axial

coding and selective coding are very comprehensive, and there is no new category emerged, and there is no new connection between categories (For reasons of avoiding repetition as well as space, the results of the supplementary studies will not be given in detail here). Therefore, the coding has been verified, and the proposed theory has passed the theoretical saturation test.

4.3 Results

4.3.1 Explanation of model concepts

(1) Digital technology

Digital technology is a modern science and technology based on information and communication technology, with modern information network as the carrier and digital knowledge and information as the production factors. According to the results of grounded analysis, digital technology mainly includes three characteristics: first, volume, which refers to the rapidly increasing use of digital technology by firms. Second, velocity, which refers to the speed and frequency with which firms process and integrate digital technology. Third, variety, which refers to various types of digital technologies.

(2) Digital technology-enabled capabilities

Digital technology-enabled capabilities refer to the ability of companies to integrate, build and reconfigure internal and external capabilities to respond to rapidly changing environments through digital technologies. Conceptually, digital technology-enabled capabilities are composed of four dimensions of basic emotions, including sensing capacity, coordinating capacity, learning capacity, and integrating capacity. Sensing capacity is defined as the ability to identify, interpret, and pursue opportunities in the environment. Coordinating capacity is defined as the ability to coordinate and deploy tasks, resources, and activities within new operational capabilities. Learning capacity is defined as the ability to adapt existing operational capabilities with new knowledge. Integrating capacity is defined as the ability to embed the integration of new knowledge and resources into operational processes by building a common understanding.

(3) Innovation performance

Innovation is defined as the successful application of new ideas generated by organizational processes in which different resources are combined to seek improvements in products or services in the marketplace and bring returns to them. Innovation performance is divided into two main categories, innovation effectiveness and innovation efficiency. Innovation effectiveness refers to the extent to which innovation is beneficial to the firm, while innovation efficiency reflects the time and effort required to achieve that level of benefit.

(4) Operational performance

Operational performance refers to the impact of the various aspects of a firm's operations on production and is an important indicator used to measure a firm's competitiveness. Operational performance in this study includes a number of aspects such as unit manufacturing costs, service quality, speed of new product introduction, flexibility, safety levels, and environmental protection.

(5) Employee engagement

Employee engagement refers to a positive, fulfilling, work-related mindset that reflects a vibrant and effective connection between employees and their work activities. Employee engagement includes three dimensions: emotional, cognitive, and behavioral, such as work dynamics, work contribution, performance of duties, and professional effectiveness.

(6) Industry competition

Industry competition in a broad sense refers to the concentration in the industry, the number of firms, the size of each firm, etc. In this study, industry competition refers to the competition between different firms in the same industry in terms of technology, systems, and markets。

4.3.2 A model framework for DT-enabled operational performance

Based on the above analysis, the six main categories distilled in the previous section are integrated in logical lines, and this study thus proposes the model framework explaining the influencing mechanism of digital technology on firms' operational performance. Figure 4.3 illustrates the theoretical framework. The model framework consists of six components: the antecedent of operational performance correspond to digital technologies in the model; the mediators of operational performance correspond to digital technology-enabled capabilities and innovation performance in the model; digital technology-enabled capabilities include four dimensions of sense, coordination, learning and integration, and innovation performance includes two dimensions of innovation effectiveness and innovation efficiency; employee engagement and industry competition are moderators of operational performance, which moderate digital technology-enabled capabilities and innovation performance, respectively; and operational performance is the outcome, reflecting the effect of all the previous factors on the operational performance of the firm.

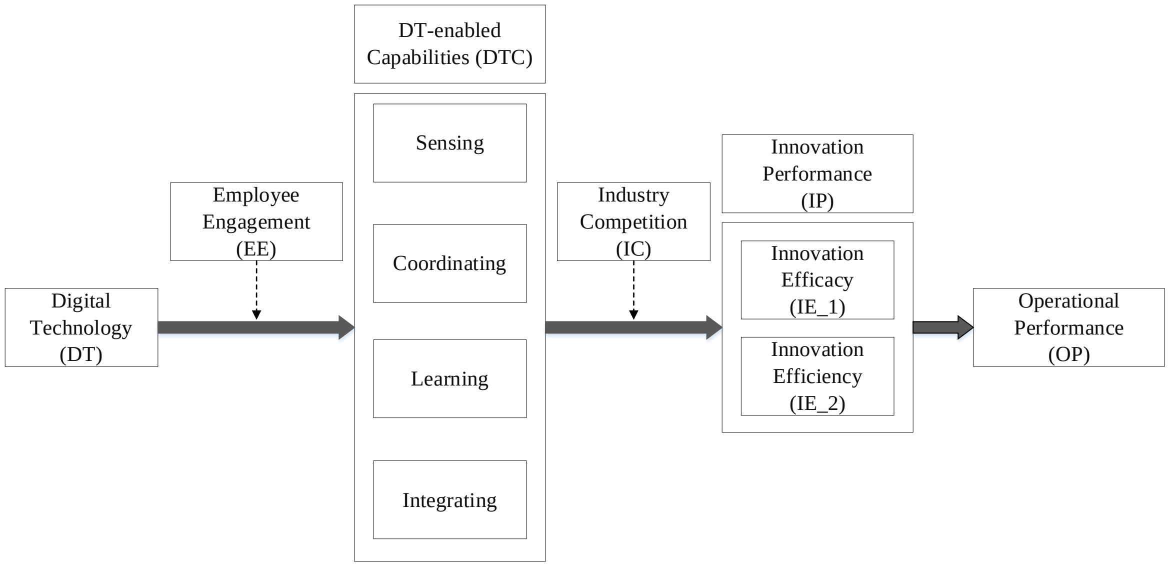

Figure 4.3 The theoretical framework for DT-enabled business operational performance

The theoretical model consists of seven logical paths. The three direct logical paths are: digital technology directly and positively affects digital technology-enabled capabilities; digital technology-enabled capabilities directly and positively affect innovation performance; and innovation performance directly affects operational performance. The two indirect logical paths: digital technology-enabled capabilities play a mediating role between digital technology and innovation performance; digital technology-enabled capabilities and innovation performance play multiple mediating roles between digital technology and operational performance. The two moderating logical paths are: employee engagement moderates the effect of digital technology on digital technology-enabled capabilities; and industry competition moderates the effect of digital technology-enabled capabilities on innovation performance.

4.4 Summary

This chapter rigorously follows the process and steps of the procedural grounded theory analysis pattern to modeling the mechanisms of digital technology-enabled business operational performance. First, an interview outline was designed around the conceptual composition, antecedents, and formation mechanisms of employees' perceptions of the impact of digital technology on business operational performance. Second, 46 respondents from different regions and industries were selected for interviews, and more than 260,000 words of original interview data were collected. Subsequently, 175 initial concepts and 38 initial categories were refined through open coding, spindle coding, and selective coding, and finally 23 sub-categories and 6 main categories were formed. Further, core category and story lines connecting main categories were identified, and the relational structure of this study was sorted out to arrive at a theoretical model framework of digital technology-enabled business operation performance mechanism.

Based on the research work in this chapter, the following conclusions are drawn:

(1) In the context of digital transformation, digital technology (volume, speed, and variety) directly affects digital technology-enabled capabilities including sensing, coordination, learning and integration. In terms of conceptual connotation, digital technology is a modern science and technology based on information and communication technology, modern information network as a carrier, and digital knowledge and information as a production factor. And in terms of conceptual structure, digital technology has three dimensions: volume, speed, and variety. Digital technology-enabled capabilities, on the other hand, refer to the ability of companies to integrate, build and reconfigure internal and external capabilities to respond to a rapidly changing environment with the help of digital technology. In terms of conceptual structure, DT-enabled capabilities are composed of four dimensions: sensing, coordination, learning and integration.

(2) Innovation performance is an important outcome variable when firms enhance their digital technology-enabled capabilities. From the perspective of conceptual connotation, innovation performance refers to a firm's ability to seek product or service improvements in the marketplace and generate returns for them through the application of new ideas from organizational processes with different resource combinations. From the perspective of conceptual structure, it can be further divided into innovation effectiveness and innovation efficiency.

(3) Innovation performance has a direct impact on the operational performance of the firm. The effectiveness and efficiency of innovation in the firm ultimately affects the operational performance of the firm. From the perspective of conceptual connotation, operational performance refers to the impact of the various aspects of the firm's operations on production. From the perspective of conceptual structure, the operational performance in this study includes various aspects such as manufacturing cost, service quality, speed of new product introduction, flexibility, safety level, and environmental protection.

(4) Employee engagement plays a moderating role in the impact of digital technology on digitally enabled capabilities. Employee engagement refers to a positive, fulfilling, work-related mindset that reflects a vibrant and effective connection between employees and their work activities. Employee engagement includes three dimensions: emotional, cognitive, and

behavioral, which can moderate the impact of digital technology on digitally enabled capabilities.

(5)Industry competition moderates the impact of digital technology-enabled capabilities on innovation performance. Industry competition can be broadly defined as the concentration in the industry, the number of firms, the size of each firm, etc. Firm competition in terms of technology, systems, and markets moderates the impact of digital technology-enabled capabilities on innovation performance.

In summary, this chapter proposes a theoretical modeling framework for how digital technology influences firm operational performance, but the findings in this chapter are based on qualitative research with a small survey sample, and the generalizability of the results needs to be cross validated by quantitative research with a relatively larger sample. To this end, this study will empirically test the mechanisms by which digital technologies affect the firms' operational performance by using questionnaires and structural equation modeling in the subsequent chapters. This hybrid research design has two main advantages. First, the absence of prior assumptions allows the researcher to distill theories from the data that best reflect the characteristics of the data rather than preconceptions; second, the reconfirmation of the resulting theory with survey data overcomes the subjectivity that can be introduced when grounded theory is used and provides maximum support for the theory.

Chapter 5: Measurement and Verification of Digital Technology on Business Operational Performance

Based on the theoretical modeling framework of how digital technologies affect the operational performance of firms presented in Chapter 4 using Grounded Theory approach, this Chapter will empirically validate the mechanisms how digital technologies affect the firms' operational performance by using questionnaires and structural equation modeling. We follow the standard empirical research paradigm for questionnaires. First, the research hypothesis is formulated based on theory. Then, the questionnaire is designed, and data is collected. Based on the data collected, the reliability and validity of the measurement scales are evaluated. Finally, the proposed structural model is tested using the partial least squares structural equation modeling technique.

5.1 Research hypotheses

5.1.1 Digital technologies (DT) and DT-enabled capabilities

Digital technology empowers enterprises mainly from the four aspects of perception, coordination, learning and integration. First, digital technology can improve the ability of enterprises to perceive the dynamic and complex competitive environment. On the one hand, the birth of digital technologies such as app and digital platform makes it possible to quickly integrate and standardize the display of industry information. These applications bring rich information to enterprises, enabling them to fully understand the needs of stakeholders (Hansen & Sia, 2015). On the other hand, through the application of digital technology, enterprises can quickly and accurately complete data collection, data sorting, data storage, data circulation, data analysis and data mining, so as to realize the comprehensive and efficient utilization of internal and external data of enterprises. By processing and analyzing the integrated data information, enterprises can accurately predict the future trend, quickly respond to customer needs, and quickly identify, explain and find the latest business opportunities and threats in the external environment (Tabrizi et al., 2019). Therefore, the application of digital technology greatly improves the perception ability of enterprises.

Secondly, digital technology can better enhance the ability of enterprises to deploy tasks, resources and activities. The application of digital technology in enterprises realizes the flow, sharing and interworking of data information in the whole process of the enterprise and various business units. The flow, intercommunication and circular feedback of data and information have opened up all key business links within the organization, improved the communication quality and efficiency between different departments and different levels, and promoted the cooperation between departments (Klewes et al., 2017). Enterprises can also allocate data information to different business units, realize the coordination of corresponding business processes, business resources and business personnel, and achieve better results in arranging tasks, allocating resources and organizing activities (Handoko et al., 2015). Therefore, the coordinating capacity of enterprises can be improved.

Thirdly, digital technology improves the ability of enterprises to acquire and apply new knowledge. On the one hand, in the increasingly symbiotic digital ecological environment, the boundary between enterprises and the external environment is gradually being broken. Through digital technology, enterprises continue to acquire new knowledge shared by enterprise stakeholders including partners, consumers and competitors, enabling enterprises to quickly connect external information sources, expand the breadth and depth of information, and realize interactive learning between external cognition and external environment (Trantopoulos et al., 2017). On the other hand, when facing new knowledge, enterprises can use digital technology to develop or update digital tools to better integrate new knowledge into their business processes. The application of digital technology enables enterprises to use new knowledge in daily operation at a faster speed, lower cost and more convenient way to promote the reconstruction and integration of new knowledge and internal and external resources (Appio et al., 2021). Therefore, the learning ability of enterprises has been improved.

Finally, digital technology improves the ability of enterprises to integrate internal and external resources. By introducing digital technology, enterprises can optimize the internal governance structure, production process and operation mechanism of the organization, and use digital technology to assist or replace inefficient manual operations, so as to meet the needs of diversified market operation and reduce internal management costs (Chowdhury et al., 2022). In addition, with the help of digital technology, enterprises can break through the constraints of traditional element boundaries, help enterprises output effective information to stakeholders, enable stakeholders to master more sufficient information, reduce information asymmetry, and promote enterprises to obtain the support of stakeholders (Aben et al., 2021; C. Liu et al., 2017).

Based on the above reasoning, the following assumptions are proposed:

H1: The application of digital technology is positively related to the ability of digital technology empowerment of enterprises.

5.1.2 Employee engagement as a moderator

Employee engagement refers to a positive, fulfilling, work-related mindset that reflects a vibrant and effective connection between employees and their work activities. When employees are engaged, they bring all aspects of themselves(i.e., cognitive, emotional, and physical) to the performance of their work role (Saks & Gruman, 2014). Since the implementers of digital technology use are employees, different levels of employee engagement inevitably affect the application and effect of digital technology. Thus, to the extent that employee engagement is an moderator between digital technology and digital technology-enabled capabilities.

Firstly, when corporates undergo technological transformation, such as the adoption of innovations or new technologies, employee acceptance or resistance to these changes will depend on level of engagement (W. Wang et al., 2021). Highly engaged employees have close association with their work as well as their corporate, pursue technological change and innovation, and view emerging digital technologies positively. Meanwhile, high employee engagement having a higher sense of corporate identity and act to achieve the corporate’s goals and mission (Afsar, Al‐Ghazali, et al., 2020). In other words, when a corporate is undergoing digital transformation, high employee engagement may strongly identify with the company's practices and respond more positively to the digitization of the work environment. Hence, highly engaged employees contribute more skills, knowledge and resources in the application of digital technology, contributing to identifying opportunities, allocating resources, etc., thereby enhancing the digital technology-enabled capabilities. Furthermore, less engaged employees maintain digital technology is a predictor of insecurity and stress, while highly engaged employees regard digital technology as a work resource (Chan et al., 2021). Highly engaged employees are willing to apply digital technology to analyze information and acquire new knowledge, thus promoting the digital technology-enabled capabilities. Accordingly, this thesis infers that the impact of digital technology on the digital technology-enabled capabilities varies due to different levels of employee engagement, and proposes the following hypothesis:

H2: Employee engagement positively moderates the relationship between digital technology and digital technology-enabled capabilities.

5.1.3 Digital technology-enabled capabilities and innovation performance

In this study, digital technology-enabled capabilities refer to the ability of companies to integrate, build and reconfigure internal and external capabilities to respond to rapidly changing environments through digital technologies. The capabilities include digital technology-enabled sensing, coordinating, learning, and integrating capability of organization. Innovation performance is usually defined as the “the degree to which a firm's innovation process is successful in terms of producing outcomes that lead to new or significantly improved products or services, processes, new marketing methods, or new organizational methods in business practices, workplace organization, or external relations, which is divided into two main categories: innovation effectiveness and innovation efficiency.

Digital technology-enabled sensing capabilities help organizations to identify market environment and digital technology opportunities. Through organizational learning to find new digital technology-enabled value-enhancing combinations inside, between and among the organization, organizations can seize the potential digital technology opportunities to respond the changing needs and meet competitive pressure of market. Further, the organizations can coordinate and integrate collective digital technology resources and knowledge to respond to dynamic environment (Pundziene et al., 2021). Accordingly, digital technology-enabled dynamic capabilities can promote organizations to renew their capabilities related to sensing digital technology opportunities, help organizations to learn digital technology-enabled value-enhancing combinations, and to coordinate and integrate intangible and tangible assets and resources after digital technology adoption (Mishra et al., 2022; Teece, 2007). These assets and resources are dynamic and have unlimited potential (Lusch & Nambisan, 2015). The rapid deployment and combination of these resources at a specific time is a key factor in innovation performances. In addition, the dynamic capability view is embedded in the evolutionary theory of innovation (Janssen et al., 2016), which emphasizes the dynamic use of organizational resources (Teece, 2018). Thus, digital technology-enabled dynamic capability is critical to innovation. Research has shown that dynamic capabilities are the key to continuous innovation and sustainable competitive advantage (Janssen et al., 2016). Thus, this study proposes the following hypotheses H3:

H3: Digital technology-enabled dynamic capability is positively related with organizational innovation performance.

5.1.4 Industry competition as a moderator

Industry competition in a broad sense refers to the concentration in the industry, the number of firms, the size of each firm, etc. In this study, industry competition refers to the competition between different firms in the same industry in terms of technology, systems, and markets. Different levels of industry competition can effectively regulate the ability and behavior of enterprises, which has been confirmed by many studies that it will significantly affect the strategic decisions of enterprises such as new product development and innovation.

Industry competition is expected to enhance the role of dynamic capability in promoting innovation performance. In the case of high-intensity competition, enterprises have to focus on the existing market. However, in order to effectively compete with peer enterprises to maintain the current market share, enterprises still need to use their existing digital technology-enabled capabilities to optimize existing field products and improve innovation performance. In addition, the high degree of market commonality and resource similarity in the case of high-intensity competition forces enterprises to learn from competitors and make more effective use of the acquired knowledge, and then promote the transformation of dynamic capabilities, such as perception and learning ability, into innovation performance.

Therefore, this study infers that due to the different intensity of industry competition, the impact of the digital technology-enabled capabilities on innovation performance will be different. In particular, we propose the following hypothesis H4:

H4: Industry competition enhances the role of digital technology-enabled dynamic capability in promoting innovation performance.

5.1.5 Innovation performance and operational performance

We believe that enterprise innovation performance is positively associated with enterprise operation performance. Previous research has shown that innovation performance can improve quality and reduce costs in the short term, thereby bringing a long-term sustainable competitive advantage to firms, thereby improving operational performance (J. Hong et al., 2019). On the one hand, effective communication with suppliers is considered as a keyway for enterprises to improve quality at the innovation level. Enterprise innovation can improve quality through communication with suppliers and knowledge development. In the context of supply chain integration, innovation performance has been found to have a positive impact on operational performance in terms of improving product quality, new distribution methods, and organizational effectiveness and efficiency (Seo et al., 2014). On the other hand, the cooperative relationship between enterprises and suppliers can encourage firms to innovate (Geffen & Rothenberg, 2000), and the incentive degree of innovation largely depends on the increase of enterprise demand for products. Firms can reduce product costs by increasing the scale of product demand (B. Kim, 2000) In the context of small and medium-sized enterprises implementing innovation strategies, product, process and organizational innovation can improve enterprise performance by reducing production costs (Exposito & Sanchis-Llopis, 2018). Based on the above reasoning, we propose the hypothesis H5.

H5: Enterprise innovation performance is positively associated with enterprise operation performance.

The research model incorporating the hypotheses is illustrated in Figure 5.1. The model constructed in Chapter 4 through Grounded theory has a high complexity (e.g., Sensing, Coordinating, Learning, and Integrating). For example, the dynamic capability of data technology empowerment includes four dimensions, and according to the requirement of measuring no less than three measurement questions per latent variable, our questionnaire will measure more than 60 questions. Considering that the respondents of this study are the managers of companies, too many survey questions will lead to a rather low quality of sample responses and respondents' willingness to participate. Therefore, the model validated in this chapter is moderately streamlined, e.g., digital technology-enabled capacities consist of four measurement questions, measuring sensing, coordinating, learning, and integrating, and similarly innovation performance consists of four questions, two of which measure innovation efficacy and two of which measure innovation efficiency. By doing so, our model includes the framework and the main latent variables of the model proposed by Grounded theory, while reducing the number of latent variables to six and keeping the number of measurement questions to 25.

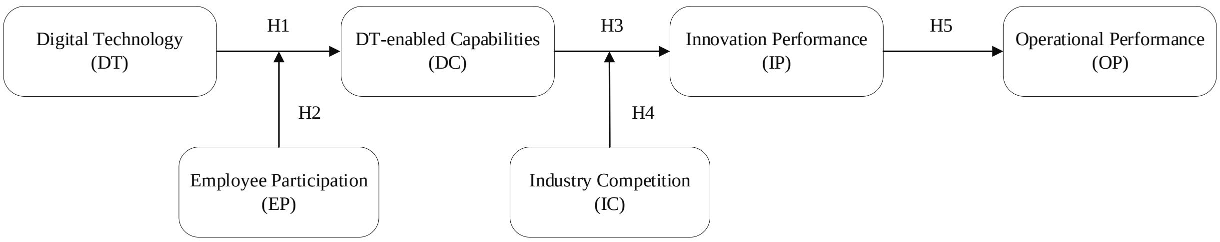

Figure 5.1 The research model

5.2 Measures

The questionnaires had two parts, the first part contained the demography, involving gender, age, level of education, and employment information. The second part consists of questions relating to digital technology, digital technology-enabled dynamic capability, employee engagement, innovation performance, operational performance and industry competition. As shown in Table 5.1, the original questions are all adapted from the well-known international journals.

The study variables were measured using 7-point Likert scales based on previous literature. The works were published in the well-known international journals. The items of digital technology are adapted from Ghasemaghaei and Calic (2020). Digital technology-enabled capability is measured using the items from Pavlou and El Sawy (2011). Employee engagement is assessed using the scale from Rasool et al. (2021) and L. Wang et al. (2021). The items of innovation performance are adapted from Ghasemaghaei and Calic (2020). Operational performance is measured using the items from Naseer et al. (2021), while those of industry competition is adapted from Naseer et al. (2021) and Tammi et al. (2020). Finally, the study includes four firm-level control variables: enterprise scale, establishment time, and annual turnover. The use of control variables can alleviate endogeneity problems.

The scales were all in English, which were translated into Chinese by forward and reverse translation. (1) Forward Translation: The Chinese translation of the original English scales was conducted by one Chinese professor and two PhD students in big data and marketing, and the Chinese version was formed after repeatedly refining the items, scoring principles, content and language. (2) Reverse Translation: One Chinese-American marketing professors were invited to translate the Chinese version back into English version, and this scale was carefully compared, reviewed, and calibrated with the original English scale, while fine-tuning it for the Chinese national context and the digital technology and operational management situation.

Table 5.1 Measurement Items

Constructs	Items
Digital technology (Ghasemaghaei & Calic, 2020)	In my firm, we use a great deal of digital technology. In my firm, we use several different digital technologies to gain insights. In my firm, we are fast in introducing our digital technology.
Digital technology-enabled capability (Pavlou & El Sawy, 2011)	My firm frequently scans the environment to identify new business opportunities. My firm is effective in utilizing knowledge into new products. Employees in my firm manage to successfully interconnect their activities. Overall, my firm is well coordinated.
Innovation performance (Ghasemaghaei & Calic, 2020)	My firm is good at developing new markets. My firm constantly cultivates the existing market. My firm quickly opens new markets. My firm efficiently cultivates the existing market.
Employee engagement (Rasool et al., 2021; H. Wang et al., 2020)	I really throw myself into my job and organization engagement. I fulfil all responsibilities required by my job. I am enthusiastic about my job.
Industry competition (S. Khan et al., 2021; Tammi et al., 2020)	In our industry, there are many other firms offering the same products or services. In our industry, price competition is highly intense. In our industry, there is much competition.
Operational performance	Customer satisfaction of my firm is good. Cost management of my firm is good.

(Naseer et al., 2021)	Responsiveness of my firm is good. Productivity of my firm is good.

5.3 Data collection

The data were collected through an online survey aimed at managers who are familiar with digital technology investment, deployment, and/or operational management. Therefore, the background of the respondents investigated in this chapter is similar to that of the interviewers in Chapter 4. Snowballing sampling or chain-referral sampling was used to recruit the participants. The whole investigation process lasts for 43 days, from May 8, 2022 to June 20, 2022. Empirical examination of our hypotheses required the selection of people who are familiar with the digital technology investment. Thus, we added a screen item "Are you responsible for or familiar with your company's investment in digital technology and its application in firm operations?" If the user answers no to this question, the questionnaire for that user is closed. A pretest conducted with 20 MBA students revealed that the questionnaire is satisfactory. Pretesting will help us determine if respondents understand the questions. Pre-tests also provide the most direct evidence for the validity of the questionnaire data for most items.

It is recommended that each variable used in a study must have at least ten responses of participants for effective results. Six variables are represented in the research framework; therefore, at least 60 responses of participants will be needed to conduct the regression analysis for effective results. Participation in this study was voluntary and responses were anonymous. In addition, the dependent and independent variables were included on different pages of the survey, thus preventing responders from identifying causal relationships between the constructs. The results of variance inflation factor (VIF) suggested that there is no common method bias in the study, as all values are between 1.046 and 1.421, lower than the common 3.3 threshold.

5.4 Data analysis and results

After removing 17 participants who failed the attention checks included in the survey, or did not complete the whole questionnaire, the final sample included 339 firms. The profiles of the firms are reported in Table 5.2. The number of employees of sample firms in 30.1 percent is between 100 to 500. More than half of sample firms have established for more than ten years. The annual turnover of sample firms in 36.6 percent is more than 100 million.

Table 5.2 Firm profiles

Variables	Content	Number of firms	Percent（%）
Number of employees	Less than 100	73	21.5
	100-500	102	30.1
	500-1000	58	17.1
	1000-3000	39	11.5
	3000-8000	22	6.5
	More than 8000	45	13.3
Established time	Less than 1 year	5	1.5
	1-3 years	29	8.6
	3-5 years	43	12.7
	5-10 years	75	22.1
	More than 10 years	187	55.1
Annual turnover	Less than 1000 thousand	22	6.5
	1000-5000 thousand	54	15.9
	5000-10000 thousand	40	11.8
	10000-50000 thousand	58	17.1
	50000-100000 thousand	41	12.1
	More than 100000 thousand	124	36.6

Note: 339 valid samples.

We use SmartPLS 3.0 partial least squares (PLS) structural equation model to test the hypothesis. PLS-SEM is appropriate when the model is complex, as in our study. Moreover, this study focuses on predicting variables, which makes the use of PLS more convenient (Bitrián et al., 2021). PLS simultaneously assesses the measurement and structural model, and these two steps are described next.

5.4.1 Analysis of the measurement model

The proposed model includes reflective constructs. First, the internal consistency reliability and convergent validity of the reflective measurement model was assessed following the criteria proposed by Hair Jr et al. (2017) (see Table 5.3). Internal consistency reliability was confirmed. Specifically, the Cronbach's alphas and composite reliability for all constructs were greater than 0.7. Convergent validity was thereafter confirmed. Specifically, individual item reliability for all factor loadings were all above 0.60 (the minimum value is 0.735 in our study) and statistically significant at 1% (Carmines & Zeller, 1979). The average variance extracted values (i.e., AVEs) were above 0.5 (Fornell & Larcker, 1981). Second, the discriminant validity of the reflective constructs was assessed following the criteria proposed by Hair Jr et al. (2017) (see Table 5.4, Table 5.5, and Table 5.6). Specifically, all the indicators' outer loadings on the associated constructs were greater than any of their cross-loadings on other constructs. And, the square roots of the AVEs of each construct were greater than the inter-construct correlations (Fornell & Larcker, 1981). And, the HTMT values were below the threshold of 0.90.

Table 5.3 Reflective measurement model results.

Variables	Items	Loading	P	Cronbach's α	CR	AVE
Digital technology	DT1	0.885	***	0.869	0.919	0.791
	DT2	0.908	***			
	DT3	0.876	***			
Employee participation	EP1	0.858	***	0.837	0.902	0.754
	EP2	0.855	***			
	EP3	0.892	***			
DT-enabled Capabilities	DC1	0.833	***	0.849	0.898	0.689
	DC2	0.830	***			
	DC3	0.869	***			
	DC4	0.786	***			
Industry competition	IC1	0.889	***	0.830	0.898	0.746
	IC2	0.835	***			
	IC3	0.865	***			
Innovation performance	IP1	0.833	***	0.824	0.884	0.656
	IP2	0.833	***			
	IP3	0.735	***			
	IP4	0.833	***			
Operational performance	OP1	0.816	***	0.830	0.887	0.662
	OP2	0.787	***			
	OP3	0.828	***			
	OP4	0.822	***			

Notes: ***p<0.01. DT1 means the first item of digital technology, EP1 means first item of employee participation, DC1 means the first item of DT-enabled Capabilities, IC1 means the first item of industry competition, IP1 means the first item of innovation performance, OP1 means the first item of operational performance, and so forth.

Table 5.4 Cross loading

Variables	Items	Digital technology	Employee participation	DT-enabled capabilities	Industry competition	Innovation performance	Operational performance
Digital technology	DT1	**0.885**	0.505	0.630	0.235	0.523	0.475
	DT2	**0.908**	0.492	0.567	0.221	0.387	0.463
	DT3	**0.876**	0.412	0.522	0.192	0.381	0.405
Employee participation	EP1	0.419	**0.858**	0.546	0.218	0.473	0.576
	EP2	0.465	**0.855**	0.568	0.181	0.495	0.615
	EP3	0.497	**0.892**	0.597	0.23	0.480	0.568
DT-enabled capabilities	DC1	0.584	0.491	**0.833**	0.243	0.575	0.538
	DC2	0.491	0.593	**0.830**	0.194	0.525	0.538
	DC3	0.537	0.638	**0.869**	0.229	0.554	0.600
	DC4	0.537	0.455	**0.786**	0.305	0.555	0.464
Industry competition	IC1	0.188	0.176	0.248	**0.889**	0.226	0.204
	IC2	0.226	0.269	0.290	**0.835**	0.222	0.215
	IC3	0.221	0.174	0.208	**0.865**	0.177	0.162
Innovation performance	IP1	0.424	0.528	0.560	0.172	**0.833**	0.569
	IP2	0.372	0.423	0.544	0.217	**0.833**	0.552
	IP3	0.336	0.337	0.456	0.178	**0.735**	0.452
	IP4	0.444	0.494	0.584	0.223	**0.833**	0.553
Operational performance	OP1	0.471	0.535	0.552	0.159	0.561	**0.816**
	OP2	0.403	0.574	0.498	0.206	0.485	**0.787**
	OP3	0.368	0.531	0.516	0.168	0.550	**0.828**
	OP4	0.404	0.560	0.536	0.209	0.544	**0.822**

Notes: DT1 means the first item of digital technology, EP1 means first item of employee participation, DC1 means the first item of DT-enabled Capabilities, IC1 means the first item of industry competition, IP1 means the first item of innovation performance, OP1 means the first item of operational performance, and so forth.

Table 5.5 Fornell-Larcker test

Variables	Digital technology	Employee participation	DT-enabled capabilities	Industry competition	Innovation performance	Operational performance
Digital technology	0.890					
Employee participation	0.531	0.868				
DT-enabled capabilities	0.648	0.657	0.830			
Industry competition	0.244	0.242	0.291	0.864		
Innovation performance	0.489	0.556	0.665	0.244	0.810	
Operational performance	0.506	0.674	0.646	0.227	0.659	0.814

Note: The values on the diagonal are the square roots of the AVEs. The values below the diagonal are correlations of constructs.

Table 5.6 Heterotrait-monotrait (HTMT) ratios

Variables	Digital technology	Employee participation	DT-enabled capabilities	Industry competition	Innovation performance	Operational performance
Digital technology	1					
Employee participation	0.618	1				
DT-enabled capabilities	0.750	0.778	1			
Industry competition	0.287	0.287	0.344	1		
Innovation performance	0.569	0.663	0.793	0.291	1	
Operational performance	0.593	0.812	0.768	0.271	0.793	1

5.4.2 Analysis of the structural model

The statistical significance of the standardized paths was assessed through a bootstrapping process with 5,000 subsamples. The model explains 56.0% of digital technology-enabled capabilities variance, 45.4% of innovation performance, and 44.9% of operational performance.

The results of the structural model are summarized in Figure 5.2. In support of H1, digital technology promotes the DT-enabled capabilities ($\beta = 0.426$; $p < 0.01$). In support of H2, DT-enabled capabilities promote the innovation performance (β = 0.654; $p < 0.01$). In support of H3, innovation performance promotes the operational performance (β = 0.672; $p < 0.01$). And, interaction with digital technology and employee participation promotes the DT-enabled capabilities (β = 0.056; $p < 0.1$). Interaction with DT-enabled capabilities and industry competitions promotes the operational performance (β = 0.060; $p < 0.1$). Therefore, all hypotheses are supported.

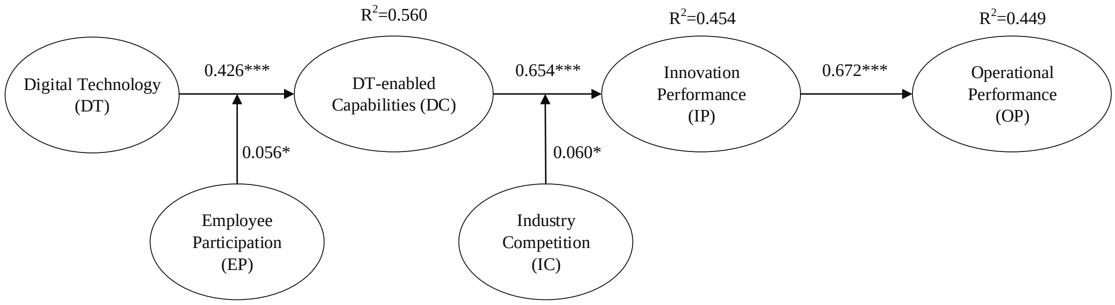

Figure 5.2 The results of structural model

Note: *p<0.1, **p<0.05, ***p<0.01.

5.4.3 Post-hoc analysis of the indirect effects

The proposed structural model results underline the importance of DT-enabled capabilities and innovation performance. Thus, this section analyzes the indirect paths of influence among these variables. We followed the procedure proposed by Hair Jr et al. (2017), and the results of this analysis are shown in Table 5.7.

The results suggested that the digital technology interaction with employee participation positively influences innovation performance through the DT-enabled capabilities (β = 0.036; $p < 0.1$). Employee participation positively influences operational performance through the DT-enabled capabilities and innovation performance (β = 0.196; $p < 0.01$). Industry competition positively influences operational performance through the innovation performance (β = 0.055; $p < 0.1$). Digital technology positively influences innovation performance through DT-enabled capabilities (β = 0.279; $p < 0.01$). DT-enabled capabilities positively influence operational performance through innovation performance (β = 0.439; $p < 0.01$). The DT-enabled capabilities interaction with industry competition positively influences operational performance through innovation performance (β = 0.040; $p < 0.1$). Digital technology positively influences operational performance through innovation performance (β = 0.187; $p < 0.01$). Employee participation positively influences innovation performance through DT-enabled capabilities (β = 0.291; $p < 0.01$). Digital technology interaction with employee participation positively influences operational performance through DT-enabled capabilities and innovation performance (β = 0.024; $p < 0.1$). Digital technology interaction with employee participation positively influences innovation performance through DT-enabled capabilities (β = 0.036; $p < 0.1$).

Table 5.7 Mediation analysis

Path	β
DT * EP --> DC --> IP	0.036*
EP -> DC --> IP --> OP	0.196***
IC --> IP --> OP	0.055*
DT --> DC -->IP	0.279***
DC --> IP --> OP	0.439***
DC * IC --> IP -->OP	0.040*
DT --> DC --> IP --> OP	0.187***
EP --> DC --> IP	0.291***
DT * EP --> DC --> IP --> OP	0.024*
DT * EP --> DC --> IP	0.036*

Note: *p<0.1, **p<0.05, ***p<0.01. DT means digital technology, EP means employee participation, DC means DT-enabled capabilities, IC means industry competition, IP means innovation performance, OP means operational performance.

5.5 Summary

By using partial least squares structural equation modeling method, we in this Chapter empirically validate the mechanisms how digital technologies affect the firms' operational performance. We followed the standard empirical survey research paradigm. First, the research hypothesis is formulated based on solid theory and the existing studies. Then, the questionnaires and scales were designed, and data was collected. After removing the participants who failed the attention checks included in the survey, or did not complete the whole questionnaire, the final sample included 339 firms. We assessed the reliability and validity of the measurement model, and common method bias, and got the satisfactory results. The results show that the application of digital technology is positively related to the ability of digital technology empowerment of enterprises. Employee engagement positively moderates the relationship between digital technology and digital technology-enabled capabilities. Digital technology-enabled dynamic capability in turn is positively related with organizational innovation performance. Industry competition enhances the role of digital technology-enabled dynamic capability in promoting innovation performance. Enterprise innovation performance is positively associated with enterprise operation performance. The results confirmed our results derived from the grounded theory in the Chapter 4.

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Chapter 6: Conclusion and Future Research

This chapter discusses the findings of the data analysis in the previous chapter 5. The theoretical contribution and practical management value of this study are described based on the discussion of the findings. Finally, the limitations of the study and the directions that can be improved in the future are discussed.

6.1 Research result and contribution

This thesis tries to address the following questions: (1) How do digital technologies affect operational performance? (2) How do digital technologies shape different dimensions of firms' capabilities? (3) How do firms' capabilities affect firms' operational performance? (4) What factors moderate the relationship between digital technology and operational performance? In order to address the above questions, this study used a combination of qualitative and quantitative research methods. Specifically, we used grounded theory and partial least squares structural equation modeling (PLS-SEM) algorithm. As a "naturalistic" approach to research, grounded theory emphasizes the natural presentation of theories, which is the opposite of positivism, where hypotheses are first made and then tested by data collection. Grounded theory holds that everything is data, which requires researchers to start with data and conduct bottom-up induction and analysis. Grounded theory is deeply influenced by symbolic interaction theory. It mainly focuses on the interactive process between social subjects, that is, the analysis of social process. Therefore, the research of process model is very suitable to use the method of grounded theory. Grounded theory can handle multi-stage problems with ease, but some commonly used quantitative methods cannot achieve good results. For example, the experimental methods commonly used in business administration research are difficult to manipulate multi-stage independent variables; The questionnaire is not good at clarifying the causality that the process model research emphasizes. Finally, grounded theory is also suitable for models with many variables and complex relationships among the variables. This study is to propose a process model, that is, the process mechanism of the introduction and use of digital technology affecting the operation performance of enterprises. This process is complex and involves multiple variables and the interaction between variables. Therefore, grounded theory is very appropriate. Considering the increasing importance of understanding the latent phenomena, the use of PLS-SEM has grown exponentially in the last few years. PLS-SEM is mainly used to develop theories in exploratory studies. It does this by focusing on explaining the variance of the dependent variable when examining the model. The objective of this study is to identify the key variables and intermediate mechanisms that contribute to operational performance. At the same time, the structural model proposed in this thesis through grounded theory is complex and contains several moderating variables as well as control variables. In addition, the study involves a small survey sample size because the research population in this study is firms rather than traditional consumers as the research sample. Besides, post-hoc tests have suggested that the data are not normally distributed. The aforementioned reasons motivate us to use PLS-SEM as a research method to validate the model proposed by the grounded theory. By applying grounded theory and structural equation modeling together, we obtained some interesting findings that can answer the research questions we initially proposed in chapter 1.

6.1.1 Research results

In today's economic and social development and the emergence of various digital technologies, organizations in many industries are accelerating their value creation processes to improve their operational performance. Digital technologies are considered to be a powerful weapon for companies to be able to build and maintain a competitive advantage in today's era of rapid development, and the ubiquity of digital technologies is bringing about profound social and industrial changes. However, this reality is not matched by the fact that existing studies have not yet reached clear conclusions on the impact of digital technologies on operational performance. Although a large number of studies have explored the potential benefits of digital technologies, the existing literature on digital technologies and business performance is still in the exploratory stage and lacks systematic in-depth studies.

To this end, this study starts from the concept of "digital technology", focuses on the question of "how the introduction and adoption of enterprise digital technology affects the operational performance of enterprises", and thoroughly explores the connotation and dimensional composition of the concepts of " digital technology" and " operational performance", and analyzes the influence mechanism and boundary conditions between them.

First, an initial qualitative exploration of the issue was conducted through a qualitative research design, drawing on the three-level coding device of procedural grounded theory (Chapter 4). The interview outline stage focused on the conceptual composition, antecedents and consequences, and formation mechanisms of corporate employees' perceptions of the impact of digital technology on operational performance, and to explore the factors that may have influenced the process. Through three stages of pre-research, formal research and supplementary research, respondents were drawn using convenience sampling combined with purposive sampling, yielding 46 interviews with a total of over 260,000 words, and open-ended coding, spindle coding and selective coding to refine and ultimately retain 175 initial concepts and 38 initial categories, resulting in 23 sub-categories and 6 main categories. Secondly, the "digital technology-enabled business performance mechanism" is selected as the core scope of this study, and a "story line" is established around it, which is used as a clue to organize the relationship structure of this thesis. Then, the theoretical saturation test was conducted to prove the adequacy of the sample and the reliability of the findings related to theoretical development through triangulation, expert experience, and additional data, and a preliminary model framework for digital technology-enabled business performance was established.

The model framework is mainly composed of six components: digital technology is a modern science and technology based on information and communication technology, with modern information network as the carrier, and with digital knowledge and information as production factors; The ability of digital technology empowerment refers to the ability of enterprises to integrate, build and reconfigure internal and external capabilities to cope with the rapidly changing environment with the help of digital technology; Innovation performance refers to that enterprises seek to improve products or services in the market and bring returns through the application of new ideas of organizational processes with different resource combinations; operational performance refers to the impact produced in various aspects of business operations as reflected in production, and is an important indicator used to measure the competitiveness of manufacturing firms; employee engagement refers to a positive, fulfilling, work-related mindset that reflects a vibrant and effective connection between employees and their work activities; and industry competition in this research context refers to the competition between different firms in the same industry in terms of technology, systems, and markets.

The theoretical model contains a total of five logic lines. There are three direct logic lines as described as follows:

(1) In the context of digital transformation, digital technology directly affects the capability of digital technology empowerment. Digital technology has three dimensions: volume, speed, and variety; the capability of digital technology empowerment consists of four dimensions: perception, coordination, learning, and integration;

(2) The capability of digital technology empowerment has a direct effect on the innovation performance of the enterprise. Innovation performance is an important outcome variable of the

enterprise after enhancing the capability of digital technology empowerment, which can be divided into innovation effectiveness and innovation efficiency in terms of conceptual structure;

(3) The innovation performance of the enterprise has a direct effect on the operational performance of the enterprise. The innovation effectiveness and innovation efficiency of the enterprise ultimately affect the operational performance of the enterprise. Operational performance in this study includes various aspects such as manufacturing cost, service quality, speed of new product introduction, flexibility, safety level, and environmental protection.

In addition, there are two logic lines that play a regulatory role:

(1) Employee engagement moderates the impact of digital technology on digital technology-enabled capabilities;

(2) Industry competition moderates the impact of digital technology-enabled capabilities on innovation performance.

Overall, the grounded theory study has fully revealed the impact of digital technology related characteristics on the operational performance of the firm. Digital technology capabilities are an important outcome of the firm's application of digital technology, and employee engagement moderates the process by which digital technology affects digital capabilities. Further, digital technology enabled capabilities promote the innovative performance of the firm, and industry competition plays a moderating role in this process. Changes in innovation performance in turn have a direct impact on the operational performance of the firm.

Next, in order to validate the model derived from the grounded theory study, the mechanisms of digital technology-enabled firm operational performance are empirically tested through questionnaires and structural equation modeling (Chapter 5). Firstly, the research hypotheses are formulated based on theories and grounded theory findings. Secondly, the questionnaires and scales are designed and divided into two parts: the first part includes demographics, covering gender, age, education and employment information; the second part includes questions related to digital technology, DT-enabled capabilities, employee engagement, innovation performance, operational performance and industry competition. The scales were all adapted from internationally renowned journals.

Then, in terms of questionnaire collection, this study first conducted a pre-test on 20 MBA students, and the results showed that the questionnaire was satisfactory. From May 8, 2022 to June 20, 2022, this study adopted the method of snowball sampling or chain recommendation sampling. After excluding the participants who failed the attention check in the survey or did not complete the whole questionnaire, the questionnaire results of 339 companies were finally collected as valid samples. After evaluating the reliability and validity of the measurement model and the deviation of common methods, satisfactory results were obtained. Thirdly, the structural equation model is used for analysis. The results of structural equation model show that the application of digital technology helps to improve the ability of enterprise digital technology empowerment. In addition, employee participation positively regulates the relationship between digital technology and DT-enabled capacities. This conclusion is consistent with the conclusion in the existing literature on employee participation. Employees with high participation may strongly agree with the company's practices and make a more positive response to the digitalization of the working environment (Afsar, Al-Ghazali, et al., 2020; Afsar, Maqsoom, et al., 2020; Chan et al., 2021). The increase in Dt-enabled capacities can further contribute to the innovation performance of firms. Notably, this study finds that industry competition positively moderates the relationship between digital technology empowerment capability of firms and innovation performance. This finding is consistent with the existing findings that high industry competition leads firms to use resources to enhance their innovation capabilities (Aghion et al., 2005). Finally, this study finds that the increase in innovation performance can enhance the operational performance of firms. All the findings of this study are in line with expectations.

In summary, this study applies a combination of qualitative and quantitative empirical research methods from the perspective of firm capabilities, and considers digital technology enabled capabilities and innovation performance as an important mechanism connecting digital technology and firm operational performance, providing new ideas for enterprise managers to gain insight into the relationship between digital technology and enterprise operational performance, thus helping them to manage digital technology implementation strategies in a more targeted manner. At the same time, the study helps enterprise managers to formulate necessary strategies and measures by revealing the boundary conditions of the relationship between digital technology and enterprise performance. In addition, this study enriches the literature on the impact of digital technology on organizational performance by revealing factors with moderating trends in the relationship between digital technology and enterprise operational performance at both the micro and macro levels, selecting two variables, employee engagement and industry competition, as moderating variables.

6.1.2 Theoretical contribution

This study makes a number of theoretical contributions to the business digital technology literature. First, we investigated digital technology affects operational performance from the perspective of firm capacity. Although existing literature claims that digital technology is necessary for firms to reap its benefits and that the use of digital technology can improve operational performance (Chi et al., 2018; W. Yu et al., 2021). In terms of the mechanisms by which digital technology affects the operational performance of firms, the existing studies report that digital technology improves business operations by reducing transaction costs, improving the efficiency of corporate assets, increasing employee productivity, and optimizing the supply chain (Athey, 2017; Ji et al., 2018; C. Li et al., 2018). Little studies examined the topic from the perspective of firm capacities. We filled this gap by empirically confirming that digital technologies can shape different dimensions of firm capabilities, which can further contribute to the innovation performance including innovation efficacy and innovation efficiency. Innovation performance, in turn, ultimately enhances the operational performance of the firm. The central mechanism by which digital technologies can have an impact on the operational performance of firms is that these technologies help firms build dynamic capabilities in different dimensions. Specifically, sensing capability is the ability of a firm to scan, learn, and interpret opportunities and risks in the business environment. Learning capacity is beneficial to acquiring and absorbing knowledge and using enough knowledge to facilitate existing operational capabilities. Integrating capability embed new knowledge into the new operational capabilities by creating a shared understanding and collective sensing-making. Coordination capability enable coordinate and deploy tasks, resources, and activities within new operational capabilities. While capabilities are abstract, especially relative to cost reduction, increased productivity and optimizing the supply chain of an enterprise, whether an enterprise has shaped these dynamic capabilities through digital technologies is key to whether digitalization can make a difference.

Second, this study highlights on the role of employee engagement by analyzing its moderating role in the relationship between digital technology and DT-enabled dynamic capacities, thus contributing the literature on enterprise digital transformation. Previous research investigating digital transformation has mainly discussed digital technology adoptive behavior and digital technology-enabled business operational performance from the perspective of technological challenges and the organizational factors, ignoring the role of employee engagement. Despite recent research mentions that employees as human resources play active role in realizing digital opportunity and empowerment, having a significant impact on a company's ability to digital transformation (Blanka et al., 2022), there is few literatures that investigate employee engagement in the context of enterprise digital transformation. This study proves employee engagement is a key enabler of enterprise digital transformation, contributing to the literature by focusing on employee level.

Third, this study emphasizes on the role of market competition by analyzing its moderating role in the relationship between DT-enabled dynamic capacities and innovation performance, thus contributing the study on dynamic capacities. Current research has been applying the dynamic capabilities model at the micro-level to investigate macro-organizational processes, systems and routines. However, the industrial context is still missing, which provides resources with which the micro and macro context of the organization is linked, that is, research on market competition in the context of dynamic capabilities have attracted far less scholarly attention. This study verifies industry competition can enhance the role of digital technology-enabled dynamic capability in promoting innovation performance, providing novel insights into the interplay between enterprise dynamic capability and market competition.

Finally, we applied a combination of inductive and deductive research paradigms, combined with a grounded theory analysis approach to generate our research model and empirically tested the proposed research model using a large sample using structural equation modeling techniques. To the best of our knowledge, this is the first study to employ the grounded theory approach in the study of the impact of digital technology on firm performance. As Tashakkori and Teddlie suggested, a hybrid approach is appropriate when there is a lack of clarity and ambiguity in existing research in the field (Tashakkori & Teddlie, 2021). Specifically, as a qualitative research method, grounded theory analysis can explore the connotation and structure of core concepts under the condition that the existing theory is insufficient, and the theoretical phenomenon explanatory power is not enough. However, the small sample size may limit the generalizability and generalizability of the conclusions. The structural equation model is effectively cross validated with a large sample, ensuring the robustness of the research results. Therefore, this study successfully applies the paradigm of combining qualitative and quantitative methods to the research of digital technology empowering enterprise operational performance.

6.1.3 Management implication and suggestion

The research helps business managers understand the paths and ways in which digital technology affects the operational performance of the business, leading to a more targeted management of digital technology implementation strategies. To begin with, there is a need for continuous development and the adoption of digital technologies, as they support the overall digital technology-enabled capabilities and innovation performance. The findings can help managers recognize which capabilities digital technology can shape in the business, leading to a better understanding of the value of digital technology to the business and the need for implementation. Therefore, enterprises must build a dynamic capability system for digital transformation, applying digital technologies in terms of volume, speed, and variety.

Specifically, to develop digital sensing capabilities, enterprises should improve rules and practices, strengthen leadership and improve strategies to understand, capture and evaluate potential business opportunities by leveraging the digital tools. At the same time, enterprises should explore new capabilities in digital scenario planning and digital reconnaissance to capture trends in new technologies and competitors. For example, informal and formal networks can be used to identify technology trends, emphasizing the need for big data analytics and artificial intelligence to sense new customer-centric trends that are difficult for strategic planners to predict. In addition, strategizing in a digital environment must be based on building a strong digitally oriented culture. Constructing a digital mindset and culture across the organization is critical to building sensing capabilities.

To develop learning capacities, enterprises need to effectively integrate technology, business and learning strategies, and the necessary condition is the process of hiring new human resources. The knowledge of new employees helps spread the digital "culture" in the company, and the training of "older" employees is just as crucial. For example, in addition to traditional workshops, toolkits, and training programs, enterprises can transform their workforces with intelligent agents to guide and learn from hands-on. Moreover, managers can build a corporate digital knowledge base (e.g., knowledge about customer needs and wants, key resources and capabilities, end-user benefits, etc.) to further transform existing operations by learning new knowledge and skills ability.

To develop integrating capacities, it must integrate new knowledge learned by employees at the organizational level, that is, centralize their individual knowledge and interaction patterns into an organizational system to deploy new integrating capability. Therefore, enterprises should support organizational practices for effective communication and information sharing among key stakeholders. Also, it is recommended that enterprises may simplify decision-making and planning processes to ensure timely decision-making and effective planning to seize opportunities. For example, enterprises can set up dedicated digital departments to effectively apply digital technologies to link new and existing businesses and share synchronized information with business partners.

To develop coordinating capacities, enterprises should first actively optimize the production process, information exchange and organizational structure of the organization through digital technologies such as big data, artificial intelligence and blockchain, so as to coordinate the work of various departments and improve operational efficiency. Secondly, it is necessary to further improve the data acquisition, analysis and application capabilities of enterprises. For example, by creating a unified digital infrastructure, digital tools and systems can be better utilized to work with coordinated allocation of resources in a more flexible manner.

Also, by revealing the boundary conditions of the relationship between digital technology and business performance, it suggests business managers to develop the necessary strategies and measures of employee engagement and industry competition. Employee engagement plays a moderating role in the impact of digital technology on digitally enabled capabilities. Therefore, managers should clarify the vital role of employees in the digital transformation process. Firstly, enterprises may regularly provide dedicated digital technology training to employees. Once employees are given the opportunity to learn new skills, they feel more engaged at work. For example, explain to employees how digital technologies help them adapt to changing work processes, and improve productivity, indicating a complementary rather than a substitute relationship between digital technology and employees. Second, enterprise managers can also adopt a digital culture strategy. On the basis of inheriting the core values of the original corporate culture, digital culture is introduced to change the attitude of employees. For example, it is necessary to collect excellent examples of working with digital technology at different organizational levels in a timely manner, and publicize them within the enterprise. In addition, enterprise managers can tangibly tie digital transformation to employee performance. The assessment standards can be improved based on employee positions, and digital-related assessment indicators can be introduced to encourage and form a mandatory mechanism.

Industry competition moderates the impact of digitally enabled capabilities on innovation performance. Enterprises should improve their DT-enabled capacity in a competitive environment in order to keep pace with innovation. First, managers should have a competitive landscape perspective. In addition to focusing on the major competitors in the market, managers should actively sense, interpret, and process signals from areas that are often overlooked, such as distant competitors. Also, managers of enterprises need to formulate digital technology strategies, invest in technology fields, help enterprises integrate into dense competition networks and moderately fierce competition relationships, and make them more competitive in terms of technical capabilities and performance, thereby improving organizational innovation performance. On the other hand, the government can create an excellent business environment for fair competition, which is conducive to improving the innovation efficiency of enterprises in the industry.

6.2 Limitations and future research

6.2.1 Limitations

1. Cross-sectional data cannot be used to infer causal relationships between variables. This study collected primary data mainly through interview research, and the interview outline designed for this study included the enterprise establishment time variable in the initial open-ended research phase, but the data collection phase was focused on a shorter period of time, resulting in the final data collected being cross-sectional. Cross-sectional data can objectively reflect the correlation between digital technology and enterprise operational performance at the research time point, but due to the lack of historical data, this study did not fully consider the impact that digital technology changes over time would have on its ability to empower and the operational performance of the enterprise, so we cannot infer a causal relationship between digital technology and enterprise operational performance.

2. The study used snowball sampling and it is possible that the sample was not representative. In this study, it is difficult to find accurate and large number of interviewees because of the small number of units in the study population and the very unconcentrated distribution. The economic and time costs would be very high if conventional sampling methods are used for screening, so we choose to use snowball sampling for sample selection. Snowball sampling is a sampling method to find respondents in a sparse population, we invite MBA students as initial research subjects, and then use their recommended familiar people as potential research subjects based on the principle of convenience. The disadvantage of this is that the people recommended by the research subjects are often similar to their own views and belong to the same group, and by referring each other, it is likely to cause selectivity bias and lead to a serious under-representation of the sample.

3. The study did not consider the impact of the characteristics of individual business managers on the performance of digital technology in the business. This study focuses on how digital technology at the firm level affects its operational performance. Firm-level variables are supposed to be controlled for, but individual manager characteristics may also have an impact on digital technology as well as firm performance. While firm-level variables such as firm size, firm establishment, and firm annual turnover are controlled for in our data processing and modeling, individual manager characteristics are not adequately considered in the impact of digital technology on firm performance. This study involves the age and gender of managers and tries to collect data in such a way that these variables are as evenly distributed as possible, but characteristics such as individual personality and management style are not controlled for.

4. The study did not consider macro-level variables. Macro-level variables include social policy, national cultural background, etc. On the one hand, digital technology and enterprise digital transformation are hot topics of concern to society and the country, and relevant policies in this field will definitely have an impact on enterprises using digital technology. On the other hand, there are great cultural differences between East world and West world. Companies in different cultural backgrounds have differences in the degree of emphasis on digital technology itself and the strategies for implementing digital technology. Therefore, the relationship between digital technology and firm performance may be affected by the national cultural background. This thesis mainly focuses on the firm itself and the industry environment in which it is located. In the future, the relationship between digital technology and firm performance can be analyzed in depth from macro variables such as national culture and policies.

5. The study did not consider some industry-level variables. In terms of industry-related variables, this study considers the impact of competition in the industry on the performance of firms by digital technology, but it is not sufficient to consider other industry-level factors that also have an impact, such as the specific application forms and degree of application of digital technology between different industries. There may be large differences, and the impact of different application forms of digital technology on firm performance is also different, so further research and discussion are needed. Future research can further explore the influence of industry factors on the relationship between digital technology and firm performance.

6. The model may have endogenous problems. Endogeneity is a key issue to be considered in empirical studies, and in this study, although we control for a portion of the variables to address endogeneity, there may be the presence of unobservable omitted variables, such as firm cooperation. Resource integration capability is an important source of competitive advantage and firm performance in the use of digital technology by firms, and resource integration often

occurs in the process of cooperation between firms and their partners, so inter-firm cooperation may also have an impact on digital technology and firm performance. This study validates the moderating effect of industry competition variables, but does not control for the cooperative relationship between different firms in the industry, and more theoretical perspectives can be used in the future to dig deeper into the role of analyzing possible omitted variables.

6.2.2 Future research

First, consider data collection at different time points to conduct research for panel data. As mentioned earlier, cross-sectional data is effective for responding to the impact of digital technology-enabled business operations at a specific time point, but is relatively limited for responding to whether this impact has characteristics such as stability in the time dimension, so in future research, further consider data collection at different time points for the research subjects (industries, enterprises, etc.) to construct panel data to further explore the underlying mechanism of digital technology-enabled business operations technology.

Second, in the future, we may consider optimizing the sampling method, for example, to obtain a representative sample by stratifying the enterprises in the research industry and region, or to optimize the sample representativeness by using the judgmental sampling method, if the total number of research subjects is large and complex, and it is difficult to use the probability sampling method to conduct statistics.

Third, further studies should control for variables related to the personal characteristics of business managers. As discussed in the previous section, although this paper has controlled for a significant number of variables that may be relevant to the operational performance of digital technology-enabled firms at the firm level, the impact of individual managers' characteristics on the performance of digital technology-enabled firms has not been fully considered in this study; therefore, in future research, further attention should be paid to the impact of personal characteristics and management philosophy of managers on the operational performance of digital technology-enabled firms, and consideration should be given to quantifying and controlling them through in-depth interviews or questionnaires to improve the scientific validity of the model.

Fourth, future research should further control for macro-level social environment variables. In addition to the relevant variables at the personal level of firm managers, which should be further concerned in future research, macro-level variables such as social policies and national cultural background should also be concerned and integrated into the model. For example, expand the collection scope of samples to cover more countries and regions, and then pay attention to the impact of different cultural backgrounds and national policy environment on the operation of digital technology enabled enterprises. Future studies can also investigate the impact of relevant policies on the impact mechanism of this thesis by examining the changes before and after the implementation of relevant policies for specific regions.

Fifth, future research should further control for industry-level variables. To further improve the validity of the model and to provide practical suggestions for the application of digital technology in different industries, future research could investigate the specific impact of digital technology on firm performance in different industry contexts, for instance, by studying the impact of digital technology on firm performance in specific industries, or by studying the characteristics of digital technology application in different industries, such as the form and extent of application, through face to face interviews or questionnaires, and studying its impact on the mechanism of digital technology empowerment.

Finally, future research can further explore and improve the model framework from a theoretical perspective. Although a myriad of variables have been controlled in the model to address endogeneity, and relevant variables that may need further research have been mentioned above, there may still be missing variables in the model that have not yet been observed, so future research can further improve the model framework from a theoretical perspective to further explore missing variables and improve the model framework, as well as provide the possibility for theoretical innovation in this area.

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Annex A

Questionnaire English version

A Survey on Digital Technology-Enabled Business Operational Performance

Dear Ms./Mr.,

Greetings! We are conducting a questionnaire survey on digital technologies enabled business operational performance and your kind cooperation will be extremely helpful to our research! There is no right or wrong answer to the question. Please fill in the information based on your own understanding and opinions. We assure you that all information provided by you will be kept strictly confidential and used only for this academic research, and that all responses will be anonymous. We are very much grateful to you for your cooperation! Please provide your answers to the questions by marking "√" on the appropriate option.

Part 1: Basic information about the business

1. What is the size of your business（Number of employees）?

☐Less than 100 ☐100-500 ☐501-1000 ☐1001-3000 ☐3001-8000 ☐More than 8000

2. How long has your business been established?

☐Less than 1 year ☐1-3 years ☐3-5 years ☐5-10 years ☐More than 10 years

3. What is the annual turnover of your business?

☐Less than 1 million ☐1-5 million ☐5-10 million ☐10-50 million ☐500-100 million ☐More than 100 million

Part 2: Scale score

"1", "2", "3", "4", "5", "6", and "7" in the following options represent respectively "strongly disagree", "disagree", "somewhat disagree" ", "neutral", "somewhat agree", "agree" and "strongly agree". Please answer based on your true feelings.

Items		**Strongly disagree <-----> Strongly agree**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Digital technology	In my firm, we use a great deal of digital technology (e.g., digital systems, facial recognition).							
	In my firm, we use several different digital technologies to gain insights.							
	In my firm, we are fast in introducing our digital technology.							
Digital technology-enabled capability	My firm frequently scans the environment to identify new business opportunities.							
	My firm is effective in utilizing knowledge into new products.							
	Employees in my firm manage to successfully interconnect their activities.							
	Overall, my firm is well coordinated.							
Innovation performance	My firm is good at developing new markets							
	My firm constantly cultivates the existing market.							
	My firm quickly opens new markets.							

	My firm efficiently cultivates the existing market.							
Employee engagement	I really throw myself into my job and organization engagement.							
	I fulfil all responsibilities required by my job.							
	I am enthusiastic about my job.							
Industry competition	In our industry, there are many other firms offering the same products or services.							
	In our industry, price competition is highly intense.							
	In our industry, there is much competition.							
Operational performance	Customer satisfaction of my firm is good.							
	Cost management of my firm is good.							
	Responsiveness of my firm is good.							
	Productivity of my firm is good.							

Annex B

调查问卷中文版

数字技术赋能企业运营绩效研究调查

尊敬的女士/先生：

您好！我们正进行一项关于**数字技术赋能企业运营绩效**的研究调查，您的合作将会对我们的研究提供极大帮助！您的回答没有对错之分，请按您的理解填写即可。**我们保证这些资料会严格保密并仅用于本学术研究，不做其他用途，内容皆为匿名作答**。谢谢您的合作！请您在选定的选项上打“√”即可。

第一部分：企业基本信息

1.您所在企业的规模（员工数量）：

☐100 人以下　☐100-500 人　☐501-1000 人　☐1001-3000 人　☐3001-8000 人　☐8000 人以上

2.您所在企业的成立时间：

☐1 年以下　☐1-3 年　☐3-5 年　☐5-10 年　☐10 年以上

3.您所在企业的年营业额：

☐100 万以下　☐100-500 万　☐500-1000 万　☐1000-5000 万　☐5000-1 亿　☐1 亿以上

第二部分：量表评分

下列选项中的“1”、“2”、“3”、“4”、“5”、“6”、“7”分别代表着“非常不同意”、“不同意”、“比较不同意”、“中立”、“比较同意”、“同意”和“非常同意”。请根据真实感受作答.

问题列表		非常不同意<----->非常同意						
		1	2	3	4	5	6	7
数字技术	您所在的企业使用了大量的数字技术（例如，数字化系统、人脸识别）							
	您所在的企业使用多种不同的数字化技术							
	您所在的企业会及时引进最新的数字化技术							
数字技术赋能能力	您所在的企业经常审视环境以识别商机							
	您所在的企业可以有效地将知识应用到新产品或服务中							
	您所在的企业员工各司其职，各个工作紧密衔接							
	总体而言，各项工作协调运作良好							
创新绩效	您所在的企业善于开拓新的市场							
	您所在的企业深耕现有市场							
	您所在的企业快速开拓新的市场							
	您所在的企业高效深耕现有市场							
员工参与	您所在的企业中，员工会全身心投入到工作和企业中							
	您所在的企业中，员工会履行工作要求的所有职责							
	您所在的企业中，员工对工作充满热情							

行业竞争	企业所处的行业中,还有许多其他企业提供相同的产品或服务							
	企业所处的行业中，价格竞争激烈							
	企业所处的行业中，行业竞争激烈							
运营绩效	您所在的企业客户满意度高							
	您所在的额企业成本管理好							
	您所在的企业响应能力好							
	您所在的企业生产力高							