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Research on Digital Transformation and Organizational Innovation of Manufacturing Firms Based on Knowledge Field

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Abstract
The digital transformation of manufacturing firms can enhance the activity of the knowledge field and inject new evolutionary momentum into organizational innovation. Its key meaning for firm management is to inject new evolutionary momentum into organizational innovation. In the era of digital information, it is very important to accurately and efficiently explore how the all-round digital transformation of manufacturing firms can stimulate organizational innovation. In this study, we focus on how to promote information exchange, trust relationship establishment, and team cohesion formation among manufacturing firms in the process of digital transformation of firms, so as to improve the activity of knowledge field and form a mechanism that can promote organizational system innovation, organizational strategy innovation, and organizational structure innovation. Based on the previous research work on digital transformation, knowledge field, and organizational innovation, we combine the latest progress of grounded theory and multi-case analysis. Through the multi-case study of eight manufacturing firms in China, the grounded theory method is used to summarize the dimensions and main characteristics of digital transformation, knowledge field activity, and organizational innovation, and to establish a multi-dimensional theoretical framework for digital transformation to promote organizational innovation by enhancing knowledge field activity. The research finds that (1) the digital transformation of manufacturing firms helps to link internal and external factors of the organization, forming the dynamic support and institutional path of organizational innovation; (2) digital technology and platform construction help multi-agent interaction, promote trust among organization members, and achieve collaborative strategic innovation; and (3) digital scene interaction and other means promote the formation of organizational team cohesion and promote organizational structure innovation. Therefore, our method integrates the theory of modern organization, aiming at expounding the core issues of system, strategy, and governance structure in the organizational innovation of manufacturing firms, and providing practical reference for firm digital information governance

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and organizational innovation. The research results are helpful to understand the mechanism of digital transformation on organizational innovation of manufacturing firms, accelerate China's digital-driven development, deepen the reform of science and technology system and mechanism, improve organizational innovation ability, and guide manufacturing firms to further realize organizational innovation under the background of digital transformation.

Keywords Manufacturing firm · Digital technology · Digital platform · Knowledge field activity · Organizational innovation

JEL Classification O30

Introduction

Promoting the digital transformation of manufacturing firms is a strategic measure for China to achieve the goal of manufacturing power, and also a key measure to realize the integration of the digital economy and the real economy (Lin et al., 2022). Digital technology is widely regarded as an important force for social change and a solution to enhance corporate governance capabilities (Garrel & Jahn, 2022). In the era of knowledge and information, how to promote the digital transformation of firms to promote organizational innovation to cope with increasingly complex social challenges has become a hot topic of common concern in academic circles at home and abroad (Zia et al., 2023). The emergence of digital platforms realizes links across value spaces; integrates digital resources; reduces the cost of information query, production, transportation, tracking, and verification of organizations; and opens up information barriers between internal departments and internal and external organizations, making the organizational structure more flexible (Zhang & Tsang, 2022). Organizational change lags behind information technology change (Köllen, 2020). Under the logic of digital operations, the pyramidal team structure, personnel, and strategies of traditional businesses have been significantly adjusted to match new market changes (Yang et al., 2021). The existing literature points out that digital transformation is conducive to spreading organizational culture and improving the frequency of organizational communication. The impact mechanism is summarized as follows: First, digital transformation leads to more blurred team boundaries and departmental boundaries, resulting in convergence (Fritze et al., 2019; Olsen & Martins, 2012; Mahapatra et al., 2010). The organization forms a good cooperative relationship with external members and integrates and utilizes new technical knowledge to achieve organizational collaborative management (Lee & Trimi, 2021). Second, knowledge exchange and transfer within the organization tend to be digitized. The use of digital information technology and platform construction helps organization members to integrate the use of knowledge and collaborative communication, reduce knowledge stickiness and dependence on the propagation path, and effectively promote knowledge integration (Hynes & Elwell, 2016). In 2019, the "China firm Digital Transformation and Data

Application Research Report" pointed out that firms apply data technology to accelerate the process of knowledge generation, diffusion, and application and actively develop new business processes, thus inducing organizational networking and improving the openness of organizational systems and other comprehensive innovations to build sustainable competitiveness. Digital transformation optimizes the integration method of resource elements, improves the speed of factor integration, shapes the absorptive capacity and knowledge management ability of the organization, and realizes the innovative development of the organization (Ding et al., 2021; Olsen & Martins, 2012). The existing literature provides ideas for the research of digital transformation on organizational innovation, but the relevant literature research is still relatively vague. At present, few kinds of literature directly test the impact of digital transformation on organizational innovation.

Under the theory of the knowledge field system, the knowledge field can effectively promote organizational technological innovation, to improve the ability and competitiveness of organizations in the external dynamic environment (Zhang et al., 2017). The existing research uses empirical analysis, case study, and SEM methods to deeply explore the influence of knowledge field activity on organizational innovation ability and analyze the influence of cognitive form on organizational innovation ability (Sun et al., 2020; Wang et al., 2014; Whelan et al., 2016). The influence of the knowledge field on organizational innovation generally includes the alternate influence of implicit cognition and explicit cognition and the result of their alternate change (Al-Filali & Gallarotti, 2012). Based on the existing research results, knowledge field activities are the main medium of knowledge circulation. In terms of research content, existing research mostly focuses on the practical significance, opportunities, and challenges of digital transformation and digital technology to promote firm operation, growth, and innovation, and lacks an in-depth exploration of the theoretical mechanism and practical path of firm digital transformation to improve the activity of knowledge field and promote organizational innovation from the perspective of knowledge (Pilehvar, 2022). In general, they are mainly based on the theoretical research on the digital transformation and organizational performance of firms from the perspective of organizational management. However, due to the particularity of big data and artificial intelligence technology, the current domestic and foreign scholars lack systematic research on the specific application process and characteristics of digital intelligence–enabled organizational innovation (Joppen et al., 2022; Samara et al., 2022). Under the background of mathematical intelligence empowerment, organizational innovation and evolution development have certain particularities (Otioma, 2023). For the local situation, under the influence of digital transformation and the knowledge field, the problem of how organizational innovation performance evolves should be analyzed in depth with specific cases (Kundu et al., 2022). In terms of research methods, most of the existing studies use single case studies, and there is a lack of multi-case studies. In the process of organizational innovation, the use of digital platforms and information technology to establish a knowledge field space to promote the dissemination and integration of knowledge between firms and the outside world increases the knowledge flow of the knowledge field and thus promotes organizational innovation (Alcaide-Muñoz & Rodríguez Bolívar, 2015). So does digital transformation affect

the activity of the knowledge field? In the existing research, there are few studies on the impact of digital transformation on organizational innovation, and the relevant research content is more decentralized. The research perspective focuses more on the research of digital transformation on certain characteristics of the organization. Based on the shortcomings of existing research and practical needs, we make the practical case analysis of eight manufacturing firms in different sub-areas in China. We focus on exploring the mechanism of digital transformation of firms to promote organizational innovation in the era of knowledge information. We use traditional organizational theory to explain the mechanism of digital technology penetrating the organization and triggering organizational structure, system, and strategic innovation. We define the definition of digital transformation, explore whether digital transformation can further influence organizational innovation by inducing knowledge field activity, and focus on the analysis of organizational structure function and evolution path caused by digital transformation. Given the actual needs and theoretical gaps, we focus on the problem of "the influence mechanism and main characteristics of digital transformation of manufacturing firms to promote organizational innovation under the theory of knowledge field system." Combined with the application characteristics of digital intelligence enabling technology, this paper analyzes typical manufacturing firms and refines the structural dimensions and main mechanisms of organizational innovation of manufacturing firms, to provide theoretical reference for the improvement of organizational innovation performance of the manufacturing industry in the era of digital information and knowledge and to supplement the research in the field of organizational innovation in traditional histological theory. Using multi-case research methods, focusing on manufacturing firms as the research object, and using the coding technology of procedural grounded theory, we conduct multi-case studies on eight manufacturing firms in different subdivisions, analyze the mechanism of digital transformation of manufacturing firms affecting organizational innovation, to enrich and expand the theoretical research of digitization and organization, and provide a reference for guiding the organizational innovation practice of manufacturing firms in China.

The marginal contribution of this paper is mainly reflected in the theoretical value and practical value: First, based on the perspective of the knowledge field, we integrate the theory of modern organization and analyze the process and influence mechanism of digital transformation to promote organizational innovation. The proposed theoretical model expounds on the core issues of system, strategy, and governance structure in the organizational innovation of manufacturing firms and gives a new explanation to the organizational innovation of manufacturing firms in the era of the digital economy, which provides a certain theoretical and practical reference for the digital information governance and organizational innovation of manufacturing firms in China. Second, the exploration of digital transformation and organizational innovation of manufacturing firms at the micro level may resonate with countries at the macro level. Therefore, this study has certain practical guiding significance for accelerating China's digital-driven development, deepening the reform of science and technology systems and mechanisms, improving organizational innovation ability, and building a strong manufacturing country.

The arrangement of this paper is as follows: Firstly, the existing research on organizational innovation, digital transformation, and knowledge field perspective of manufacturing firms is reviewed, and it is preliminarily proposed that the digital transformation of firms may have a profound impact on organizational innovation from multiple perspectives and levels by enhancing the activity of knowledge field. Next, we introduce our research methods and select eight manufacturing firms as the research object. We use the grounded theory to discuss the mechanism of digital transformation enabling organizational innovation and use the case to verify that digital transformation can further realize the innovation and development of the organization under the activity of the knowledge field. We give our results and then discuss the innovations of our results. Finally, the research conclusions, management implications, deficiencies, and prospects of this paper are summarized, which lays a foundation for subsequent research.

Literature Review

Research on Organizational Innovation of Manufacturing Firms

The fundamental purpose of organizational innovation is to rejuvenate the organizational form and structure (Vankov & Vankov, 2023). The theoretical circle has carried out extensive and in-depth research on organizational innovation. At present, the research on organizational innovation includes phenomenon description and theoretical discussion. Scholars mainly study organizational innovation from the perspectives of influencing factors (Anzola-Román et al., 2018; Garcia-Morales et al., 2018; Peng & Li, 2021) and performance evaluation of organizational innovation (Zhang, Long et al., 2021; Zhang, Chen et al., 2021) and define the connotation and definition of organizational innovation from the process and result (Vial, 2021; Liu et al., 2011; Hu et al., 2016). Based on the correlation analysis of organizational type, scope, adoption stage, and other elements with organizational innovation, including new ideas or behaviors, new products or services, and new projects or management systems, the concept of sub-dimension of organizational innovation, namely management innovation, is introduced (Tan Luc et al., 2022). The research on organizational innovation of manufacturing firms integrates multiple themes such as evolutionary mechanism and matching quantification. The evaluation index system is mostly constructed to study the measurement of organizational innovation, and the selection of evaluation indicators shows a diversified trend (Ye et al., 2021). According to the degree of organizational innovation and the division of technological innovation, some scholars divide organizational innovation into breakthrough innovation and incremental innovation and study the changes in firms in structure, production, skills, and control (Li et al., 2019). Some scholars emphasize the new achievements of the organization and pay attention to the specific performance of new product development market share and efficiency. The above research is analyzed from multiple perspectives, considering the ability of organizations to use new knowledge and new technologies. Starting from the internal motivation of the organization, organizational innovation is a moderately creative work that employees in the organization are motivated to

spontaneously carry out. In the process, internal motivation is better than environmental driving (Neumann, 2023). Some scholars also define organizational innovation from the perspective of process and reorganize internal resources. Organizational innovation includes the evolution process of adaptive variation, selection, and retention (Elsiddig, 2022; Neumann, 2023). Through case studies, scholars have found that in manufacturing firms in different stages of the life cycle, their organizational innovation process and development focus will be dynamically adjusted. Organizational innovation is driven by organizational mission objectives, technology, market environment, business policies, and resource mobilization capabilities (Nordin, 2012).

By investigating the situation of high-end garment manufacturing firms, Matarazzo et al. (2021) found that the openness of the governance model can promote organizational learning. Therefore, the essence of organizational innovation is the process of improving the efficiency of organizational activities by changing the organizational structure and management methods to adapt to the external environment and internal requirements under a given goal. Combined with the innovation process, organizational innovation is divided into three stages: innovation formation, realization, and solidification (Otioma, 2023; Khelfaoui et al., 2023; Garcia-Morales et al., 2018). After the above analysis, it can be seen that the existing research has not reached a consistent conclusion on the connotation of organizational innovation, and scholars have focused on different directions from different perspectives on the definition of organizational innovation. The definition of organizational innovation is summarized from different angles, and it is proposed that the existing research defines it as product, service, and process innovation from the perspective of the innovation target. From the perspective of innovation formation, it is progressive and destructive. From the perspective of innovation management objectives, it is management innovation and technological innovation, which is also the embodiment of the multiple perspectives of organizational innovation. We draw on the multiple definitions of organizational innovation and believe that it is more in line with the practical needs of organizational innovation. In the current research on organizational innovation, after comprehensive consideration, we regard organizational innovation as a process of resource integration for organizations to acquire new technologies or management methods and regard organizational innovation as a whole. Therefore, under the background of continuous improvement of technological innovation level, manufacturing firms further regard organizational innovation as an important goal of development, realize the coordinated development of technological innovation and organizational innovation, and form an organizational paradigm through knowledge field activity.

Research on Digital Transformation

As a new paradigm, digital transformation has attracted the attention of scholars at home and abroad. Since digital transformation is a new concept in recent years, there are many qualitative analyses in academic research. Kreiterling (2023) suggested using the term “transformation” rather than “change” to describe the digital activities of firms. The discussion on the topic of digitization and digital transformation has gained the common attention of many disciplines such as information system

research and management research (Meyer et al., 2023; Trischler & Li-Ying, 2023). Information system researchers often discuss how firms adopt and use digital technology and the development direction of new digital technology based on the perspective of technology application (Nabi et al., 2022; Wen et al., 2022). Digital technology has had a disruptive impact on all business departments and functional departments of firms. Many firms have set off a new organizational change (Hu et al., 2022). Digital transformation presents self-growth and integration. Specifically, based on the data homogenization of digital technology innovation, self-growth promotes firms to use repeated programming for continuous innovation and realizes the continuous improvement and continuous iteration of digital innovation results (Mcadam et al., 2012). The integration is mainly reflected in the fact that the boundaries between industries and departments tend to be blurred in the process of digital transformation, and the output level of cross-border innovation of firms is improved, which is conducive to the formation of information exchange and team cohesion by manufacturing firms using digital technology and platforms (Cichosz et al., 2020).

In the empirical research, the measurement of "digital transformation" mainly includes four indicators: digital access level, equipment level, application level, and platform construction level. Digital transformation aims to use digital resources and technologies to break through resource constraints and develop new opportunities. Its difference from concepts such as digital technology and digital innovation is to emphasize the process of transformation, and digitization is an important medium for transformation (Wen et al., 2022). Combine information, computing, communication, and connectivity technologies through digital technologies to improve production processes and create organizational systems and strategic innovations. The process of collecting, restructuring, and absorbing digital resources reflects the characteristics of digital transformation and has been recognized by most scholars (Trischler & Li-Ying, 2023; Liu et al., 2021). The strategic framework of digital transformation is divided into four dimensions: the use of technology, the change of value creation, the change of structure, and the financial aspects. It is widely recognized by the chief information officer and the business manager responsible for digital transformation (Cichosz et al., 2020; Fritze et al., 2019). Scholars in the field of firm management research pay more attention to exploring the changes of digital technology to the organization's key business operations and organizational operation logic, as well as the changes brought by this change to the original products/services, business processes, organizational structure, and management concepts of the firm (Karimi & Walter, 2015; Kauffman & Weber, 2018; Liu et al., 2011). Existing research believes that the digital transformation of firms is by no means a simple application of digital technology. This transformation runs through various organizational activities such as business model, organizational operation process, business model, and organizational structure in the process of organizational management. Based on the value chain perspective of the business model, the digital transformation of firms is defined as the organizational transformation of how to use digital technology to develop a new digital business model and create more value (Ding et al., 2021). Starting from the factor input of firm digital transformation, digital talents and digital capital supplement the traditional firm elements. Data resources refer to resources that can be digitized and measured by currency and also

include technical resources and social resources. Digital platform helps to improve the innovation management ability and team core competitiveness of firms.

Digital transformation presents self-growth and integration (Hu et al., 2022). Specifically, based on data homogenization of digital technology innovation, self-growth promotes firms to use repetitive programming for continuous innovation, to achieve continuous improvement and continuous iteration of digital innovation results; convergence is mainly reflected in the blurring of industry and sector boundaries in the process of digital transformation, and the improvement of the output level of cross-border innovation, which is conducive to the formation of information exchange and team cohesion by manufacturing firms using digital technologies and platforms. Based on the research from the perspective of business process, digital transformation is defined as the application of new digital technology to enable organizations to make major business improvements in optimizing the customer experience and optimizing or creating new business operation models. The digital transformation of firms includes the transformation of firm objectives, governance structure, organizational structure, marketing mode, and industrial mode. Digital transformation is aimed at value creation, using digital technology to drive industrial change and promote the high-quality development of firms. The existing research on digital transformation explores the impact of firms on daily organizational activities such as organizational operation processes, value creation, and business models by using digital technology. In summary, based on the system and overall perspective, we define digital transformation as the transformation of key business operations brought by digital technology applications, digital platform construction, and other industry practice data and information management, which leads to the transformation of original products and management concepts.

Research from the Perspective of the Knowledge Field

The concept of "field" in the organization and the management theory comes from the electromagnetic field theory of physics. The "field" in the organizational context refers to the state of conscious or unconscious interaction and communication among the members of the organization based on commonality in the four aspects of "theme, rule, carrier, and desire" (Myszak, 2023). With the exchange and communication of knowledge among the members of the organization, the space formed during the transfer, sharing, utilization, and innovation of knowledge is defined as the knowledge field (Wilkins et al., 2022). Knowledge field activity is defined as the sum of all media or situational products that have a certain scope of communication and social influence, reflecting its activity and openness (Mcadam et al., 2012). Based on the concept of knowledge field, scholars put forward the concept of knowledge field activity from the perspective of the dynamic activity of the knowledge field, that is, based on the same values and knowledge-sharing vision, the subjects of knowledge exchange promote the exchange and interaction of knowledge through the concept of trust and sharing between each other (Imamoglu et al., 2023). The innovation activities of the organization are mainly carried out in the knowledge field. How digital technology supports the organization to improve its ability to create performance

determines the dynamic activity of the knowledge field to a large extent (Ardito et al., 2020). Knowledge field activity is a series of collective learning behaviors that improve technology, creativity, and cohesion based on the shared values and communication modes of members.

According to the mutual transformation of explicit knowledge and implicit knowledge, the knowledge field is divided into initiation field, dialog field, systematization field, and practice field (Škare & Biberić, 2015). We discuss the influence of institutional perspective, behavioral perspective, and resource perspective on knowledge field activity. Some scholars point out that the relationship between knowledge field activity and organizational innovation is not obvious in high-tech firms (Matarazzo et al., 2021; Nordin, 2012). The reason may be that the process of exploring, transforming, and using new knowledge in the knowledge field does not directly generate creative activities. Under the mutual influence of inquiry and exploitative learning, the knowledge field affects the creative activities of the organization to a certain extent (Triguero & Fernández, 2018). However, some studies point out that in the long run, the knowledge field can positively promote organizational innovation behavior and performance (Wen et al., 2022; Trischler & Li-Ying, 2023).

According to the relevant theories of cognitive psychology, in the knowledge field, knowledge exchange includes the process of mastering, innovating, and applying new knowledge, and attaches importance to the input and output process of big data knowledge and skills (Liu et al., 2021; Hu et al., 2022). At the time level, it includes the process from initial knowledge acquisition to knowledge accumulation and innovative application in organizational activities (Li et al., 2019). In the knowledge field, the exchange of big data and information makes the organization gradually transform into an infusion-acceptance learning supplement inertia, which reserves sufficient knowledge materials and data for the development of organizational innovation and forms the original incentive for organizational innovation (Mcadam et al., 2012). In the expansion stage of cognition, the extended idea in the knowledge field further refines the abstract concept, uses digital information technology to find omissions or technical deficiencies in the knowledge system, and formulates organizational strategies (Ardito et al., 2020). There are few measurement scales for the activity of the knowledge field, and most scholars measure this variable based on comprehensive multi-person research results. Scholars have paid extensive attention to the study of knowledge field activity as an antecedent variable, and there are relatively few studies on knowledge field activity as a result variable (Ardito et al., 2020). Therefore, we start from the background of digital transformation to explore the impact of the knowledge field on organizational innovation. In the reconstruction stage of the knowledge base, the digital platform outputs new products, organizational innovation is further transformed into productivity, and the organizational system is improved. Organizational innovation is realized through knowledge integration and reconstruction. Organizational innovation through knowledge integration and reconstruction (Triguero & Fernández, 2018). How digitization promotes organizational innovation in different dimensions through knowledge field activity remains to be further studied. Based on the existing research, we define the knowledge field as the space and place where knowledge and knowledge carriers interact. The activity of the knowledge field is defined as the exchange

and interaction of knowledge between the subjects of knowledge exchange through mutual trust and sharing ideas under the same values and knowledge-sharing vision.

In summary, we believe that digital transformation reflects a multi-dimensional construct integrating digital network, data management, digital technology, and platform construction, including the process of element linking, multi-agent interaction, and scenario interaction, to realize the organizational system and strategic and structural innovation through the path of establishing a trust relationship, enhancing team cohesion and collaborative governance. This not only reflects a variety of digital transformation processes at the firm level but also involves the processing and integration of information and knowledge at different levels, which in turn affects the organizational behavior and organizational innovation performance of firms. The digital transformation of firms may have a profound impact on organizational innovation from multiple perspectives and levels by enhancing the activity of the knowledge field. The existing research has formed rich results but still faces the following deficiencies: (1) The research focuses on the connotation of knowledge field activity, digital innovation, and organizational innovation ability. However, in the existing research, there is no consistent conclusion on the influencing factors and paths of organizational innovation. In the process of digital transformation of manufacturing enterprises, whether the knowledge information exchange and organizational structure within the organization have changed, and whether the knowledge field activity has played an important intermediary role, the above questions need to be answered. The relationship among digital transformation, knowledge field activity and organizational innovation needs to be further explored. (2) lack of dynamic analysis of the relationship between digital change and manufacturing firm organizational innovation. The path of organizational innovation of manufacturing firms has not been revealed, there is a certain theoretical "gap," and this problem is the key to achieving manufacturing firms from "survive" to "strong." Therefore, based on the grounded theory, this paper discusses how manufacturing firms realize organizational management, organizational strategy, and organizational structure innovation from the perspective of the knowledge field through multi-case analysis.

Method

The problem-driven research process is further explored through multi-case studies. Compared with case studies, more stable results can be obtained by following the replication logic and comparative analysis of multiple case studies. The multi-case method is used to study the influence of manufacturing firms on organizational innovation through the knowledge field. The multi-case study is more suitable for describing the particularity of actual activities and behaviors of internal organization management, highlighting the organizational context and organizational innovation process, and revealing the relationship between digital transformation and organizational innovation. Grounded theory is a common qualitative research method, which continuously summarizes and classifies fragmented data and information, and finally establishes the required theory. The research method of procedural grounded theory uses systematic and standardized operation process construction theory to

reduce research uncertainty, which is more suitable for multi-case studies, and can better reveal and explain the organization's operation mode, operation mechanism, innovation performance, and other issues in specific situations. Given this, we use the procedural grounded method to establish the theory based on the data collection and data analysis of the "grounded in" system, to fully understand the digital transformation, knowledge field, and organizational innovation of the center, grasp some important details, and obtain breakthrough research conclusions. Starting from the phenomenon of digital transformation and organizational innovation of manufacturing firms. We use a multi-case study to explore the causal relationship between manufacturing enterprises ' digital transformation, knowledge field and organizational innovation.

Case Selection

The selection of manufacturing firms is based on the following criteria: First of all, the selected sample firms have been established for more than 3 years, passed the creation period of great risk, and gradually entered the time cycle of organizational innovation, and on the other hand, to facilitate access to sufficient case information, thereby enhancing the validity of the conclusions (Suh & Battaglio, 2022, Luftman et al., 2017). Digital transformation of manufacturing firms to "digital technology + digital platform" two-wheel drive is the driving force for organizational innovation, so that the organizational structure has been improved, and organizational strategy burst (Olsen & Martins, 2012; Urbinati et al., 2020). Second, focus on manufacturing firms in different segments. Manufacturing firms in different segments have different organizational goals, management boundaries, and organizational sizes (Trenerry et al., 2021; Karimi & Walter, 2015). By accurately identifying the multi-dimensional needs of firms in the process of organizational innovation, it is helpful to focus on the direction of organizational innovation. In the process of organizational innovation of manufacturing firms, the focus of development goals and strategic objectives is adjusted dynamically, to explore the path of organizational innovation. Finally, the sample firms should also have the corresponding typicality, which should be deep, extensive, and multi-level. To a certain extent, it represents the future development trend of Chinese manufacturing firms and explores the enabling mechanism of digital transformation to organizational innovation more comprehensively.

In this study, eight manufacturing firms in Beijing, Nanning, Xuzhou, Qingdao, Shanghai, Nanchang, Zhengzhou, and Wuxi were selected as the research objects. They are Engineering Machinery Co., Ltd., Hengyi Petrochemical Co., Ltd., Xugong Group Engineering Machinery Co., Ltd., Haier Group, China Baowu Steel Group Co., Ltd., Oriental Automobile Manufacturing Co., Ltd., PetroChina Group, and Dongfang Automobile Manufacturing Co., Ltd. The reasons for case selection are as follows: First, there are certain differences in digital technology, construction purpose, organizational structure, development goals, and optimization of construction fields among the eight companies. Therefore, if you want to comprehensively and objectively describe the digital transformation model, organizational innovation

performance, and knowledge field and obtain a more universal theory, you need to fully consider the characteristics of each type. Second, the eight cases selected are large-scale manufacturing firms in China. The organizational governance model and operation mechanism are relatively perfect, the organizational innovation results are relatively rich, and the recognition among all sectors of society and peers is high and representative. Based on the above standards, we selected eight manufacturing firms as samples to collect and analyze the public data and reports of firms.

1. The selected case has strong representativeness and typicality, which can guide the development of local manufacturing firms. At present, the development of the above eight firms has reached a certain scale, the benefits of digital transformation and organizational innovation are obvious, and the logic of industrial development is clear. Haier Group and other firms focus on the research and development of core components, with independent research and development and related supporting capabilities, and are in a leading position at home and abroad.
2. The selected firms have good development prospects and research value. Firms continue to implement a comprehensive strategic layout and gradually realize digital transformation and innovative development, which is closely related to the research issues of this paper. Firms use digital intelligence to achieve deep integration of core components R&D and manufacturing, digital technology services, data management, organizational system innovation, and other links, which has a high degree of matching with research issues.
3. The selected firms have carried out a large number of activities related to digital transformation, knowledge exchange, and organizational innovation, and data acquisition is relatively easy. The firm-related digital technology community has been clear, with relatively obvious digital technology characteristics and organizational innovation strategic layout. There are a large number of rich and clear digital technologies and organizational information that can be used for case analysis, and the latest business information can be collected through relevant technical industry reports and typical firm website information.

Data Collection

Through multiple channels, the following three sources are included to collect firm data.

First, the official website details the firm's growth process, news events, business performance, and other information. By querying the official website of the firm, industry analysis reports, research literature, relevant news reports, and other network information, we collect and sort out information such as firm characteristics and development trends, including firm annual reports (quarterly reports), corporate social responsibility reports, and firm interim report.

Second, public literature, including authoritative media on the firm news reports: search keywords such as firm digital transformation, organizational innovation, and knowledge field in domestic and foreign paper databases such as HowNet, VIP, and WOS, and collect relevant literature, publicly published research papers, firm

official website information, "China firm innovation and development report," etc. The firm's news reports and news commentary materials were collected, with particular attention to news reports on digital transformation. A total of 186 articles and about 60,000 words of related reports were collected.

Third, team members directly observe and record important information through field visits to corporate headquarters, big data management platforms, and intelligent manufacturing centers, and obtain first-hand information on digital transformation, knowledge fields, and organizational innovation. Based on formulating the interview outline, the research group went to the firm for on-the-spot observation and in-depth interviews. The subjects of the survey were mainly senior researchers of each center's science and technology innovation team. Each interviewee was interviewed for about 1 h, forming a 60,000-word investigation report. To complement and cross-validate with other data, ensure the reliability and objectivity of the research data.

Finally, a database of 207,000 words was constructed, which provided detailed data support for the case study. To ensure the credibility of the evidence with multi-angle data sources, according to the research questions, the proposition is put forward based on data analysis, and relevant evidence data are collected to verify the proposition to ensure the validity of the research. By coding and mining data categories, identifying category attributes, and exploring category relations step by step, the theoretical construction is carried out through inductive analysis, and the theoretical research model is formed. The descriptive statistical results of various types of data are shown in Table 1.

Data collection is mainly divided into two stages: (1) through public channels, research on firms and digital technology product experience, sorting out the survey sample organization development status, and the use of digital technology and digital platforms in the firm and (2) describing the mechanism of digital transformation of manufacturing firms affecting organizational innovation.

Data Coding and Analysis

Open Decoding

Open decoding refers to breaking up the content of text data based on fully understanding the meaning of written data discourse and then disassembling the text data into different nodes by encoding meaningful units (Urquhart et al., 2010). We follow the step-by-step coding technology of procedural grounded theory, and based

Table 1 Description of various types of data

Number	Data type	Data description
1	Official website information	216 articles, about 80,000 words
2	Open literature	186 articles, about 60,000 words
3	Field investigation and interview data	60,000 words

on manual combing. The specific steps are as follows: first, determine the coding group. The members are composed of an associate professor in the direction of digital transformation research, an associate professor in the direction of organizational behavior research, and a professor in the direction of organizational innovation research. They are independently coded and recorded accordingly. Second is the comparative analysis. In the process of coding, if new concepts and categories appear, they need to be repeatedly compared and corrected. When there are inconsistencies in opinions, they need to be verified by experts outside the group. Finally, the data obtained by coding is compared with the relevant literature, and then re-encoding is carried out to help solve the previous doubts and finally achieve theoretical saturation. Before open coding, researchers need to set corresponding numbers for the cent data to avoid confusion between the text data of the interviewees during the data analysis (Matavire & Brown, 2013). Subsequently, the words, sentences, and paragraphs in the text data are repeatedly and carefully read and pondered. With "digital transformation of manufacturing firms, knowledge field, and organizational innovation" as the core of the problem, the repeated meaning units are constantly searched and compared, and they are set as different nodes and coded to form the basic analysis unit in the process of data analysis.

Based on the open decoding process, 125 initial concepts such as knowledge storage within the organization, new knowledge diffusion in the organization, knowledge integration in the organization system, knowledge organization system sharing service platform construction, three-dimensional integrated information community development, and knowledge base management system are obtained. To explore the mechanism of digital transformation on organizational innovation, after careful analysis, 110 concepts are retained and abstracted into 32 initial categories such as knowledge creation, sharing platform, and digital talent management as shown in Table 2.

Spindle Decoding

Principal axis coding is based on the results of open coding to refine the relationship between concepts. Among them, principal axis coding means that researchers use the most important or most frequent open coding to deeply classify, synthesize, and organize text data and then find the number of semantic relationships and associate them with each other (Urquhart et al., 2010). Through this coding paradigm, concepts and categories are linked, that is, the conditions under which a phenomenon occurs are used to comprehensively consider the actions and results taken against the situation, to grasp the essence of the phenomenon. The purpose of spindle coding is to cluster the initial categories refined by open coding again and find and establish the potential relationship between the initial categories (such as causality and parallel relationship), abstractly form a higher level of the main category, and prepare for the next step to find story clues. Combined with the existing relevant literature, explore the internal relationship between the initial categories. For example, the three initial categories of "strategic process and core value creation, insight into market opportunities, and value proposition drive" formed by open coding can

Table 2 Concepts and categories of open coding

Scope	Concept	Scope	Concept
Knowledge creation	Storage of knowledge within the organization; new knowledge expansion in the organizational structure; integration of new knowledge in the organizational system	Organizational strategy consistency	Consistency between organizational innovation behavior and strategy; the match between organizational responsibility and power; organization operation control strength
Digital service platform	The construction of a public service platform for knowledge organization and system; three-dimensional integrated management information community development; knowledge base management	Human–computer interaction	Soft and hard integration; the input feedback loop of the sensor; digital description of personal dimension; robot natural emotional interaction system
Talent training	Digital human resources management system; digital training; digital combat project	Management flattening	The organization effectively activates the team; team building; organizational structure adaptation; breaks organizational boundaries; organizational elements link
Project development	Project staffing, internal responsibility, linear project, matrix project, project plan	Digital positioning technology	GPS positioning; mobile phone base station positioning; radio frequency identification positioning; Bluetooth positioning system; ultra-wideband positioning system
Organizational communication	Organizational communication skills; use of media software; communication virtual situation construction	Strategic process and core value creation	Release strategic layout; strategic management efficiency optimization; develop overall, long-term, programmatic goals
Digital transmission technology	Digital information processing; face and fingerprint recognition; intelligent visual inspection of finished products	Collaborative approach	Intelligent organization collaboration; online cooperation; data processing; inclusive organization

Table 2 (continued)

Scope	Concept	Scope	Concept
Digital recording technology	Intelligent voice input; monitoring camera records	Organization ecosystem	Organizational system internal and external circulation; flow and information transmission; organization module output; team and organization environment planning; system repair and adjustment
Employee innovation performance	Employee creative thinking; enhance employee innovation ability; enhance employee autonomy	Digital connection technology	Multi-device networking control; multimedia communication technology
Construction of common elements	Construct the external environment of the organization, construct the internal environment of the organization, construct the purpose of the organization, identify the management subject and the management object	Digital trust construction	Reliability of virtual occasions; the sincerity of the digital world
Social network development	Organizational intelligence; angle of the complex adaptive system; online service channel construction	Digital trading platform	Digital commodity trading platform; digital asset trading platform; digital bill trading platform
Organizational conflict	Conflict of interests, inconsistent understanding, conflict or attack between members	Digital resource platform	The coverage and service scope of digital resources; navigation integration mode; user rights control and copyright control
User management refinement	User data collection; user channels; user layering; user portraits; customer relationship management	Organizational culture	Firm digital culture; empower firm culture construction; advocating open and shared corporate culture
Organizational goal and direction control	Business process centralized management; organizing cross-border cooperation; organization of top-level design	Organizational vision	Organization vision construction; the common value of the organization staff; technology helps resumption of work and production, develop sharing economy

Table 2 (continued)

Scope	Concept	Scope	Concept
Insight into market opportunities	Meet the needs of organizational personalized insights; market information collection and research; macro trends; medium market competition and micro customer understanding	Value proposition driven	Technology and data constitute a two-wheel drive; mining data value and realizing business innovation; deep learning and value management in the cloud
Team building	Provide opportunities to use existing resources; low-risk operations; exploratory team building	Data processing and governance	Data governance mechanism; internal data processing system; data quality control; improve the efficiency of external data processing
Data element identification	Digital cage system; improve internal data quality; raw data management	Organizational commitment	Employee pride; promote the construction of organizational channels; employee loyalty, recognition of organizational value and culture

be integrated into an "axis" under the construction paradigm, that is, organizational strategic innovation. The researchers further carry out axial coding and selective coding around the text data, classify, refine, and comprehensively adjust again, merge the code numbers with similar meanings, and sort out the correlation between the code numbers. Since the 32 code numbers obtained by open coding are a list of different meaning units, they are collated and analyzed. Through similar comparison, heterogeneous comparison, horizontal comparison, vertical comparison, and other methods, 32 code numbers are classified into 10 more refined code numbers. Cluster analysis is performed on the relatively independent open decoding results to obtain the spindle decoding and analyze the conceptual hierarchy of each category. The open decoding is integrated into the initial category. Finally, 10 main categories are abstracted and summarized, and the results of spindle decoding are shown in Table 3.

In the process of technological innovation, organizations should improve their ability to grasp and adapt to the technological environment and policy environment, apply digital technology to the process of organizational innovation, and promote organizational innovation by reshaping and driving the value process. Summarizing the motivation of knowledge field activity to promote organizational innovation is shown in Fig. 1.

Table 3 Main categories formed by spindle coding

The main category	Subcategory	The main category	Subcategory
Information exchange	Knowledge creation; project development; human–computer interaction; organizational communication	Data management	Data processing and governance; user management refinement; data element identification
Digital platform construction	Digital trading platform; digital resource platform; digital service platform	Team cohesion	Organizational culture; construction of common elements; team building
Digital technology development	Digital connection technology; digital transmission technology; digital recording technology; digital positioning technology	Organizational system innovation	Employee innovation performance; organizational goal and direction control; organizational strategy consistency
Trust relationship	Collaborative approach; organizational commitment; organizational conflict; organizational vision	Digital network	Social network development; digital trust construction
Organizational strategy innovation	Strategic process and core value creation; insight into market opportunities; value proposition driven	Organizational structure innovation	Management flattening; talent training; organization ecosystem

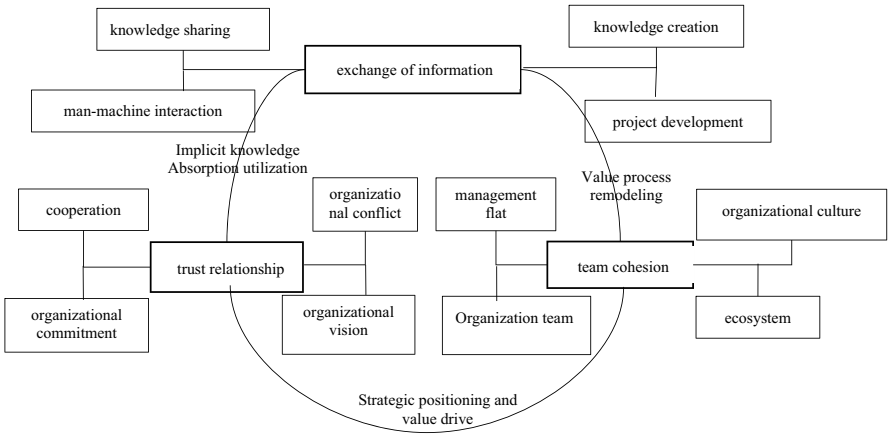

Fig. 1 Motivation of knowledge field activity to promote organizational innovation

Selective Decoding

Selective coding is to further integrate and refine the existing categories more abstractly, generate and explore the main categories around the theme, and thus establish the connection between categories (Urquhart et al., 2010). Researchers have established three new nodes around the theme of "digital transformation and organizational innovation" on the above 10 numbers, namely "digital transformation," "knowledge field," and "organizational innovation." Combined with the original data, 10 main categories were analyzed. "Digital platform construction," "digital technology development," "digital communication," and "data management" are the digital backgrounds on which organizational innovation depends, which can be summarized as "digital transformation," "information exchange," "trust relationship," and "team cohesion," which can be summarized as "knowledge field activity." "Organizational system innovation," "organizational strategy innovation," and "reorganizational structure innovation" are the multidimensional effects of organizational innovation. Finally, 10 main categories are abstracted into three core categories. Under the support of digital transformation, sample firms realize information exchange through element links, thus forming the motivation and approach of organizational system innovation, through multi-agent interaction to establish a trust relationship, achieve organizational strategic innovation through collaborative governance, form team cohesion through scenario interaction, trigger common development goals, and promote organizational structure innovation through in-depth development of organizational integration. The storyline around this core category is as follows: First, manufacturing firms achieve deep digital transformation by building digital networks, building digital platforms, and improving digital technology and data management. Through digital transformation, multi-agent interaction and factor links are realized. Information exchange is realized in situational interaction. Through digital

transformation, information exchange among organizational members is formed, trust relationship is formed, and team cohesion is enhanced. Under the joint action of digital transformation and knowledge field, it promotes the innovation of organizational systems, strategy, and structure; it comprehensively uses trust mechanism, learning mechanism, and other mechanisms to regulate the learning behavior of organizational subjects and promote the realization of organizational innovation goals. The relationship between the decoding results of organizational innovation and the core categories is shown in Fig. 2.

Theoretical Saturation Test

The remaining quarter of the data was used to test the saturation of the grounded theory. After analyzing the material, no new definition and type were found, so the model constructed by the grounded theory passed the theoretical saturation test.

Discussion

The mechanism model of digital transformation on organizational innovation is explained. Digital transformation consists of four dimensions: digital platform construction, digital technology development, digital communication, and data management. The specific explanation of the model is as follows:

Digital Transformation Empowers the Flow of Knowledge Field

In the context of digital transformation, digital technology has gradually penetrated different areas and links of the organization. With the platform and distribution of organizational innovation activities, the organizational logic of innovation activities is richer. The construction of digital platforms breaks the information asymmetry by sharing knowledge and information with other organizations. High-frequency data interaction promotes the development of organizations in the digital direction and realizes the creation of organizational value (Jantz, 2015).

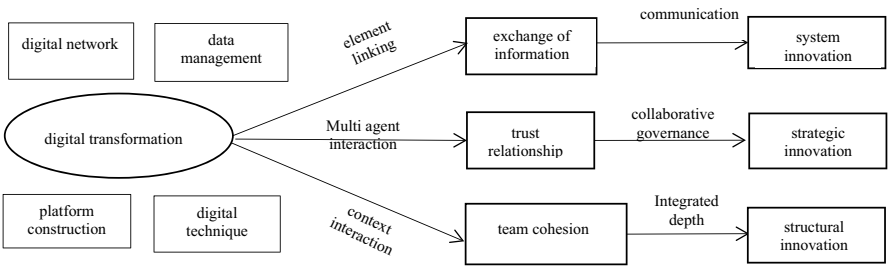

Fig. 2 The relationship between the decoding results of organizational innovation and the core category

Digital Transformation Enables Information Exchange

The digital transformation of manufacturing firms helps organization members to exchange information, mainly to promote organizational knowledge creation, project development, human–computer interaction, and organizational communication activity. First, we explain the results of Liu et al. (2021); digital technology leads business activities to reconstruct the value chain model and enhance knowledge creativity, thus providing impetus for organizational innovation. Second, the construction of digital platforms has increased the intensity of human–computer interaction and organizational communication. Aviv et al. (2021) used the method of social media analysis (SMA) to explore the value overlap of digital communication to the interaction between specific stakeholders in the organization, and the degree of organizational communication has been significantly improved. Our research further confirms the research results of Aviv and other scholars and further improves the framework of knowledge management infrastructure. Based on the theory of information asymmetry and resource-based management, it is proved that digital transformation can help firms develop knowledge-intensive business processes. Finally, based on the above division of labor, the digital network promotes the two parties of the organization to break through the traditional relationship paradigm and gradually form a new technical cooperation network. In the process of industrialization, firms have adjusted the management mode of division of labor and cooperation several times and adjusted the organizational distribution to achieve the overall organizational communication and overall efficiency of firms; this further validates the results of Cichosz et al. (2020). Our research complements Hu et al.'s (2022) research. With the deepening of the digital transformation of firms, firms use information technology innovation to achieve resource bricolage and organizational improvisation, thereby improving organizational innovation performance.

Digital Transformation Empowers Organizations to Form Trusting Relationships

Digital transformation promotes the alternating conversion process between implicit consciousness and explicit consciousness in the knowledge field. The two sides of the cooperation form a strategic partnership by using cloud technology, expanding knowledge by sharing resources, and promoting the process of alternating between explicit consciousness and implicit consciousness. Different from Karimi and Walter (2015) from the perspective of dynamic capabilities, based on the trust relationship between organizational members realized by digital technology applied to management information systems, our research starts from the perspective of the knowledge field. With the expansion of the stream of consciousness, the conscious elements in the field conflict with each other to form a new knowledge base, providing heterogeneous resources for the knowledge field. Digital applications facilitate broader strategic partnerships with organizations. At the same time, our research further supplements the research results of Liu et al. (2021) on manufacturing firms. With the deepening of the digital transformation of firms, the adaptability of firms is improved, which is the research result from the perspective of resource allocation. Second, we believe that

digital applications can play a role in the knowledge field to achieve the establishment of organizational trust. In summary, the digital transformation of manufacturing firms has promoted the increase and circulation of professional knowledge and established an organizational trust relationship. The formation of the credit relationship provides more knowledge for the knowledge field, and the dual mechanism will play an important role at the same time in improving the vitality of the knowledge field and organizational innovation performance (Kauffman & Weber, 2018). Starting from the basic process of organizational value creation, collaborative parties first form relationships with each other and then establish overlapping functional areas at organizational boundaries. In this process, digital technology can also continuously consolidate and enhance the relationship with each other according to the stage characteristics of organizational development, to better carry out value co-creation activities (Trenerry et al., 2021; Vial, 2021).

Digital Transformation Leads Organizations to Team Cohesion

Digital transformation promotes situational interaction and guides the organization to form team cohesion. Digital technology and digital platforms are important factors leading to situational interaction in the knowledge field. This further extends the results of Urzo et al. (2019). The digital platform promotes organizational value co-creation and high-level situational factors drive low-level operational activities to form team cohesion. First, the construction of digital platforms can promote the improvement of data openness. From the theoretical perspectives of complex networks and complex systems, organizations widely connect information, knowledge, and resources and form organizational cohesion through cross-border integration and factor connection activities. Second, digital technology development can realize value creation, and the boundary of innovation subjects is expanding and may form an ecosystem (Kim, 2020).

From the dual perspective of digital technology and platform, Legros and Galia (2012) studied the complex network formed by multinational firms through the construction of an organizational ecosystem, to realize the co-creation of organizational value. In the field of knowledge management, digitization promotes the collaborative response of firms to the internal and external environment of the organization, which is reflected in the knowledge innovation behavior of firms. From the perspective of knowledge management, firms can not only form a benign relationship of efficient communication mutual benefit and mutual trust with the main body but also explore and apply the existing knowledge base on a deeper level, to exert the aggregation effect of knowledge (Kim & Vandenberghe, 2021). Therefore, our research further confirms the positive impact of enhancing information technology (IT) business consistency on corporate performance pointed out by Luftman et al. (2017) and complements the innovation results at the organizational level. Based on the above analysis, digital transformation can positively motivate organizations to form team

cohesion based on the knowledge field. Knowledge field activity is the front factor influencing organizational innovation.

The Mechanism of Digital Transformation Enabling Organizational Innovation

Can digital transformation further realize organizational innovation and development under the activity of the knowledge field? Through further analysis of the model, the mechanism of digital transformation enabling organizational innovation is summarized as follows.

Information Exchange to Induce Institutional Innovation

Organizational system innovation focuses on employee innovation performance and organizational goals. The exchange of information among members of the organization can play an important role in promoting organizational system innovation. This is consistent with the results of Luftman et al. (2017); the innovation ability of employees is generally regarded as the first step of organizational innovation. The introduction of digital technology plays an important role in cultivating employees' innovation ability, effectively mobilizing their creative potential and innovation motivation. The digital transformation of firms helps to create a creative atmosphere within the organization, thus forming a lasting impact on organizational system innovation. At the behavioral level, digital change can stimulate knowledge field activity, knowledge sharing, and employee communication activities. Through extensive analysis of the whole process of knowledge creation and application promotion, knowledge field activity is the key to promoting knowledge flow and inducing organizational system innovation. Through the construction of a digital platform, employees are more likely to share behavior and establish the basis for a better organizational system. Therefore, the research in this paper further explains the research of Mcadam et al. (2012) from the perspective of behavior, that is, knowledge sharing is an organizational behavior actively formed by organizational members in the context of the digital transformation of firms. At the same time, At the same time, in the social context, we supplement the research of Kim (2020). Kim (2020) found that individualism-collectivism orientation can affect knowledge sharing and achieve innovation. The reason is that the knowledge field can stimulate the exchange of information between members of the organization, accurately identify and respond to the development of organizational innovation needs, and enable organizational innovation to be realized.

But at the same time, the conflict between the old and new institutional logic of the organization is inevitable. The working mode of digital technology and digital platforms leads to some practical problems that cannot be explained by traditional division of labor theory. This further extends the research results of Mahapatra et al. (2010) and Socorro Márquez and Reyes Ortiz (2021) on strategic interdependence and governance effectiveness. The cognitive differences of organizations in the fields of resources, technology, knowledge, innovation ability, and cultural strategy may have an impact on the

organizational system. The digital divide may also arise while achieving organizational creation. While bringing impetus to the creation and development of organizations, digitization has also brought about problems such as the abuse of digital technology, the increase in the gap between the rich and the poor, and the digital divide. Different from the research results of Matarazzo et al. (2021), we believe that firms should coordinate organizational development goals at different levels such as science and technology, management, structure, and environmental protection to form a sustainable and inclusive digital transformation to support the innovation and development of organizational systems. Resolving organizational conflicts requires diminishing organizational cultural and strategic differences at the executive and board levels. In the multi-level development of the organization, coordinate the link between individual and organizational development. Organizations can use digital platforms to further establish a precise institutional framework and establish more lasting and firm organizational beliefs through organizational commitment, to ensure the implementation of organizational system innovation and echo the demands of organizational innovation and development for digital transformation; this is an important complement to the results of Nordin (2012). In Table 4, the case evidence of digital transformation, knowledge field activity, and organizational system innovation of manufacturing firms is listed.

Building Trust Relationship to Induce Organizational Strategic Innovation

According to George's Law, the speed of organizational structure transformation lags far behind technological change, which explains the challenges faced by digital transformation at the organizational level. The organizational structure of manufacturing firms is more complex, due to the presence of mobile components with higher complexity. The key to organizational strategic innovation is to motivate employees to make changes. For example, Haier Group actively promotes the use of Internet platforms, digitizes the entire firm business process under the coverage of 5G networks, and clarifies the influencing factors of organizational strategic changes and the effect of organizational strategic innovation in the process of digital transformation. According to the research of Trenerry et al. (2021), the workplace of digital transformation is the integration of multi-level factors. Therefore, under the background of firm digital transformation, the activity of the knowledge field is further improved, the information exchange among organizational members is more perfect, and the organizational innovation at the strategic level is induced through the trust relationship. This is a further mechanism explanation and case verification of the research of Trenerry et al. (2021) and Vial (2021). The progress of digital technology represented by information technology has accelerated and has been widely used. Xugong Engineering Machinery Co., Ltd.has a low customer satisfaction index. Through the establishment of a digital platform, the company has achieved process revision and organizational division of labor, opened up digital channels, and thus put the customer satisfaction index at the forefront. In the process of transforming into a digital platform, Hengyi Petrochemical Co., Ltd. has accumulated profound professional knowledge and introduced the concept of the digital twin. General Electric uses

Table 4 Case evidence of digital transformation, knowledge field activity, and organization system innovation of manufacturing firms

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Engineering Machinery Co., Ltd	Digital technology; digital platform; data management	Information exchange	Quality system innovation	Engineering Machinery Co., Ltd. uses digitization to empower traditional industrial quality innovation, efficiency reform, and power innovation. Through the introduction of digital technology in the production process, management informatization is carried out, and production service automation and business model networking are carried out through the introduction of digital platform technology. Through innovative industrial platform construction and constant improvement of the platform level, to further strengthen the communication with other manufacturing firms, play the leading role of the head firm, and formed the organization's quality management system

Table 4 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
PetroChina Group	Data management; digital network	Information exchange	Operation system innovation	In recent years, PetroChina Group has formed a digital network including supply chain online, production operation online, and marketing system online through data management. Gradually change the development system that simply aims at the operational efficiency of the firm, reduces the reconstruction process, and improves the effectiveness of the organizational operation system
Haier Group	Digital platform	Information exchange	Product development system innovation	Haier Group is a typical digital firm. It continues to build digital platforms to develop agile digital product development methods and builds agile teams among organizational members to achieve large-scale agile applications within the organization. Haier Group has formed several full-time agile teams to carry out long-term cooperation, work together to complete digital product development, and form cooperation system innovation

Table 4 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
China Baowu Steel Group Co., Ltd	Data management; digital network	Information exchange	Customer management system innovation	China Baowu Iron and Steel Group Co., Ltd. is actively engaged in digital transformation, from the original coverage of the entire value chain within the industry as a whole information capacity to data processing to the use of artificial intelligence information technology to discover and create new business opportunities, which have been a great success; one of the important experiences is the construction of digital networks. Adhering to the customer-first corporate culture, taking the initiative to carry out communication within the organization, maintaining a close communication relationship with front-line users, doing everything to solve their actual needs, while doing a good job in product promotion and landing, and actively obtaining feedback to optimize and improve

Table 4 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Hengyi Petrochemical Co., Ltd	Digital technology; data management	Information exchange	Production system innovation	Hengyi Petrochemical Co., Ltd. actively improves the degree of digital production and manufacturing efficiency. Organize nearly 10,000 person-times of professional training related to intelligent manufacturing to improve the professional knowledge related to intelligent manufacturing, and use big data management technology to carry out personalized solutions to meet the rapid production needs of new products and increase its radiation effect on the organizational system

digital information technology to deal with inter-departmental coordination management issues and form an organizational strategy for coordinated development. In Table 5, the case evidence of digital transformation, knowledge field activity, and organizational strategic innovation of manufacturing firms is listed. Organizational commitment plays an important role in the process of trusting relationships. This further verifies the research results of Garcia-Morales et al. (2018), that is, organizational commitment can maintain employees' loyalty and sense of belonging to the organization under the changes brought about by digital transformation. Organizational commitment also reflects employees' deep understanding of team values and organizational culture. When there is enough recognition among organization members, there is a binding force between individual goals and organizational goals.

Organizational commitment includes organizational goal identification and employee pride, reflecting different psychological states within the organization and employees. In the context of digital transformation, the management paradigm is accelerating, and digital technology gradually affects the organizational model and operational mechanism to achieve the ultimate goal of organizational strategic innovation. Therefore, unlike Yang et al. (2021) and Zhang et al. (2017), from the research on digitization, inter-organizational technological activities, and the research on the relationship between emerging market knowledge search and open innovation performance, we further explore the relationship between members within the organization. Focusing on organizational culture and core values, the integration of organizational innovation strategy development and digitization is achieved. Through real-time communication, a clear incentive mechanism is established to transform digital transformation from a project to an organizational strategy. Knowledge field activity also supports the continuous process of digital transformation. Given the different needs in the process of organizational strategic innovation, firms have built a digital platform. For example, the limited firms of China Baowu Iron and Steel Group have carried out strategic alliances with other advanced firms and actively promoted their exploratory activities and utilization activities to develop the organization's breakthrough technology innovation and organizational progressive technological innovation. Guided by the digital transformation, intelligent upgrading, and integration innovation of the Internet industry, the inclusive digital platform formed by the enabling organization strategy is transformed from human-intensive to human–computer interaction. Firms through the network, cloud platform, and other digital information technology principles break the space constraints and with the help of innovation systems and other social subjects carry out a wide range of cooperation and exchange, which is conducive to the realization of organizational strategic innovation. Table 5 lists case evidence for digital transformation, knowledge field activity, and organizational strategic innovation in manufacturing firms.

Forming Team Cohesion to Induce Organizational Structure Innovation

The interaction between teams is affected by various factors such as team boundary and cross-context management at the organizational level, team level, and cross-level level, which is not conducive to innovation activities between teams.

Table 5 Case evidence of digital transformation, knowledge field activity, and organizational strategic innovation of manufacturing firms

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Hengyi Petrochemical Co., Ltd	Digital platform; data management	Trust relationship	Resource -sharing strategy innovation	Hengyi Petrochemical Co., Ltd. actively tried a variety of digital tools and methods to establish a digital communication platform. With the help of digital means and the principle of communication and mutual assistance, it formed a learning and friendship organization to build safety, established a trust relationship between firms, improved the operational efficiency of firms, and formed a resource-sharing strategy
Engineering Machinery Co., Ltd	Digital technology; data management	Trust relationship	Business strategy Supply chain strategy Marketing strategy	Engineering Machinery Co., Ltd. actively creates a digital environment and establishes new connection methods for business elements, supplier elements, and marketing elements to achieve instant online contact between team members. Under the link of new organization members, organizational performance is improved, and new business strategy, supply chain development strategy, and marketing strategy are reconstructed around online links

Table 5 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
China Baowu Steel Group Co., Ltd	Digital platform; digital technology	Trust relationship	Strategy realization process innovation	The business personnel of the limited firms of China Baowu Steel Group Co., Ltd. quickly established digital capabilities. Within the work team, organizers use automated tools and digital platforms to enable business people to quickly turn their visions into operational systems and to test their viability through a small pilot. Continuously optimize automation tools and platforms and carry out team strategic innovation. Team members will master the common working language and quickly implement the strategy

Table 5 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Oriental Automobile Manufacturing Co., Ltd	Digital network; digital platform; data management	Trust relationship	Marketing strategy	Based on the consensus on stability and value, Oriental Automobile Manufacturing Co., Ltd. has created an overall Internet digital solution for several stores in China and supported the application of mobile terminals in the form of the Internet of Things through the layout of offline wireless use connection points and digital network platforms. Through the integration of hardware and software, the system can reach and count massive data, return to the background, realize big data integration and data analysis, and establish a network connection with different stores. At the same time, the precipitation of big data assets can also provide preparation for the fine sales strategy of firms. For example, before the end of the year, firms should understand the number of weekend arrivals in a store in a region and can use the precise figures of the Internet of Things to help each store formulate a more reasonable sales strategy

Table 5 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Haier Group	Digital network; digital technology	Trust relationship	Behavior strategy	The external power of the open-source community connection organization is constructed by the Haier Group. Multiple community members participate in the internal and external motivation of establishing an open social connection organization. Through the participation of multiple social members, the trust relationship is formed, and the organization realizes independent progress and innovation, to obtain internal and external motivation and create new value based on social openness. Organizations can improve organizational performance through personnel online, production online, customer online, and management online. Organization members use digital technology more efficiently, form changes in behavior patterns, and enable teams to push ideas outside the organization more quickly, thereby meeting organizational needs and accelerating strategic innovation

Table 6 Case evidence of digital transformation, team cohesion, and organizational structure innovation of manufacturing firms

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
PetroChina Group	Data management Technology development	Team cohesion	Governance structure innovation Institutional mechanism reform	PetroChina Group promotes informatization, digital transformation, and industrial chain support, focusing on supporting the development of new businesses, to achieve the goal of the new business layout. In the data management process, further, streamline headquarters function and improve team cohesion, with a focus on strengthening large-scale project management and investment and new energy management functions. Through the optimization and adjustment of the organizational system, improve the corporate governance ability, realize the reform of the system and mechanism, and announce a new organizational change plan

Table 6 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Hengyi Petrochemical Co., Ltd	Data management Digital technology	Team cohesion	Organization core competitiveness Organize professional team	Hengyi Petrochemical Co., Ltd. through the use of digital platforms and high investment, strong scientific research strength, advanced manufacturing equipment, and the industry's top firms to establish a partnership, build a professional, efficient quality control team, and formation of customer satisfaction to maintain the method. Using internal and external environmental factors to establish a local competitive advantage, thus forming the core competence of the organization
Engineering Machinery Co., Ltd	Digital platform Digital technology Digital network	Team cohesion	Data-driven operations	Engineering Machinery Co., Ltd. uses digital networks to aggregate data generated online by the business. Relying on the data intelligence provided by the algorithm will change human decision-making into data decision-making and reduce "human impact." Using the digital platform to gradually transform the human-driven operation of the organization into a digital operation, forming an efficient network structure of the organization, reducing organizational management pressure, and reducing management costs

Table 6 (continued)

Case firm	Digital transformation	Knowledge field activity	Organizational innovation	Case evidence
Haier Group	Digital technology Digital network	Team cohesion	Cross-border organizations and projects	Haier Group combines IT resources with other departments to develop cross-border organizations and projects, improve team cohesion, and promote and accelerate the transformation of organizational structure through multiple dimensions. The innovative organizational structure design within the firm is an important result of digital transformation
China Baowu Steel Group Co., Ltd	Digital platform	Team cohesion	Innovative organization Evolutionary organization	China Baowu Steel Group Co., Ltd. in the form of a self-organizing structure is also constantly restructuring, from the traditional pyramid organization gradually transformed into an innovative organization, the team together, and the progressive self-organization continues to develop. Digital platforms are also the main medium for empowering organization members to manage and implement functions

According to Whelan et al. (2016), there are differences in organizational context and structure at the team level. According to the specific organizational situation, development stage, and overall goal of the firm, the digital interface system selects appropriate control measures according to the cross-border integration and interaction of the firm organization to coordinate the interaction between the team level, the organizational level, and the cross-level of the firm, thus promoting the orderly flow of production factors and forming team cohesion to induce the efficiency and benefit of organizational structure innovation. Our research results complement the research results of Trischler and Li-Ying (2023) from the qualitative perspective of the case. This makes it more instructive to use digital technology to realize the cooperation and sharing of team members within the organization. Under the theory of organizational support, the digital support of organizational scenarios is formed, and the boundary constraints of innovation elements are gradually broken through to form an open, authorized, and people-oriented organizational scenario. Through effective connection, the coordination management is completed, and the dynamic balance of the organization is maintained.

Under the background of the vigorous development of digital technology, due to the expansion of data scale, the organizational structure is becoming more and more complicated, transparent, and visualized, forming a complex evolutionary system with adaptive ability, including multiple actors and hierarchical structure, to achieve good cooperation among organizations. Based on the research results of Tchamyou et al. (2017) and Yousaf et al. (2022), we believe that with the improvement of individual value of employees, the interaction of symbiosis, co-creation and co-governance among organizational subjects emerges, and the internal structure is flattened, so as to improve the accuracy of team management and control and drive the workflow docking of organizational subjects. With the continuous formation of the internal cooperative management and innovation community of the organization, the cooperative relationship among the main bodies of the organization presents the trend of integration. According to the research results of Urbinati et al. (2020) and Otioma et al. (2023), digital technology plays an important role in the process of organizational open innovation. Different from the research of Urbinati et al. (2020), our research results are as follows. Based on the theory of process reengineering, digital technology makes a comprehensive decomposition of the organizational operation process, thus forming team cohesion, which is conducive to the comprehensive reconstruction of the organizational structure.

At the cross-level of the organization team, the differences in organizational structure lead to different expectations of organizational development goal orientation and innovation task scope. At this time, the organization faces dilemmas such as "Duopoly management." Digital technologies and platforms have created new operational management situations and formed associated structural changes. According to the individual-environment fit theory, the positive attitude and behavior of individuals depend on the support of organizational context, which makes employees form a stronger affective commitment to the organization. Combining the results of Škare & Biberić (2015) and Myszak (2023), we believe that the release of organizational value improves the ability of individuals to take risks and responsibilities and to a certain extent improves employees' independent decision-making ability and

team cohesion. The digital platform can realize the overall connection, strengthen the multi-dimensional extensive interaction of cooperative organizations, and realize the innovation of organizational structure by contributing to creativity and innovation performance. Table 6 lists case evidence for digital transformation, team cohesion, and organizational structure innovation in manufacturing firms.

Conclusions

Research Conclusion

Based on the grounded decoding analysis of multi-case studies, eight manufacturing firms are selected as research samples. We use grounded theory to construct digital transformation, knowledge field, and organizational innovation and establish four characteristic dimensions of digital transformation of manufacturing firms: digital network, data management, platform construction, and digital technology. Combining the interview method and factor analysis method, we use grounded theory to conduct qualitative research on digital transformation, knowledge field, and organizational innovation construct and deeply think about the process of firm organizational innovation under the background of new technology. According to the theoretical framework model formed by grounded theory, information exchange, trust relationship, and team cohesion are the three key conditions for organizational innovation. This paper constructs the theory of the digital transformation process of manufacturing firms, analyzes its evolution process and the key mechanism affecting organizational innovation, and summarizes the mechanism of digital transformation enabling organizational innovation of manufacturing firms from the perspective of the knowledge field. Digital transformation improves the ability of organizational information exchange through factor links and knowledge exchange in the knowledge field and forms the dynamic support of organizational system innovation. Secondly, digital transformation promotes multi-agent interaction in the knowledge field, establishes the trust relationship between internal and external members of the organization, and encourages organizational strategic innovation. Digital transformation forms team cohesion through situational interaction in the knowledge field and integrates in-depth development to stimulate organizational structure innovation.

Management Inspiration

Actively promote the application of digital technology. Strengthen the communication between the members of the organization of manufacturing firms, so that business processes and information management are interconnected. To promote the organization into a critical period of digital transformation, manufacturing enterprises should use digital technology and network cooperation improve organizational innovation performance. Digital intelligence transformation and technological transition accelerate the transformation and adjustment of the innovation ecosystem and also create new opportunities for firms to explore emerging technology fields

again. However, the growth of emerging technologies is a complex and dynamic process, involving complex and diverse resources and factors. Innovation pre-judgment and fine-tuning are the keys to nurturing technological innovation. Therefore, firms should build an innovation collaboration system dominated by core firms, flexibly use a variety of innovation policies, and fully mobilize the innovation power of the whole society. Only by continuously stabilizing their sustainable development capacity can they seize the opportunity of technological change in the ever-changing market demand and seek new paradigm changes.

Promote digital platforms. Manufacturing firms can use the digital platform to grasp real-time information on multiple subjects such as organization, market, and customers promptly, adapt to the development and change of the organization, form the fine management mode of the organization, effectively improve the operation efficiency of the organization, and promote the big digitization covering the optimization of organizational operation, operation control, and production process management. Establish a platform-based organization model dominated by core firms to promote the evolution of the innovation ecosystem. Actively build an innovation platform, integrate heterogeneous resources in different industries, drive the overall optimization and iteration of the innovation ecosystem to adapt to the uncertain external environment, actively build a new product promotion model and an innovative ecological operation model, and drive the common development of upstream and downstream firms, to achieve a win–win situation.

Establish a digital talent training system. Strengthen the training of digital talents in manufacturing firms, and improve the talent pool under the needs of organizational innovation and development. Driving firms to continuously tap market demand and technological value to expand new usage scenarios have an impact on the mainstream technology paradigm. This process requires long-term R&D investment and multi-disciplinary and multi-agent cooperation to effectively promote the virtuous cycle of technology R&D and application. Based on fully collecting the real needs of users, firms should put forward new value propositions based on the difference in external demand, expand market business, change from product provider to service provider, and realize the invasion of the mainstream market. Create policy protection space for new technologies, so that new technologies can be developed and transformed in a relatively stable and isolated niche and promote the cross-integration and development of disruptive innovation.

Limitations and Prospects

As an exploratory multi-case analysis of the digital transformation and organizational innovation practice of manufacturing firms, we carried out a certain degree of theoretical exploration and empirical test on the above problems, but there are still inevitable limitations.

First, the digital transformation of manufacturing firms in China is developing rapidly, and the eight cases selected are all large-scale manufacturing firms. Therefore, the applicability of the proposed theoretical model to other firms of scale and property rights remains to be further demonstrated. Future research will adopt a

combination of qualitative and quantitative methods for further exploration. Future research can further explore the universality of the conclusions by enriching the sample group and can also further compare the impact of different firm difference indicators such as different scales and ages on different characteristic dimensions of digital transformation.

Second, the sample representativeness of this study is insufficient, and the sampling comes from a specific region. Although we strive to select cases with typicality, diversity, and comprehensiveness in the selection of research objects, due to the completeness of the case data and the difficulty of obtaining it, there are certain regional limitations in the research conclusions. Regional differences (such as traditional cultural differences, and economic level differences) and organizational structure differences may lead to changes in results, so external validity is insufficient. In the future, stratified sampling or large-scale surveys can be used to further investigate the differences in digital transformation and knowledge field activity between different regions and different forms of organizational structures and to explore the impact mechanism behind them, to better promote the research results.

Third, due to the limited number of selected cases, whether the research conclusions can be universally applied to other industries remains to be verified. In the future, cross-case analysis can be used to increase the number of samples in related industries. At the same time, empirical analysis methods can be used to test the relevant conclusions and continuously improve the theoretical model.

Fourth, qualitative research methods have some inherent limitations. Although we seek to cover professional scholars in different educational environments in the selection of coders, it is still impossible to ignore that the coding results will be subject to the subjective selection bias of the coders. In the future, field research and observation methods can be used to examine the behavior performance in the real work environment, and tracking data can also be collected to explore the development trend of firm organizational innovation and its dynamic relationship with digital transformation variables. Through the development of experimental paradigms, more scientific and rigorous qualitative research methods are used for interdisciplinary research cooperation, and this research is continuously supplemented and verified or revised.

Author Contribution ZX: design the experimental method for the differential model, analyze the experimental data, and write the first draft of the paper. Verified the experimental design and supervised and guided the research topic. FD: provided research funding and participated in the review and revision of the paper.

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Data Availability The data that support the findings of this study are available on request from the corresponding author upon reasonable request.

Declarations

Conflict of Interest The authors declare no competing interests.

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