Computers & Industrial Engineering 162 (2021) 107774

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Digital transformation: A systematic literature review

Xiaoteng Zhu, Shilun Ge, Nianxin Wang *

Department of Information Management, School of Economics and Management, Jiangsu University of Science and Technology, China

ARTICLE INFO

Keywords:
Digital transformation (DT)
Bibliometric analysis
Citation analysis
Co-citation analysis
Main path analysis
Visualization analysis

ABSTRACT

Digital transformation (DT) has emerged as an important phenomenon in the discipline of business and management. The purpose of this paper is to examine intellectual structure of DT research. We conducted a variety of bibliometric and visual analysis methods on DT research published in the 20-year period of 2000–2020. A total of 865 papers from Web of Science were selected for our analysis. Our main path analysis identified 12 important papers in this field, and revealed the three development stages of DT research: the embryonic stage, the development stage, and the thriving stage. We also identified influential countries, institutions, and journals in DT research, and seven research themes including digital business strategy, strategic action field, digital technology, agile digital transformation, digital enterprise architecture, DT of manufacturing, and DT of consulting services. This paper is one of the first studies to examine the knowledge structure of DT research by using citation/co-citation analysis methods. Recommendations for future research directions in DT are provided based on our findings.

1. Introduction

Digital transformation (DT) refers to the process through which an organization responds to environmental changes by using digital technologies such as mobile computing, artificial intelligence, cloud computing, and the Internet of Things (IoT) to change its value-creation processes (Vial 2019). DT has human-oriented characteristics and usually involves the integration and innovation of technology and business. Since DT can help companies improve their strategic agility while enhancing the customer experience, simplifying operations, or creating new business models, DT has become a means for entrepreneurs to internalize external pressure as a driving force for change in the face of competitive and unpredictable external environments (Accenture 2019). According to the "2019 Digital Transformation Market Trends Report," 78% of survey respondents felt that DT is imperative for a company's survival, with 24% regarding DT as their top priority (Taylor 2019). The International Data Corporation, a technology market research organization, projected that the proportion of DT expenditure in total information and communications technology investment will exceed 50% by 2023. It is estimated, moreover, that the global DT market will reach $7.1 trillion by 2023 (Bob Parker 2019).

DT research is continually developing and improving. It involves multiple target countries, regions, organizations, and industries (e.g., healthcare, media, education, manufacturing) (Kutnjak et al. 2019; Svadberg et al. 2019). Current DT research has formed a number of relatively concentrated themes. Martín-Peña et al. (2018) summarized the evolution of business models and competitive advantage in the DT of the manufacturing industry. Mukhopadhyay and Bouwman (2019) analyzed the key factors and strategies of digital platform governance from the perspective of ecosystems. Cortellazzo et al. (2019) reviewed research on leadership in the context of DT, including the role of leadership and the new capabilities leaders need to possess. Lock (2019) described the communication mode between an organization and its different stakeholders and proposed relevant theories and research processes. Büyüközkan and Göçer (2018) reviewed the development status of the digital supply chain (DSC), and proposed a new DSC conceptual model and a roadmap for future practice. Such studies highlight the fact that DT has emerged as an important phenomenon in fields of strategy, psychology, innovation, and informatics, and strategic IS research.

The above-mentioned reviews provide useful information for DT research and further the accumulation of DT knowledge. We propose, however, that a new literature review is necessary for the following two reasons. First, previous DT literature reviews have mostly focused on

* Corresponding author.
E-mail addresses: 13121186756@163.com (X. Zhu), jzgsl@jzerp.com (S. Ge), nianxin.wang@gmail.com (N. Wang).

https://doi.org/10.1016/j.cie.2021.107774
Received 10 March 2021; Received in revised form 27 September 2021; Accepted 24 October 2021
Available online 6 November 2021

specific topics, making it difficult to provide a comprehensive and systematic view. Henriette et al. (2015) were the first to systematically review DT research from a broad perspective; they summarized DT's effect on enterprises' digital capabilities, business models, operations, and customer service. Since then, rapid innovation has promoted the leap-forward development of DT, continuously broadening its scope and application. Consequently, to help keep researchers up to date, a reexamination of the state of DT research is needed.

Second, existing reviews are insufficiently objective. Such studies are based on traditional survey methods and only account for a small portion of the literature (generally no more than 300 articles). They are mainly based on subjective analyses by experienced researchers in the field, which inevitably influences the interpretations. For example, providing an overview of current DT research, Vial (2019) proposed a theoretical framework for DT comprising eight factors; however, that study only subjectively considered 290 articles from among the thousands of papers on DT. While a degree of subjective opinion is inevitable, literature reviews based solely on subjective analysis may be limited by the author's time, energy, and understanding, and the selection of papers may be biased by the researcher's personal interests.

This study used bibliometric analysis methods (e.g., citation, co-citation, and main path analysis) to effectively and objectively sort and summarize the thousands of DT-related papers and analyze the citation network of DT literature. A total of 865 DT papers were ultimately collected and analyzed. We used the quantifiable advantages of bibliometric methods to overcome the limitations of subjective human judgment. Although subjective analysis is still needed to interpret the results of bibliometric analysis, this method can greatly reduce the influence of human factors, thus providing a more objective and accurate description of DT research. In this way, subjective and objective analysis can complement each other and improve the quality of the literature review.

This study aimed to delineate the knowledge flows of DT research; identify the important papers; graphically map the influential countries, institutions, and journals; and distinguish the research themes comprising the intellectual structure of DT. We hope to supplement the judgment of experienced researchers in the field through qualitative analysis, quantitative analysis, and the visualization of results to help both executives and researchers understand the evolution and research status of DT objectively and systematically. At the same time, this work can reveal future development trends in DT research.

2. Methodology

This study used a series of bibliometric and visualization techniques, such as citation analysis, co-citation analysis, and main path analysis, to provide a systematic, objective, and thorough review of DT research.

2.1. Citation/co-citation analysis

Citation analysis is a valuable method in bibliometrics. It can be used to identify widely cited works and authors in a specific field, quickly extract mainstream research in the field from a large amount of information, and, to some extent, reflect the evolution path and future development trends of the research (Chang 2004; Shiau and Dwivedi 2013).

Co-citation refers to two or more works being cited by other literature at the same time (Small 1973), and citation frequency is the co-citation intensity between two cited papers. There are two main types of co-citation analysis: document co-citation analysis and author co-citation analysis, which are widely used in bibliometric analysis (Chen et al. 2010a; Nerur et al. 2008). Papers containing the same citation often have similarities in terms of concepts, research methods, or research topics (Osareh 1996). Therefore, the co-citation clustering formed by co-citation analysis is helpful for defining the knowledge structure of a given field. The application of co-citation analysis continues to expand, and the amount of research in the field of information science is increasing rapidly as well. This study used CiteSpace software to perform cluster analysis on the cocited reference network of DT research and identify the knowledge structure of the current literature.

2.2. Social network analysis

Social network analysis (SNA) is a method based on relational data or network data that uses mathematical or computational models to analyze network structures to study relationships between social actors (Zhang 2010). It has the characteristics of intuition and visualization. A social network is a group of social participants connected by one or more types of relationships, which can include individuals, groups, organizations, emails, journal articles, or websites, among others (Zhang 2010). SNA analyzes the network status, resources, and mutual relationships among network participants and the influence of network structure on individuals. SNA is becoming increasingly popular among researchers in various fields, such as sociology, management, and economics (Wang et al. 2016).

The combination of bibliometrics and SNA technology is helpful for further understanding communication and exchange of ideas via citation and cointroduction. Using bibliometric methods, we established a knowledge network containing various types of information, such as papers, journals, authors, and countries. On this basis, we used SNA to better understand the relationships between participants (papers) and how the communication mode between papers affects the path of knowledge flow and knowledge structure formation in the DT field.

2.3. Main path analysis

Main path analysis is a powerful tool that can identify chains of significant links in an acyclic directed network, thereby extracting the skeleton of a large and complicated directed network (Liu and Kuan 2016). By simplifying the network, it reveals the important knowledge flows in the citation network and tracks the development path of the research field. Its advantage lies in considering the direct and indirect influence of the article simultaneously, emphasizing the connection between the citing and cited paper. Therefore, compared to the traditional "citation counting" method, which only considers direct influence, main path analysis reveals a more accurate path of knowledge transmission (Liu et al. 2013).

Determining the importance of each citation link in a network is key to correctly identifying the main path, which is usually measured by calculating the number of times a citation link has been traversed (Liu et al. 2013). Hummon and Doreian (1989) first defined main path analysis, calling the sequence of links and nodes in a network the "search path." They developed three methods of measuring traversal counts to identify the main path in a citation network: Search Path Link Count

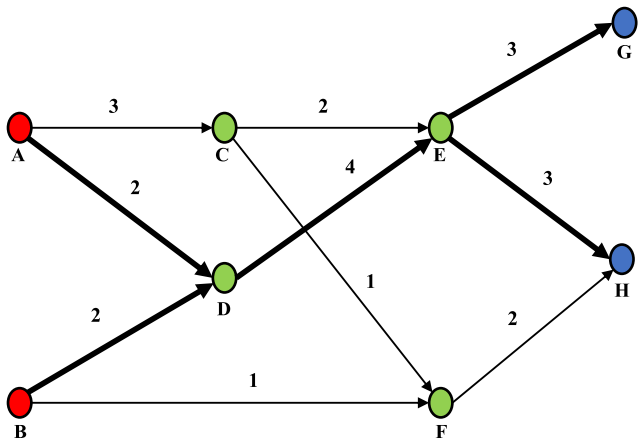

Fig. 1. A simple citation network with SPC values shown.

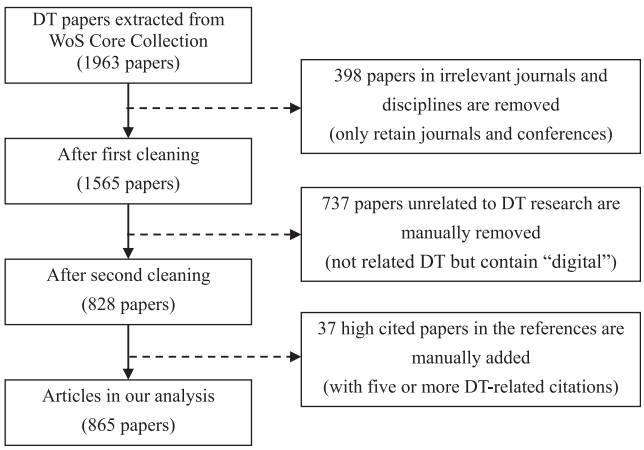

Fig. 2. Data collection process.

(SPLC), Search Path Node Pair (SPNP), Search Path Count (SPC), and Node Pair Projection Count (NPPC). Comparing different measurement traversal counting methods, Batagelj (2003) found that search path count (SPC) had particularly advantageous features. Therefore, this study chose SPC to measure traversal counts.

Fig. 1 briefly demonstrates the calculation process of SPC. In a citation network, "source" is the source of knowledge, which is cited but does not cite other nodes. Meanwhile, the end point of knowledge propagation is the "sink" node, which cites other nodes but is not cited (Liu and Lu 2012). There are two sources in Fig. 1 (A and B) and two sinks (G and H). There are a total of eight paths from all sources to all sinks. The SPC of each link is the total number of times the link is traversed. For example, the SPC value for link A-C is 3 because there are three paths through it: A-C-E-G, A-C-E-H, and A-C-F-H. The link B-F is traversed by only one path of B-F-H, so its SPC value is 1. The higher the SPC value, the more important the role of this link in knowledge transfer (Batagelj 2003). The main path method can be divided into "local" and "global." The local main path is the link with the largest traversal count from the current starting point, while the global main path is the path with the highest overall SPC value, which complements the local main path from the overall perspective (Liu and Lu 2012). As shown in the Fig. 1, the local main paths in the citation network are A-C-E-G and A-C-E-H, and the SPC values are both 8. The global main paths are A-D-E-G, A-D-E-H, B-D-E-G, and B-D-E-H, and the SPC values are all 9.

This method is widely used in current bibliometrics research (Liu and Kuan 2016), and its effectiveness has been verified in many previous studies. This study conducted global and local main path analysis to identify the major themes of DT research and describe how these themes have evolved over time.

2.4. Data collection

The Web of Science (WoS) Core Collection was used to obtain a representative data set of DT literature. Various keyword combinations were used to obtain an exhaustive list of DT papers from WoS. Based on reading abstracts as well as a few widely cited articles, and after conducting several tests, we designed the final search criteria using the following keyword combinations: "digital transformation" OR "digital strategy" OR "digital disruption" OR "digital business strategy." The earliest DT-related literature available in WoS appeared in 2000. We therefore collected DT papers published from early 2000 to 03/01/2020, a 20-year window.

The searches resulted in 1963 papers. Since many of the articles were not related to DT, we performed data cleansing. First, we successively refined the data set based on WoS document type and discipline category. A total of 224 papers were excluded; only journal and conference papers were retained. After document type was refined, we further excluded 13 obviously irrelevant disciplines (e.g., optics, chemistry), and 174 papers in those disciplines were excluded. This reduced the number of papers to 1565. Second, we read the abstracts (and full text if necessary) of all papers and manually removed 737 papers that contained the word "digital" in the text but did not investigate DT-related topics. After this further reduction, 828 papers remained.

In addition, we identified highly cited articles not indexed in the WoS database. Specifically, we used all articles cited by the 828 papers to create a citation network and selected articles with five or more DT-related citations in this network for the dataset. This resulted in 37 additional papers. The final dataset included 865 papers ranging from 2000 to 2020. Fig. 2 illustrates how we collected DT articles for this study.

3. Results

3.1. Main path analysis

To reveal how DT has developed over time, we used an SPC algorithm to identify the main path of the citation network comprising 865 articles. Based on these data, we conducted global and local main path analysis, and the results were consistent. Fig. 3 shows the global main path of DT research, drawn using the Pajek program package. In Fig. 3, arrows indicate the direction in which knowledge flows, and the thickness of the lines reflects the value of the SPC. The global main path of DT research consisted of 12 papers (see Table 1) published between 2010 and 2020. Combining these 12 articles, we roughly divided DT research into three stages: the embryonic stage (2000–2012), development stage (2013–2017), and thriving stage (2018–2020).

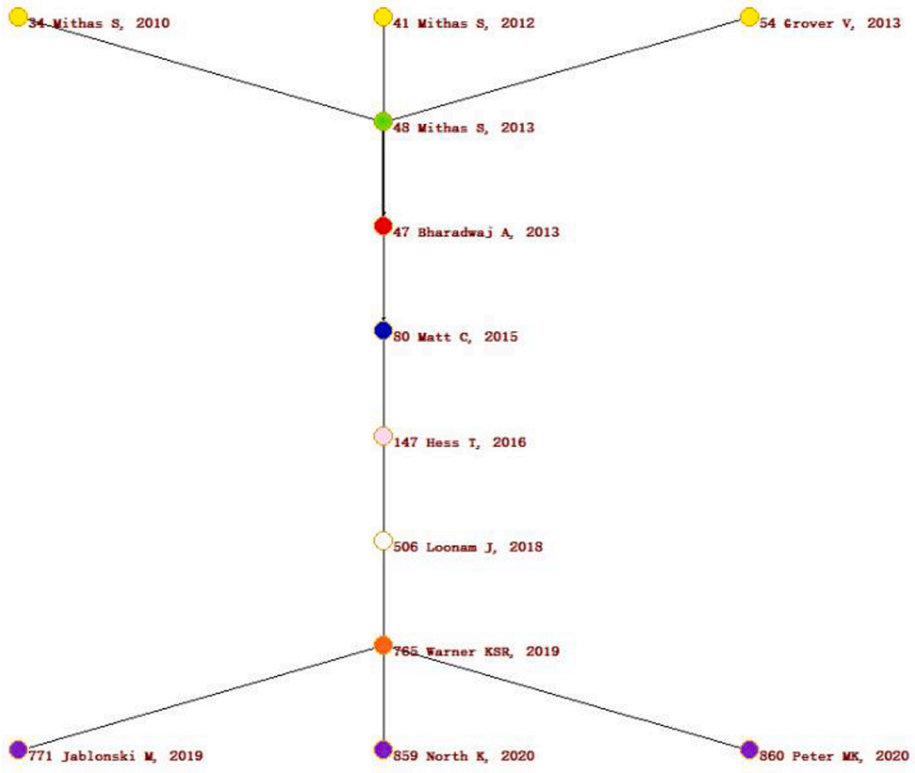

Fig. 3. Global main path of DT.

Table 1
Papers on global main path.

No	Author	Title	Journal
1	Mithas and Lucas (2010)	What is Your Digital Business Strategy?	IT Professional
2	Mithas et al. (2012)	Digital Business Strategies and the Duality of IT	IT Professional
3	Grover and Kohli (2013)	Revealing Your Hand: Caveats in Implementing Digital Business Strategy	MIS Quarterly
4	Mithas et al. (2013)	How a Firm's Competitive Environment and Digital Strategic Posture Influence Digital Business Strategy	MIS Quarterly
5	Bharadwaj et al. (2013)	Digital Business Strategy: Toward A Next Generation of Insights	MIS Quarterly
6	Matt et al. (2015)	Digital Transformation Strategies	Business & Information Systems Engineering
7	Hess et al. (2016)	Options for Formulating a Digital Transformation Strategy	MIS Quarterly Executive
8	Loonam et al. (2018)	Towards digital transformation: Lessonslearned from traditional organizations	Strategic Cgange-Briefings in Entrepreneurial Finance
9	Warner and Wäger (2018)	Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal	Long Range Planning
10	Jablonski and Jablonski (2019)	Social Factors as a Basic Driver of the Digitalization of the Business Models of RailwayCompanies	Sustainability
11	North et al. (2020)	Promoting digitally enabled growth in SMEs: a framework proposal	Journal of Enterprise Information Management
12	Peter et al. (2020)	Strategic action fields of digital transformation: An exploration of the strategic action fields of Swiss SMEs and large enterprises	Journal of Strategy and Management

3.1.1. Stage 1: Embryonic stage (2000–2012)

During this stage, DT articles were few and scattered. Though some DT papers were retrieved from WoS as early as 2000, they were of low influence and less cited due to fragmented or unstructured topics. Therefore, there was no DT literature during 2000–2009 in the global main path. As it was a new concept at this stage, researchers had not yet developed a unified understanding of DT's meaning and content. That said, with regard to DT, all of these papers involved the application of big data, cloud computing, IoT, and other digital technologies.

At the end of this stage, researchers began to study digital strategy. The first in the global main path was Mithas and Lucas (2010). Based on previous DT decentralization research, they started to study companies' digital business strategies (DBS). Proposing the concept of *ITracy digital literacy*, they noted that DBS requires synchronizing business strategy

with IT strategy. Here, IT needs to be governed effectively, and IT infrastructure needs to be rigorously managed. Along the path, Mithas et al. (2012) explored the effect of IT duality on a company's DBS and identified the difference between DBS and traditional business strategy. The concept of DBS was thus further clarified.

3.1.2. Stage 2: Development stage (2013–2017)

By this stage, researchers had more or less reached consensus on the research topics of DT, with mainstream research focusing on DBS and digital transformation strategy (DTS). Research on DBS had become relatively mature by 2013. Grover and Kohli (2013) proposed a visibility-value framework to explain how a company's DBS achieves balance between the visibility of its systems (e.g., software, processes, information) and the ability to extract appropriate value from such systems. Different from previous DBS research focused on optimizing a company's internal operations, Mithas et al. (2013) focused on the competitive environment outside the industry and the digital strategic positioning of a company. Meanwhile, Bharadwaj et al. (2013), aiming to establish a rigorous DBS research framework, integrated the existing strains of DBS research and identified four key research topics: scope, scale, speed, and sources of business value creation and capture. That work played an important role in linking past and present DBS research, highlighting directions for future research in the field.

Building on DBS research, Matt et al. (2015) proposed the concept of DTS and delineated the different meanings of IT strategy, DBS, and DTS. DBS refers to the future business opportunities and strategies required by a company that is partly or wholly based on digital technology; DTS, meanwhile, concerns how an enterprise can achieve these future states. Examining three German media companies that successfully achieved DT, the same team further posed 11 strategic questions and their possible answers. That work provided a reference for managers to conduct DTS while also offering guidance for future DTS research (Hess et al. 2016).

3.1.3. Stage 3: Thriving stage (2018–2020)

During stage 3, the number of DT papers had increased significantly, and researchers' attention had shifted from pure conceptualization to specific implementation problems, resulting in many different research directions. Loonam et al. (2018) reviewed 10 cases of successful DT in the literature and proposed a conceptual framework intended to help management understand the actions required to implement DT. Warner and Wäger (2018) considered the importance of dynamic-capability building in a company's DT, as well as the role and influence of agility. Jablonski and Jablonski (2019) used the analytic hierarchy process (AHP) to analyze the importance of different social factors affecting the DT of railway enterprises. Further expanding the research on the relationship between dynamic capability and DT, North et al. (2020) developed a digital maturity framework to assess the digital levels of small and medium-sized enterprises (SMEs). Meanwhile, Peter et al. (2020) pioneered a conceptual framework for DT based on strategic action field (SAF) theory to explore the drivers of DT in a company.

In conclusion, the global main path of DT research has shown a general trend of "dispersion–aggregation–dispersion." While the research directions were immature during the early period, after 2013, DT research started to take shape, focusing on DBS and DTS. Today, as new digital technologies are continually introduced, the research directions have become more refined, and interdisciplinary approaches have been enhanced. Based on this review, future research trends will likely include dynamic-capability building, enterprise agility, and DT among SMEs. The concept of DT has become clearer and more consistent, and the research has become increasingly mature.

3.2. Visualization analysis

3.2.1. Country and Institution visualization

Country and institution visualization can identify countries, regions, and institutions that play an important role in a research field. Fig. 4 presents the country visualization, while Table 2 specifies the top 10 influential countries or regions (both were created by using CiteSpace). The width of the circle indicates the importance of the node. The links between the nodes represent the relationships; the thicker the link, the stronger the connection.

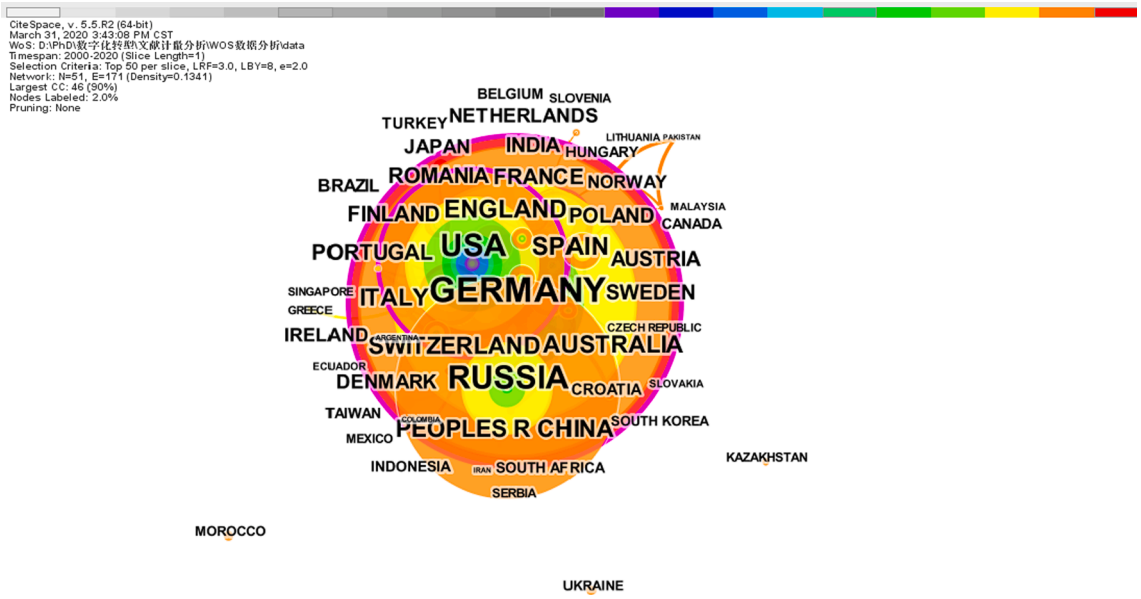

Fig. 4. Country visualization.

Table 2
Top 10 countries or regions based on frequency.

No	Countries or Regions	Frequency	No	Country	Frequency
1	Germany	168	6	Switzerland	33
2	Russia	114	7	People's Republic of China	31
3	USA	96	8	Italy	31
4	England	38	9	Australia	29
5	Spain	35	10	France	26

Fig. 4 shows that European and American countries have been the leaders in DT research. At the same time, there have been rapid increases in the volume, quality, and influence of Chinese DT research. The figure also reveals research relationships that have emerged among various other countries and regions.

Fig. 5 shows the most influential institutions in DT research while Table 3 lists the top 10 institutions. The most influential institutions were located in Russia, Germany, Italy, and Switzerland.

3.2.2. Cited Journal visualization

Cited journal visualization can be used to study the characteristics of academic journals related to DT research. Fig. 6 shows the 15 most influential journals based on co-citation frequency: *MIS Quarterly, Harvard Business Review, MIT Sloan Management Review, Organization Science, Strategic Management Journal, Information Systems Research, Digital Transformation, Academy of Management Review, Business & Information Systems Engineering, MIS Quarterly Executive, Thesis, Academy of Management Journal, Management Science, Journal of Strategic Information Systems, and Journal of Management.*

3.2.3. Cited reference visualization

Using the clustering analysis function in CiteSpace, as shown in Fig. 7, we identified seven focus areas of DT research: (1) digital business strategy, (2) strategic action field, (3) digital technology, (4) agile DT, (5) digital enterprise architecture, (6) DT of manufacturing (industry 4.0), and (7) DT of consulting service.

Fig. 5. Institution visualization.

Table 3
Top 15 institutions based on frequency.

No	Full Institution Names	Abbreviated Institution Names	Frequency	Country
1	Reutlingen University	Reutlingen Univ	15	Germany
2	Peter the Great St. Petersburg Polytechnic University	Peter Great St Petersburg Polytech Univ	13	Russia
3	Voronezh State University of Engineering Technology	Voronezh State Tech Univ	9	Russia
4	Munich University of Applied Sciences	Munich Univ Appl Sci	8	Germany
5	Polytechnic University of Milan	Politecn Milan	8	Italy
6	University of Rostock	Univ Rostock	8	Germany
7	Plekhanov Russian University of Economics	Plekhanov Russian Univ Econ	7	Russia
8	Russian Academy of Sciences	Russian Acad Sci	7	Russia
9	National University of Science and Technology MISIS	Natl Univ Sci & Technol MISIS	7	Russia
10	Swiss Federal Institute of Technology Switzerland	Swiss Fed Inst Technol	7	Switzerland

Fig. 6. Cited journal visualization.

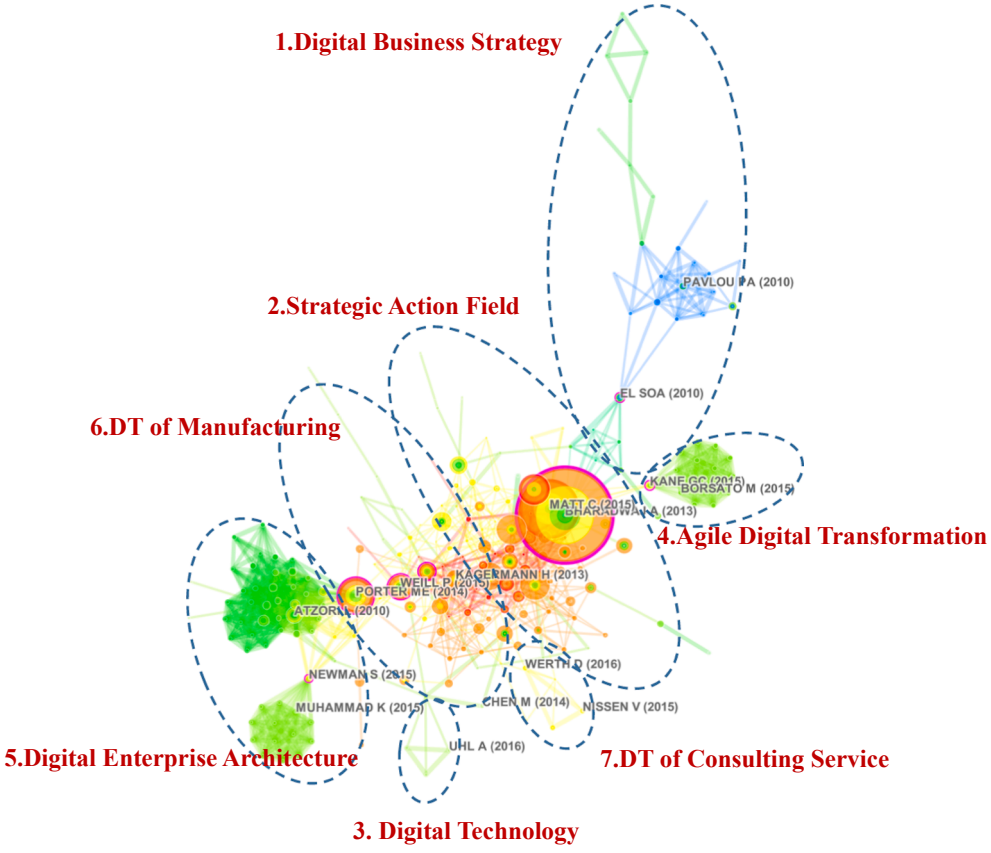

Fig. 7. The cited reference visualization.

Factor 1: Digital business strategy (DBS)

Over the past two decades, ongoing improvements in digital technologies related to information, communication, and connectivity have introduced new capabilities. To adapt to the new digital era, internal business structures, such as organizational business models and IT functions, have also changed. Driven by both internal and external factors, DBS came into being (Bharadwaj et al. 2013; Fitzgerald et al. 2013).

Digital technology has subverted traditional business strategies and processes, causing them to develop in the directions of modularity, cross-functionality, and globalization. Analyzing e-commerce in relation to retail from an international perspective, Zhu and Kraemer (2005) revealed the effects of technological capability on e-commerce. Mithas and Whitaker (2007) found that information intensity positively affected occupational decomposition; specifically, enterprises and managers need to consider the modularization of occupations when formulating global business processes. Investigating customer service performance among competitive North American insurance companies, Ray et al. (2005) found that different IT resources and capabilities affected customer service performance differently. Constructing a dynamic capability model, Banker et al. (2006) explained how information systems, including new information technologies and software, affected the manufacturing ability of enterprises and improved their performance. Kohli and Grover (2008) summarized the value, risk, and performance effect of IT investment in the context of new technology. Meanwhile, using the case of Kodak's failed DT, Lucas and Goh (2009) illustrated the disruptive challenge digital technology poses to enterprises' business models.

Facing complex situations involving increasing environmental turbulence and accelerated organizational change, digital technology has become an important means for enterprises to establish strategic advantages (Bharadwaj et al. 2013). Pavlou and Sawy (2006) showed that effective IT use can improve the dynamic capability of new product development and help enterprises establish competitive advantages in turbulent environments. That study further discussed how to build new competitive abilities by complementing organizations' dynamic and improvisational capabilities (Pavlou and El Sawy 2010). Proposing the concept of digital ecodynamics, El Sawy et al. (2010) explored the complexity and dynamic interactions of ecosystems composed of environmental turbulence, dynamic capabilities, and IT systems. Meyer et al. (2005), meanwhile, proposed a new method and theory to explore the dynamic process of nonlinear changes in the organizational field. Davis et al. (2009) aiming to clarify the different strategic positionings of mature and entrepreneurial organizations, developed a theory regarding the relationship among structure, performance, and dynamic environments.

The above mentioned studies promoted the convergence of IT strategy and business strategy, defined as DBS by Bharadwaj et al. (2013). That study integrated previous research perspectives, proposed a DBS research framework, and specified four key themes in DBS (i.e., the scope, scale, speed, and source of business value creation and acquisition). That paper is an important node in DT research. Subsequent studies conducted various investigations based on the four above-mentioned themes and made various improvements.

DBS upended the traditional islands of function and process, forming links across companies and supply chains. Taking logistics as an example, Rai et al. (2012) revealed the information flow process between enterprises with the support of IT and explored how IT can create relationship value in interenterprise relations. Mithas et al. (2013) examined the effect of external competitive environments on shaping the scope of DBS among enterprises (i.e., their degree of digital business participation). Carcary et al. (2016), meanwhile, suggested that a successful DT requires an enterprise to develop the organizational capacity needed to support digital technology and to strengthen its digital capacity and dynamic capacity building.

The scale of DBS is no longer limited to products and supply chains but is influenced by IT infrastructure, the network effects of multilateral platforms, information and data richness, and alliance partnerships (Bharadwaj et al. 2013). Doherty et al. (2016) established an IT maturity framework to test IT strategic planning abilities, achieve rapid and efficient IT architecture adjustment, and make DBS play the role of improving dynamic ability. Using data from a large bank, Setia et al. (2013) showed how information quality can improve an organization's business network to improve customer response abilities and expand the size of the enterprise's DBS.

Time plays an important role in digital business environments, reflected in new product releases, operational decision-making, supply chain choreography, new business network construction, and dynamic response capability (Bharadwaj et al. 2013). Rai et al. (2012) found that companies can optimize interenterprise supply chains and improve efficiency by strengthening interenterprise business and IT functions through partner networks. In recent years, due to the aggravation of environmental turbulence, enterprises and researchers have paid more attention to the role of an enterprise's dynamic capacity building in DBS speed. Based on the theory of disruptive innovation, Karimi and Walter (2015) found that dynamic responsiveness can improve an enterprise's ability to respond to digital disruption, build digital platforms, and accelerate DT. Meanwhile, Park and El Sawy (2013), from the perspective of digital ecodynamics, studied various configurations of IT systems, organizational dynamic capabilities, and environmental turbulence to help organizations choose the strategies that best suit their environments.

The effectiveness of DBS is mainly reflected in the methods and sources of value creation. Focusing on design capital and action, Woodard et al. (2013) explained how digital product design can contribute to creating and acquiring business value and how enterprises with strategic value advantages can stay ahead in new value creation cycles triggered by technology. Pagani (2013) also studied enterprises' coping strategies in such value creation cycles but proposed using a digital value network as the control point configuration, arguing that enterprises with many control points in the network have advantages in DBS-related dynamic execution and strategic value.

In addition to the four main aspects mentioned above (i.e., the scope, scale, speed, and source of business value creation and acquisition), some researchers have studied the risks of DBS (Carcary and Doherty 2016) and of business process models (Tomáková and Nisler 2017). The DBS research field has been constantly improved and refined, becoming a major area of DT research.

Factor 2: Strategic action field

DBS specifies the direction for enterprises' DT and helps them set forward-looking goals. Based on this, DTS is more focused on the specific processes and operations needed to realize DT. Entrepreneurs and researchers are increasingly exploring the actions needed to implement such strategies.

Business model evolution under strategic guidance is a prominent manifestation of the change in the value creation approach brought about by DT. DaSilva and Trkman (2014) redefined the business model concept in the context of DT, distinguishing it from "business strategy" and "business process". They noted that the business model takes into account both value acquisition and value creation, placing greater emphasis on the latter. Laudien and Daxbock (2016), Loebbecke and

Picot (2015) analyzed business model change from the perspectives of IoT and big data, respectively. With the support of such technologies, various new business models based on cooperation requests or ecosystem drivers have been formed (Ritala et al. 2014; Weill and Woerner 2015). Among them, digital platforms have demonstrated strong advantages in integrating innovation and value creation from different sources (Kenney and Zysman 2016; Parker and Van Alstyne 2014). With the ongoing DT of enterprises, how to build a business model with sustainable value creation has become a hot research topic (Warner and Wäger, 2018).

The digital-strategy implementation process integrates the concept of digital innovation. Hinings et al. (2018) described digital innovation as "the creation and application of innovative products and services." DT integrates the effects of various types of digital innovation, which is reflected in changes in value concepts, enterprise structure, and industry rules, and plays an important role in improving organizational agility and reshaping the innovation network (Lyytinen et al. 2016; Rigby et al. 2016).

As a process, DT is not accomplished overnight. At different levels of digital readiness and DT stages, enterprises need to adopt diverse digital technologies and business models, which determine whether DT will be successful (Carolis et al. 2017). Therefore, it is particularly important to correctly identify the digital maturity of an organization to make timely and reasonable adjustments to its strategy and internal structure.

The DT of an organization has a strong effect on the responsibilities of leaders, the organizational culture, and other aspects. The chief digital officer (CDO) is a new type of leader in this process. Singh et al. (2017) and Lee et al. (2014) analyzed the role of CDOs in management and the skills and abilities they need in terms of internal and external collaboration, traditional and big data application, and value effect. With the continuous development of global DT and the increasing volatility of competitive environments, the challenges faced by enterprises in DT are becoming prominent, specific, and complex. Yet, existing studies have not focused extensively on such dilemmas (Heavin and Power 2018). Therefore, how to address these specific obstacles should be further explored.

Factor 3: Digital technology

In recent years, new digital technologies have continuously emerged, constantly posing new challenges for enterprises and society and becoming important driving factors for DT. The five most representative technologies are mobile technology, cloud computing, big data, social media, and IoT (Spil et al. 2017). Armbrust et al. (2010) used data comparison to illustrate the differences between cloud computing and traditional computing, further clarify the cloud computing concept, and predict the related obstacles and future development directions for enterprises. Cloud computing and the IoT further promoted the development of big data technology. Examining the close relationships between these technologies and big data, Chen et al. (2014) described the big data value chain, including the four stages of data generation, acquisition, storage, and analysis, and introduced its application in fields such as enterprise management and medical systems. With the acceleration of organizational reform and changes in competitive environments, the application of a single technology can no longer meet the needs of enterprise transformation. Organizations are increasingly inclined to adopt various digital technologies to integrate technology and business in response to the challenges posed by digital strategic management (Uhl and Lars 2014).

Digital technology strongly affects not only enterprise development but also other areas of society, in which the role of education reform cannot be ignored. Keane et al. (2009) proposed an IT course for the new generation of IT professionals that emphasized experience. Ferreira et al. (2017) and Moreira et al. (2017) developed a DT course in the higher education stage that integrates new innovative technologies, such as mobile computing and social media, and supports high-level organizational DT of organizations.

The development of digital technology is constantly changing, and its effects on the DT of enterprises and society will continue to deepen. Therefore, research in this field will continue to update, expand, and refine.

Factor 4: Agile digital transformation

Agile DT, which has received considerable attention in recent years, is considered a new way to change enterprise value creation against the background of DT (Vial 2019). Noting that digitization is a dynamic process, Hirt and Willmott (2014) suggested that the "plug and play" of digital assets led to a disintegration of the value chain, which opened opportunities for focused, fast-growing competitors. As a result, enterprises developed a higher demand for keen insights and the ability to quickly adapt to change. Kane et al. (2015) suggested that agile DT is more important than digital technologies or skills, especially in the new context of agility, adaptation, and opportunity.

While earlier studies focused on the importance of agility, more recently, researchers have paid more attention to the concrete application of agility in DT. Suomalainen et al. (2015) found that in a turbulent business environment, the importance of continuous planning dramatically increases. With planning cycles getting shorter and organizations becoming more transparent, agility profoundly affects business continuity planning. Bondar et al. (2017a) studied the agile DT of enterprise architecture (EA). Taking highly agile collaborative engineering services in the global automotive supply chain as an example, that study explained how to guide EA development using the Zachman framework, providing ideas for solving the problems of EA change. Meanwhile, comparing various architectural frameworks, the Zachman framework was found to play an effective and crucial role in agile DT (Bondar et al. 2017b).

Factor 5: Digital enterprise architecture

EA is a set of principles, methods, or models used to design and implement organizational structure, business processes, information systems, and infrastructure (Lankhorst 2013). It pertains to the interrelationships between enterprise business processes and IT systems, and the proportions shared by different parts of the enterprise (Tamm et al. 2011). EA management helps enhance consistency between a business and IT to support goal achievement and management evolution (Buckl et al. 2009). In recent years, the rapid development of IT has led to subversive changes in enterprise management, and EA has attracted increasing attention in organizational DT. Buckl et al. (2010) argued that EA management is a necessary tool for adapting to volatile markets and seizing new opportunities. Aier et al. (2011) noted that enterprises change in response to a combination of top-down planned transformation and bottom-up evolution. Changes in business requirements require the reintegration of IT, while deepened customer interaction also has a huge effect on internal processes and people in enterprises (Bente et al. 2012). Accordingly, sound EA planning can effectively promote, control, and monitor changes in enterprise transformation. Based on this overview, EA research has gradually formed a collaborative, adaptive, and service-oriented trend and has been integrated into digital EA with the following characteristics.

Integration/Collaboration

Since new digital business modes change rapidly, EA needs to make timely adjustments, many elements of which are affected in varying degrees. Thus, how to coordinate various relationships becomes a difficult problem for enterprises (Jugel et al. 2015). Collaborative EA effectively combines a long-term-oriented top-down approach with a pragmatic bottom-up one, which provides innovative solutions to enterprises that are undergoing enterprise-wide change (Bente et al. 2012).

The development of collaborative EA is promoted by the IoT. As a digital technology that is creating a fully integrated Internet, the IoT subverts traditional business operation modes and fundamentally affects enterprises' digital strategies (Gubbi et al. 2013). The integration and collaboration of EA blur the lines between IT systems and reality; thus, organizations must reintegrate their IT systems to extend their previous EAs (Zimmermann et al. 2015). Spiess et al. (2009) proposed an architecture that integrates the IoT into enterprise services to adapt to changes in design and services brought about by IoT. Bente et al. (2012) introduced collaborative EA based on practice and expert opinion, and analyzed the limitations of its current application. Antunes et al. (2013) noted that EA management involves different elements and domains to coordinate business and information technologies. That study built a stakeholder requirements analysis model and reduced model consistency barriers for integrating multiple models. Jugel et al. (2015) developed a decision model for collaborative EA to analyze the process of collaborative decision-making among different stakeholders.

Adaptive/Agile

DT creates higher requirements regarding the agility and adaptability of enterprises. The continued adaptability of an enterprise greatly depends on its adaptive EA capabilities (Gill 2013). Based on agile, agent system, and service science, Gill (2013) established an adaptive enterprise service system (AESS) model that shifted attention from products to services. This shift in perspective is critical for building adaptive EA in the DT of complex enterprises. That study investigated cloud-enabled adaptive EA in the context of the Australian government and demonstrated the rationality of developing architecture using an agile EA approach (Gill et al. 2014).

Service orientation

DT involves shifting from a "product-centric" to a "customer-centric" strategy, and service-oriented EA has thus become a new trend. Investigating a financial services enterprise, Chen et al. (2010b) developed an IT-consistent enterprise system development framework (BITAM-SOA framework) that supports an enterprise-wide service-oriented system. Zimmermann et al. (2011) investigated the practical application of vendor platforms in service-oriented environments, studied the latest service-oriented frameworks and approaches, and developed an enterprise software architecture reference model to assess the architectural quality and maturity of service-oriented enterprise systems. Alwadain et al. (2013) analyzed and compared five widely used EA frameworks with the integration of service-oriented architecture (SOA), providing a reference for enterprises to choose an EA framework that meets their requirements and supports SOA.

Digital enterprise architecture

With the continuous enrichment of digital technology, enterprise DT is gradually maturing. Researchers started paying more attention to the convergence of the three trends (i.e., integration/collaboration, adaptive/agile and service orientation) in EA. Zimmermann et al. (2015) were the first to explore how to introduce a service-oriented integrated EA into an adaptive system, focusing on IoT and the DT of IT. Using a meta-modal approach, they integrated IoT objects, business categories, processes, applications, services, platforms, and infrastructure into a collaborative digital EA environment. Then, integration technologies such as semantic technology, Web services, cloud computing, and big data management were used to integrate service-oriented information systems and adaptive digital EA, establishing a new generation of adaptive and dynamic digital EA systems (Zimmermann et al. 2016a). Zimmermann et al. (2016b) investigated decision management in enterprises from multiple perspectives, especially decision support for the development and evolution of sustainable EA. Masuda et al. (2017a) focused on the DT of multinational corporate architectures. That study proposed an "adaptive integration EA framework" and, based on a global healthcare enterprise, verified the effectiveness of its realization of DT. It also discussed how to reduce the risks of DT architecture and provided suggestions for the development of DBS (Masuda et al. 2017b).

Research on the convergence of EA has developed gradually, while EA model maintenance, management processes, and risks continue to be further investigated.

Factor 6: DT of manufacturing

DT began in media and other industries but entered manufacturing relatively late. However, given the huge manufacturing industry system, the research has quickly formed a scale and continued to expand. The DT of manufacturing is closely related to the concept of Industry 4.0, which originated in Germany. At present, most researchers regard the two as equivalent—that is, Industry 4.0 is the DT of the manufacturing industry (Cozmiuc and Petrisor 2018; Fonseca 2018; Rajnai et al. 2018). This study adopted this view and included literature based on Industry 4.0 in the analysis of the DT of the manufacturing industry.

According to the characteristics of the manufacturing industry, researchers have studied various factors related to DT, such as digital-driven technology, EA, value innovation approaches, transformation strategies, and the effects of DT. Table 4 summarizes the five main

Table 4
Research content of DT of manufacturing industry.

Research Content	Content Description	Representative Literature
Digital Technologies	• Internet of Things (IoT) • Big Data (BD) • Cloud Computing (CC) • Predictive Analytics (PA) • Visual Computing	(Ardolino et al. 2018; Berman and Bell 2011; Brettel et al. 2014; Iansiti and Lakhani 2014; Oesterreich and Teuteberg 2016; Posada et al. 2015; Schuh et al. 2014)
Organizational Structure	• Enterprise Architecture (Cyber-Physical Systems architecture) • Leadership	(El Sawy et al. 2016; Fatorachian and Kazemi 2018; Lee et al. 2015; Monostori 2014; Monostori et al. 2016; Schuh et al. 2014)
Value Innovation Approach	• Value Proposition • Business Model • Enterprise / Industry Platforms	(Bogner et al. 2016; Brettel et al. 2014; Gawer and Cusumano 2014; Iansiti and Lakhani 2014; Moeuf et al. 2018; Muller et al. 2018; Oesterreich and Teuteberg 2016; Pritchett 2014; Sanchez 2017; Schmidt et al. 2016)
Digital Strategy	• DBS • DTS	(Hermann et al. 2016; Qin et al. 2016; Ross et al. 2017; Van Alstyne et al. 2016)
Digital Maturity	• Readiness Measurement Model • Digital Maturity Model • Digital Maturity Index	(Bogner et al. 2016; Gill and Boskirk, 2016; Lichtblau et al. 2015; Sanchez 2017; Schuh et al. 2017)

research areas. Researchers have identified key technology categories to promote the DT of manufacturing, the key success factors related to adopting new digital technologies, and methods for utilizing these technology resources. Some studies have focused on the transformation of the internal structure of enterprises represented by cyber-physical systems architecture, and explained the origin, driving factors, and future expectations. Others have studied new value-creation methods and approaches in the DT of manufacturing from different perspectives, and described the new business models and value propositions that enterprises develop to achieve transformation. Hermann et al. (2016) and others focused on the development of digital strategy. The above four aspects (i.e., digital-driven technology, EA, value innovation approaches, transformation strategies) not only involve the preparation stage or initial stage of enterprise DT but also run throughout the whole process of DT. To adjust them in time for rapid growth, entrepreneurs need to correctly assess the current and future stages of enterprise transformation. In addition to measuring the degree of digitalization of enterprises, researchers have also begun to focus on the effect of the DT of manufacturing, as well as the obstacles and risks encountered in the transformation of manufacturing enterprises.

Factor 7: DT of consulting service

The business consulting industry is mainly responsible for the management and operation of various projects, and it has played a significant role in promoting DT in different industries (Werth et al. 2016). However, in the early stages of DT, there were no studies of the DT of the consulting industry itself. Nissen et al. (2015) studied the development of the consulting market in Germany since the end of 2005. They explored the quality requirements, opportunities, and risks involved in the DT of business consulting from the customer's perspective and noted that consulting service virtualization is the main manifestation of the DT of consulting services. To help companies identify appropriate technologies and tools for the virtualization of consulting services, Nissen et al. (2018) proposed combining AHP and quality function expansion (QFD) to choose the best combination of technologies and tools.

Seifert and Nissen (2018a) analyzed the DT of a large IT and management consulting company in Germany. They found that DT affected not only the external client-facing process of the consulting firm but also its internal processes; they suggested building a digital platform to realize the virtualization and DT of internal processes. Although research on virtual consulting services is still in the early stages, the main themes and blind spots in the field have been summarized through literature review (Seifert and Nissen 2018b). Based on a three-year study, Nissen and Seifert (2018) presented core findings regarding the virtualization of consulting services, the current position of the German business consulting industry in the DT process, and future development in the field.

Others have made important contributions to the DT of consulting services. Werth et al. (2016) reviewed the digital potential of business consulting in the early stages and proposed a method to respond quickly—namely, an integrated sales and consulting platform called an electronic consulting store. This platform represented the first application of DT to consulting firms. It provided insights into the future role of consultants by observing the responses of stakeholders to the application of the platform. Greff et al. (2018) developed a digital-driven design model (=d-3 model), representing the start of digital reengineering. It revealed the digital potential of new technologies for the business consulting industry and the possibilities for future study.

3.3. DT research framework

Based on main path analysis and clustering analysis, DT research topics were divided into three levels: strategy level, operation level, and industry level (Fig. 8). The strategy level plays a leading role in DT research, which includes DBS and DTS. DBS research was the first to form a scale, and it has existed throughout the whole process of DT research, occupying an important position in the literature. With the deepening of research, more and more researchers have studied DT as a process, examining the driving factors, structural changes, changes in value creation, and the effect of DT. This led to research on DTS. Although DTS and DBS both pertain to enterprise DT, they have different emphases. DBS focuses on the goal of enterprise DT, while DTS pays more attention to the methods and processes used to achieve the goal.

Under the guidance of strategic DT research, researchers began to explore the concrete operations of DT. Early researchers focused on digital technologies such as cloud computing, big data, and IoT as the main driving factors of DT, which brought about disruptions and strategic responses by organizations. Some studies focused on changes in value creation methods, based on enterprise agility. To adapt to changes in enterprises' value creation modes, it is necessary for EA to be adjusted, which is crucial to the success of DT. These two topics related to concrete operations both concerns improving enterprises' dynamic capabilities.

With DT research becoming more refined, it has come to encompass all industries. The DT of manufacturing, called Industry 4.0, and the DT of consulting services are typical fields. As an important DT topic, manufacturing has been widely studied over the last decade. While research on the DT of consulting services began later, it is involved in the DT processes of many other industries; it thus plays an integral role and has formed a scale.

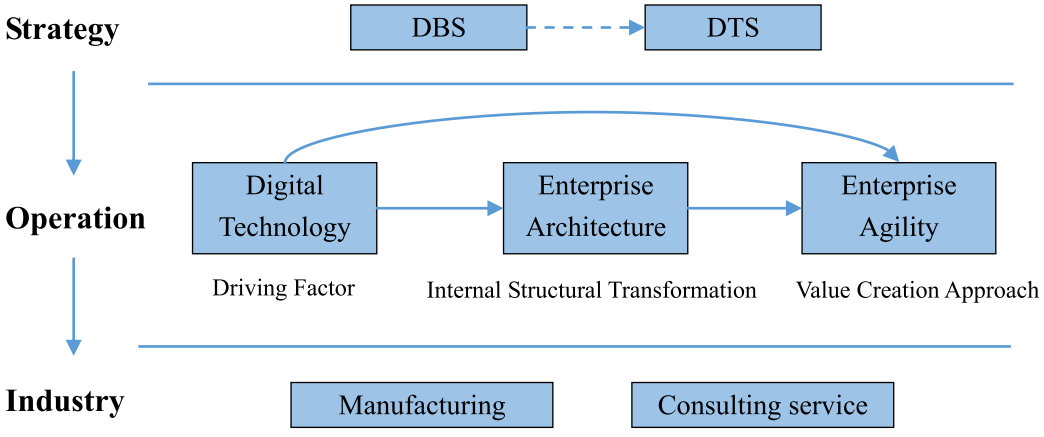

Fig. 8. Research framework of DT.

Table 5
DT future research directions.

Research levels	Research Themes	Research Contents	Contemporary Trends	Research Thrust
Strategy level	Digital business strategy (DBS)	Objectives of DT • Scope • Scale • Speed • Sources of business value creation and capture	The focus shifts from conceptual papers to empirical questions • Business process management (BPM) • Maturity (readiness) of the enterprise DT • Resistance to the implementation of DT strategy • The organizational and social impact of DT strategy implementation • The impact of DT on strategic management theory	Propose a DT framework based on the Strategic Action Field (SAF) theory
	Digital transformation strategy (DTS)	Specific methods and processes to achieve the objectives		
Operation level	Driving Factor	Digital Technology • Mobile technology • Cloud computing • Big data • Social media • Internet of Things	• A variety of digital technology integration applications • The application of blockchain, 5G and other new digital technologies	Organization dynamic capacity building
	Value Creation Approach	• Value propositions • Business model • Enterprise agility	• Value networks • Adaptive agile organizational design	
	Internal Structural Transformation	• Enterprise architecture (EA) • Organizational structure	• Risk control in the DT of EA • Organizational culture • Leadership • Employee roles and skills	
Industry level	Manufacturing	The concrete implementation of DT strategy and application	• Differences in the choice and adaptability of digital technology among various industries • Sustainability of economy, ecology and society in the DT of industry • Advantages and obstacles for SME to realize DT • Cross-industry cooperation	The urgent need for industry ecosystem construction
	Consulting Service			

4. Future research directions

In this section, we will discuss future directions in DT research based on the above-mentioned framework. Future research directions of digital transformation are summarized in Table 5.

4.1. Strategy level

Fundamentally speaking, DT is not about technology but about strategy (Warner and Wäger, 2018). Strategy indicates the direction for an organization, industry, and country to conduct DT. Our analysis showed that previous studies have introduced the concepts of DBS and DTS in greater detail. Although both involve digital strategies, the connotations are different. DBS is an overall strategy that integrates IT strategy and business strategy and specifies the general direction for organizational development (Bharadwaj et al. 2013; Matt et al. 2015). Most previous studies have described the nature and role of DBS in terms of four key attributes: scope, scale, speed, and the source of creating and capturing business value (Bharadwaj et al. 2013). DBS provides goals but does not specify how to achieve them. DTS solves this problem quite well. On the basis of DBS, DTS refines the strategy step by step according to priorities in four different dimensions: the use of technology, changes in value creation, structural changes, and financial aspects (Bharadwaj et al. 2013; Hess et al. 2016). DTS provides more practical guidance for the implementation of the DT of enterprises.

Despite considerable progress in the field, there is room for improvement in DT research. With the rapid growth of DT research and the continuous deepening of DT practice, conceptual papers focused only on the concepts of digital strategy will likely diminish while more attention will be paid to substantive and empirical issues.

In the strategic practice of enterprise DT, various new problems will arise. The first concerns business process management (BPM). Although BPM is not a new topic, in the DT context, BPM logic and dynamic management approaches that match digital strategy still need to be established. The second issue concerns the maturity (readiness) of enterprise DT. Accurate assessment of the current digital maturity stage of an organization is a prerequisite for the timely adaptive adjustment of a strategy. Some researchers have developed maturity models (Büyüközkan and Güler, 2020) intended to assess digital maturity levels. However, at present, there is no unified standard for the definition of the digital stage (North et al. 2020), and the digital capabilities required for each stage need to be further elaborated. The third issue concerns resistance to DTS implementation. The process of DT can be difficult. Organizations face many unpredictable obstacles in the process of strategy implementation. By analyzing these obstacles and methods for overcoming them, researchers can provide advice for latecomers. The last question concerns the effect of DT on strategic management theory. Strategic management theories provide guidance for the formulation of digital strategies. At the same time, the rapid development of digitalization poses new challenges to existing strategic management theories, which in turn promote innovation in strategic management theories.

4.2. Operation level

Digital technology is always the driving force of DT. Over the past 20 years, IS researchers have studied the role of digital technology in enterprise strategy (Bharadwaj et al. 2013; Hess et al. 2016) and business model innovation (Martín-Peña et al. 2018; Wan et al. 2017). As digital innovation technologies continue to emerge, the research content will be constantly updated and will pay increasing attention to the integration of various DT-related technologies. In addition, we found that many existing studies are related to SMACIT, while few have involved blockchain, 5G, and other digital technologies, which require further research in the future.

Technological innovation brings about changes in value creation methods. The research in this field has attracted wide attention, especially with regard to fierce competitive environments, where enterprise agility is particularly important (Gerster et al. 2020). Some researchers have investigated the establishment of agility in the development of information systems; however, the understanding of this field remains insufficient. Against the background of DT, value innovation will generate many new research topics. For example, how should an

enterprise choose a new business model that is suitable for its own transformation? How can the agile organizational design form be expanded to adapt to the expanding scale and changing needs of enterprises that have conducted DT?

Changes in value innovation require adaptive changes to the internal structures of enterprises. Researchers have studied EA from multiple perspectives, including adaptability, service orientation, and decision-support analysis. Future work should focus on risk control in the DT of EA. A number of papers have focused on IT system architecture, but few have studied organizational structure change. Otherwise, organizational culture, leaders, staff roles, and skills will change in the process of DT. Various new research questions are worth exploring. For example, how does an organization maintain relationships among virtual team members? To what extent does organizational culture affect the choice and acceptance of digital technology? What is the effect of leadership on an organization's DT?

Overall, the specific operation process of DT emphasizes the dynamicity of an organization, the influence of which is reflected in all aspects. How can we better understand performance management in a dynamic environment? What is the effect of enterprise dynamic capability on the effective implementation of new digital technologies? How does DT drive organizations to build the necessary dynamic capabilities?

4.3. Industry level

Industries and academia have both paid a great deal of attention to the DT of the manufacturing industry. Disruptive digital manufacturing technologies bring about innovations in production and management modes and promote the structural transformation of supply chain management and configuration (Martín-Peña et al. 2018). Given the characteristics of the manufacturing industry, researchers have mostly used case analyses to investigate its business model and the economic and management effects of DT. In addition, the development of sustainable industry and operation engineering in the context of DT has also attracted great attention in the field, including lean manufacturing in Industry 4.0, big data-driven and smart communications, safety and security, artificial intelligence for sustainability, the circular economy in a digital environment, business intelligence and virtual reality, etc. (Tseng et al. 2021).

Despite such work, many issues still require further study. For example, what are the differences in the choice and adaptability of digital technology among different manufacturing industries? How can economy, ecology, and society be sustainability maintained in the DT of the manufacturing industry? How can industrial value networks be used to realize customer integration in the supply chain? What are the advantages and obstacles for manufacturing SMEs in realizing DT?

The customer-centric concept of DT has caused the DT of the service industries (e.g., healthcare, education, financial services) to become another major research trend. With the innovation and development of service models in various industries, the research fields will be further enriched. Aside from manufacturing and service industries mentioned above, the role of DT in promoting the construction of industry ecosystems and cross-industry cooperation still has considerable room for further research.

5. Conclusion

Over the past 20 years, DT research has accumulated a wealth of diverse findings. In recent years, the rapid expansion of the DT field has led to a sharp increase in the number and types of studies, yet there is still a lack of a comprehensive review. In this study, bibliometrics was used to overcome the problem of dealing with a large amount of data. By analyzing 865 papers collected from the WoS database from 2000 to 2020, we systematically reviewed DT and explored knowledge structure of DT research. Based on the citation data of these papers, we used main path analysis to trace the knowledge evolution of DT papers and identified the research themes of DT research by clustering the co-citation data.

5.1. Contributions to the DT literature

Our review contributes to the DT literature in several ways (See Table 6). First, our systematic review employs multiple bibliometric methods to analyze multiple research fields, and thus provides a holistic view of the DT research. Different from past studies, which have predominantly focused a specific topic in digital transformation, such as digital platform, digital supply chain, and DT business model (Büyüközkan and Göçer 2018; Cortellazzo et al. 2019; Martín-Peña et al. 2018; Mukhopadhyay and Bouwman 2019), this study is one of the first to use the bibliometric analysis to multiple research fields of the DT research including strategy, management, innovation, and informatics, thus our systematic review provides can a holistic view on knowledge structure of the DT research.

Second, the study makes use of the advantages of quantification and objectivity of bibliometric analysis to reduce the potential bias caused by subjectivity, which could supplement and validate the intuitive conclusions of experts in the DT research. Existing DT reviews only account for a small portion of the literature (generally no more than 300 articles) and are mainly based on subjective analysis of experienced researchers in this field (Lock 2019; Vial 2019; Wan et al. 2017). In contrast, this study collects 865 DT articles and conducts a quantitative analysis by using the bibliometrics method. We analyze the knowledge structure of the most influential countries, institutions, and journals in DT research, determine the main research themes, and discuss the future research directions. In this way, combination of subjective and objective analysis can improve the quality of the literature review.

Third, the study uncovers the historical evolution process of DT research, and identifies the influential papers in its evolution process using main path analysis. To our knowledge, no prior research on the DT has used the main-path analysis to conduct the DT evolution process analysis. Our main path analysis reveals three development stages of the

Table 6
An overview of potential contributions.

Contributions	Current state of relevant literature
Provide a systematic review of DT research across multiple fields of strategy, management, innovation, and informatics by comprehensively searching and analyzing through bibliometric analysis.	Existing DT literature reviews have mostly focused on specific topics based on traditional survey methods (Büyüközkan and Göçer 2018; Cortellazzo et al. 2019; Martín-Peña et al. 2018; Mukhopadhyay and Bouwman 2019), making it difficult to provide a comprehensive and systematic view.
Reduce potential biases caused by subjectivity making use of quantitative analysis of 865 DT papers, and supplement and verified the subjective judgements of experts in the field.	Previous literature is mainly based on the subjective analysis of experienced researchers in this field and only account for a small portion of the literature (generally no more than 300 articles) (Lock 2019; Vial 2019; Wan et al. 2017), which inevitably affects the interpretation and is insufficiently objective.
Enhance our theoretical understanding of DT evolution process by figuring the development stage of DT research, and identify the influential papers in its evolution process using the main-path analysis.	No prior research on the DT has used main-path analysis to conduct DT evolution process analysis.
Use the clustering analysis function to identify seven major knowledge groups of the DT research, and structure the seven knowledge groups into three levels.	There is scant research describing a systematic research framework. Some existing DT literature reviews employ a preset subjective framework to structure the related research themes for specific topics (Büyüközkan and Göçer 2018; Pihir et al. 2019).

DT research: the embryonic stage, the development stage, and the thriving stage, and the global main path of DT research has shown a general trend of "dispersion–aggregation–dispersion". This finding extends past literature reviews on digital transformation from a cross-sectional perspective to an evolutionary perspective, which can provide insights for future studies.

Finally, different from previous reviews on digital transformation that employ a preset subjective framework to structure the related research themes (Büyüközkan and Göçer 2018; Pihir et al. 2019), we use the clustering analysis function in CiteSpace to identify seven major knowledge groups of the DT research (digital business strategy, strategic action field, digital technology, agile DT, digital enterprise architecture, DT of manufacturing, and DT of consulting service), and structure the seven knowledge groups into three levels: the strategy level, the operation level, and the industry level. Our framework will help researchers gain an in depth understanding of the current status of the DT research field.

5.2. Practical implications

The implication for practice of this research is embodied in proposing a research framework to guide companies on how to carry out DT in practice. The research framework constructed in this study not only brings researchers a new perspective, but also provides a navigational tool for practitioners when initiating digital strategy and implementing digital transformation path. First, the most critical and most concerned issue for firms that are preparing for DT is to formulate the right and appropriate digital strategy. There are two similar constructs in the strategy level. Through content analysis, we can see that there are differences between DBS and DTS in terms of objectives, content and functions. DBS is more inclined to the macro goals, while DTS focuses on the specific DT implementation process. Therefore, when formulating digital strategies, enterprises should generally follow the sequence of making DBS first and then transition to DTS gradually. Second, firms should choose the digital technology combination that is suitable for their own development under the guidance of DBS and DTS. Different digital technologies and technology combinations have diverse effects on the DT of enterprises. Digital technology will change business processes and promote the transformation of internal structure and value creation approaches of enterprises. Under the dual effects of external technology introduction and internal structure transformation, the enterprise's agility and dynamic capability are continuously improved. Third, in the specific practice of enterprise DT, it is also necessary to evaluate and adjust the enterprise DT strategy in a timely manner according to the implementation status and specific digital technologies. Therefore, the research framework of DT provides references for practitioners to understand DT, formulate DT strategy, select digital technology and value creation approaches, and develop digital ability.

In sum, this study comprehensively reviewed DT research by combining main path analysis and visualization analysis. It confirmed previous conclusions and provided new information. We hope this review will provide researchers and practitioners with a new perspective to better understand the current situation and future development trend of DT research.

5.3. Limitations

This study has some limitations. First, the WoS Core Collection was used as the data source. It covers, but is not limited to, all top journals and conferences of management and operation manage. However, due to retrieval conditions and data source limitations, we cannot guarantee coverage of all DT-related publications. Second, we selected two data types: journal articles and conference papers. Therefore, perspectives found in books or other types of publications may have been overlooked. Since most chapters containing valuable opinions are published in journals, we do not think this omission had a significant effect on the analysis. Third, we specified seven topics in DT research based on cluster analysis, yet some meaningful topics were no doubt not covered in this study. Finally, it is impossible to completely eliminate human subjectivity in scientific research, and our bibliometric analysis method could not be completely objective. While it is still necessary to interpret the statistical data manually to make the results more meaningful, our method greatly reduced the influence of subjective factors.

CRediT authorship contribution statement

Xiaoteng Zhu: Methodology, Validation, Visualization, Writing – original draft. **Shilun Ge:** Resources, Methodology, Supervision. **Nianxin Wang:** Conceptualization, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank the senior editor and anonymous reviewers for their help and support during the review process. This research is supported by National Science Foundation of China (grant number: 71971101 and 71972090), and the Key Project of Philosophy and Social Science Research in Colleges and Universities of Jiangsu Province (grant number: 2019SJZDA032).

References

Accenture (2019). "Accenture-China-Digital-Transformation-Index-2019," Accenture.
Aier, S., Buckl, S., Gleichauf, B., Matthes, F., & Winter, R. (2011). "Towards a More Integrated Ea Planning: Linking Transformation Planning with Evolutionary Change," *Enterprise Modelling & Information Systems Architectures: International Workshop on Enterprise Modelling & Information Systems Architectures*.
Alwadain, A., Fielt, E., Korthaus, A., & Rosemann, M. (2013). A Comparative analysis of the integration of Soa elements in widely-used enterprise architecture frameworks. *International Journal of Intelligent Information Technologies, 9*(2), 54–70.
Antunes, G., Bakhshandeh, M., Mayer, R., Borbinha, J., & Caetano, A. (2013). Using ontologies for enterprise architecture analysis. *Enterprise Distributed Object Computing*, 361–368.
Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G., & Ruggeri, C. (2018). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research, 56*(6), 2116–2132.
Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., … Zaharia, M. (2010). A view of cloud computing. *Communications of the Acm, 53*(4), 50–58.
Büyüközkan, G., & Göçer, F. (2018). Digital supply chain: literature review and a proposed framework for future research. *Computers in Industry, 97*, 157–177.
Büyüközkan, G., & Güler, M. (2020). Analysis of companies' digital maturity by hesitant fuzzy linguistic Mcdm methods. *Journal of Intelligent & Fuzzy Systems, 38*(1), 1119–1132.
Banker, R. D., Bardhan, I. R., Chang, H. H., & Lin, S. (2006). Plant information systems, manufacturing capabilities, and plant performance. *Mis Quarterly, 30*(2), 315–337.
Batagelj, V. 2003. "Efficient Algorithms for Citation Network Analysis," *Preprint Series* (41).
Bente, S., Bombosch, U., and Langade, S. 2012. "Collaborative Enterprise Architecture," *Collaborative Enterprise Architecture*).
Berman, S. J., & Bell, R. 2011. "Digital Transformation: Creating New Business Models Where Digital Meets Physical," *IBM Institute for Business Value*), pp. 1-17.
Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. V. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly, 37*(2), 471–482.
Bob Parker, S. F. 2019. "Idc Futurescape: Worldwide Digital Transformation 2020 Predictions," IDC FutureScape.
Bogner, E., Voelklein, T., Schroedel, O., & Franke, J. (2016). Study Based Analysis on the Current Digitalization Degree in the Manufacturing Industry in Germany. In E. Westkamper, & T. Bauernhansl (Eds.), *Factories of the Future in the Digital Environment* (pp. 14–19). Amsterdam: Elsevier Science Bv.
Bondar, S., Hsu, J. C., Pfouga, A., & Stjepandic, J. (2017). Zachman Framework in the Agile Digital Transformation. In C. H. Chen, A. C. Trappey, M. Peruzzini, J. Stjepandic, & N. Wognum (Eds.), *Transdisciplinary Engineering: A Paradigm Shift* (pp. 67–74). Amsterdam: Ios Press.
Bondar, S., Hsu, J. C., Pfouga, A., & Stjepandić, J. (2017). Agile digital transformation of system-of-systems architecture models using Zachman framework. *Journal of Industrial Information Integration, 7*, 33–43.
Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2014). How virtualization, decentralization and network building change the manufacturing landscape: an

industry 4.0 perspective. *World Academy of Science, Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 8*(1), 37–44.
Buckl, S., Matthes, F., Schulz, C., and Schweda, C. M. 2010. "Exemplifying a Framework for Interrelating Enterprise Architecture Concerns," in: M.A. Sicilia, C. Kop and F. Sartori (eds.). *Ontology, Conceptualization and Epistemology for Information Systems, Software Engineering and Service Science,* Berlin: Springer-Verlag Berlin, pp. 33-46.
Buckl, S., Matthes, F., and Schweda, C. M. 2009. "Classifying Enterprise Architecture Analysis Approaches," in: R. Poler, M. VanSinderen and R. Sanchis (eds.). *Enterprise Interoperability, Proceedings,* Berlin: Springer-Verlag Berlin, pp. 66-79.
Carcary, M., and Doherty, E. 2016. "'The Digital Wild West': Managing the Risks of Digital Disruption," *European Conference on Information Systems Management*.
Carcary, M., Doherty, E., and Conway, G. 2016. *A Dynamic Capability Approach to Digital Transformation: A Focus on Key Foundational Themes*. Nr Reading: Acad Conferences Ltd.
Carolis, A., De, Macchi, M., Negri, E., and Terzi, S. 2017. A Maturity model for assessing the digital readiness of manufacturing companies, *IFIP International Conference on Advances in Production Management Systems (APMS)*, Hamburg, Germany: Springer International Publishing, pp. 13-20.
Chang, C.-M. (2004). Distinct journal preference of successful Ec researchers: a citation analysis. *Electronic Commerce Studies, 2*(1), 1–18.
Chen, C., Ibekwe-Sanjuan, F., & Hou, J. (2010). The structure and dynamics of co-citation clusters: a multiple-perspective co-citation analysis. *Journal of the American Society for Information Science and Technology, 61*, 1386–1409.
Chen, H. M., Kazman, R., & Perry, O. (2010). From software architecture analysis to service engineering: An empirical study of methodology development for enterprise Soa implementation. *IEEE Transactions on Services Computing, 3*(2), 145–160.
Chen, M., Mao, S. W., & Liu, Y. H. (2014). Big data: A survey. *Mobile Networks & Applications, 19*(2), 171–209.
Cortellazzo, Laura, Bruni, Elena, & Zampieri, Rita (2019). "The role of leadership in a digitalized world: A review. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.01938
Cozmiuc, D., & Petrisor, I. (2018). Industrie 4.0 by siemens: Steps made next. *Journal of Cases on Information Technology, 20*(1), 31–45.
DaSilva, C. M., & Trkman, P. (2014). Business model: What it is and what it is not. *Long Range Planning, 47*(6), 379–389.
Davis, J., Eisenhardt, K., and Bingham, C. 2009. "Optimal Structure, Market Dynamism, and the Strategy of Simple Rules," *Jason Davis* (54).
Doherty, E., Carcary, M., & Conway, G. (2016). *Development of an It Strategic Planning Capability for the Digital Age*. Nr Reading: Acad Conferences Ltd.
El Sawy, O. A., Kraemmergaard, P., Amsinck, H., and Vinther, A. L. 2016. "How Lego Built the Foundations and Enterprise Capabilities for Digital Leadership. *Mis Quarterly Executive* (15:2), pp. 141-166.
El Sawy, O. A., Malhotra, A., Park, Y., & Pavlou, P. A. (2010). Seeking the configurations of digital ecodynamics: It takes three to tango. *Information Systems Research, 21*(4), 835–848.
Fatorachian, H., & Kazemi, H. (2018). A critical investigation of industry 4.0 in manufacturing: theoretical operationalisation framework. *Production Planning & Control, 29*(8), 633–644.
Ferreira, M.J., Moreira, F., Seruca, I., 2017. Digital organization – a new challenge in the information systems curriculum. International Technology, Education & Development Conference.
Fitzgerald, M., Kruschwitz, N., Bonnet, D., Welch, M., 2013. Embracing digital technology: a new strategic imperative. MIT sloan management review (55:1).
Fonseca, L. M. (2018). Industry 4.0 and the digital society: concepts, dimensions and envisioned benefits. *Proceedings of the International Conference on Business Excellence, 12*(1), 386–397.
Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation. *Journal of Product Innovation Management, 31*(3), 417–433.
Gerster, D., Dremel, C., Brenner, W., & Kelker, P. (2020). How enterprises adopt agile forms of organizational design: A multiple-case study. *Data Base for Advances in Information Systems, 51*(1), 84–103.
Gill, A. Q. (2013). Towards the Development of an Adaptive Enterprise Service System Model. *Americas conference on information systems*.
Gill, A. Q., Smith, S., Beydoun, G., & Sugumaran, V. (2014). Agile enterprise architecture: a case of a cloud technology-enabled government enterprise transformation. *pacific Asia Conference on Information Systems*, 1–10.
Gill, M., & Van Boskirk, S. (2016). Url: The Digital Maturity Model 4.0./Benchmarks: Digital Business Transformation Playbook, 2016," *URL: https://forrester. nitro-digital. com/pdf/Forrester-s* (20).
Greff, T., Neu, C., Johann, D., & Werth, D. 2018. Digitization driven design - a guideline to initialize digital business model creation. In B. Shishkov (ed.). *Business Modeling and Software Design, Bmsd 2018*, Berlin: Springer-Verlag Berlin, pp. 308-318.
Grover, V., & Kohli, R. (2013). Revealing your hand: Caveats in implementing digital business strategy. *Mis Quarterly, 37*(2), 655–662.
Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of things (Iot): A Vision, architectural elements, and future directions. *Future Generation Computer Systems-the International Journal of Escience, 29*(7), 1645–1660.
Heavin, C., & Power, D. J. (2018). Challenges for digital transformation – towards a conceptual decision support guide for managers. *Journal of Decision Systems, 27*, 38–45.
Henriette, E., Feki, M., & Boughzala, I. 2015. The shape of digital transformation: A systematic literature review. *Mediterranean Conference on Information Systems*.
Hermann, M., Pentek, T., & Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. In *Hawaii International Conference on System Sciences* (pp. 3928–3937).
Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive, 15*(2), 123–139.
Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization, 28*(1), 52–61.
Hirt, M., & Willmott, P. (2014). Strategic principles for competing in the digital age. *McKinsey Quarterly, 5*(1), 1–13.
Hummon, N., & Doreian, P. (1989). Connectivity in a citation network: The development of DNA theory. *Social Networks - SOC NETWORKS, 11*, 39–63.
Iansiti, M., & Lakhani, K. R. (2014). Digital ubiquity. *Harvard Business Review, 92*(11), 90–99.
Jablonski, M., & Jablonski, A. (2019). Social factors as a basic driver of the digitalization of the business models of railway companies. *Sustainability, 11:12*, 29.
Jugel, D., Schweda, C. M., and Zimmermann, A. (2015). Modeling decisions for collaborative enterprise architecture engineering. In: A. Persson and J. Stirna (eds.). Advanced Information Systems Engineering Workshops, Caise 2015, Berlin: Springer-Verlag Berlin, pp. 351-362.
Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2015). Strategy, not technology, drives digital transformation. *Mit Sloan Management Review & Deloitte, 27*.
Karimi, J., & Walter, Z. (2015). The role of dynamic capabilities in responding to digital disruption: A factor-based study of the newspaper industry. *Journal of Management Information Systems, 32*(1), 39–81.
Keane, L. B., Patten, K. P., Brookshire, R. G., Cardon, P. W., and Norris, D. 2009. Toward developing an experiential learning curriculum model in information technology. Americas Conference on Information Systems.
Kenney, M., & Zysman, J. (2016). The rise of the platform economy. *Issues in Science and Technology, 32*, 61–69.
Kohli, R., & Grover, V. (2008). Business value of it: An essay on expanding research directions to keep up with the times. *Journal of the Association for Information Systems, 9*(1), 23–39.
Kutnjak, A., Pihiri, I., & Tomičić Furjan, M. 2019. *Digital Transformation Case Studies across Industries – Literature Review*.
Lankhorst, M. 2013. "Enterprise Architecture at Work - Enterprise Modelling, Communication and Analysis - Second Edition." Springer, pp. 191-196.
Laudien, S. M., & Daxbock, B. (2016). The influence of the industrial internet of things on business model design: A qualitative-empirical analysis. *International Journal of Innovation Management, 20:8*, 28.
Lee, J., Bagheri, B., & Hung-An, K. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters, 3*, 18–23.
Lee, Y., Madnick, S., Wang, R., Wang, F., & Zhang, H. Y. (2014). A cubic framework for the chief data officer: Succeeding in a world of big data. *Mis Quarterly Executive, 13*(1), 1–13.
Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., … Schröter, M. (2015). *Impuls-Industrie 4.0-Readiness*. Aachen-Köln): Impuls-Stiftung des VDMA.
Liu, J., & Lu, L. (2012). An integrated approach for main path analysis: Development of the Hirsch index as an example. *Journal of the American Society for Information Science and Technology, 63*, 528–542.
Liu, J. S., & Kuan, C. H. (2016). A new approach for main path analysis: Decay in knowledge diffusion. *Journal of the Association for Information Science and Technology, 67*(2), 465–476.
Liu, John S., Lu, Louis Y. Y., Lu, Wen-Min, & Lin, Bruce J. Y. (2013). Data envelopment analysis 1978–2010: A citation-based literature survey. *Omega, 41*(1), 3–15.
Lock, I. (2019). Explicating communicative organization-stakeholder relationships in the digital age: A systematic review and research agenda. *Public Relations Review, 45:4*, Article 101829.
Loebbecke, C., & Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research Agenda. *Journal of Strategic Information Systems, 24*(3), 149–157.
Loonam, J., Eaves, S., Kumar, V., & Parry, G. (2018). Towards digital transformation: Lessons learned from traditional organizations. *Strategic Change-Briefings in Entrepreneurial Finance, 27*(2), 101–109.
Lucas, H. C., & Goh, J. M. (2009). Disruptive Technology: How Kodak Missed the Digital Photography Revolution. *The Journal of Strategic Information Systems, 18*(1), 46–55.
Lyytinen, K., Yoo, Y., & Boland, R. J. (2016). Digital product innovation within four classes of innovation networks. *Information Systems Journal, 26*(1), 47–75.
Martín-Peña, M., Diaz-Garrido, E., & Sánchez-López, J. (2018). The digitalization and servitization of manufacturing: A review on digital business models. *Strategic Change, 27*, 91–99.
Masuda, Y., Shirasaka, S., Yamamoto, S., & Hardjono, T. (2017). An adaptive enterprise architecture framework and implementation: Towards global enterprises in the era of cloud/ mobile it/digital it. *International Journal of Enterprise Information Systems, 13*(3), 1–22.
Masuda, Y., Shirasaka, S., Yamamoto, S., and Hardjono, T. 2017b. *Risk Management for Digital Transformation in Architecture Board a Case Study on Global Enterprise*. New York: IEEE.
Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering, 57*, 339–343.
Meyer, A., Gaba, V., & Colwell, K. (2005). Organizing far from equilibrium: Nonlinear change in organizational fields. *Organization Science - ORGAN SCI, 16*, 456–473.
Mithas, S., Agarwal, R., & Courtney, H. (2012). Digital Business Strategies and the Duality of It. *It Professional, 14*(5), 2–4.
Mithas, S., & Lucas, H. C. (2010). What is your digital business strategy? *It Professional, 12*(6), 4–6.
Mithas, S., & Whitaker, J. (2007). Is the world flat or spiky? Information intensity, skills, and global service disaggregation. *Information Systems Research, 18*(3), 237–259.

Mithas, S. s. r. u. e., Tafti, A. a. i. e., and Mitchell, W. w. m. d. e. m. r. u. c. 2013. "How a Firm's Competitive Environment and Digital Strategic Posture Influence Digital Business Strategy," *MIS Quarterly* (37:2), pp. 511-536.

Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The industrial management of Smes in the Era of Industry 4.0. *International Journal of Production Research, 56*(3), 1118–1136.

Monostori, L. (2014). In *Cyber-Physical Production Systems: Roots, Expectations and R&D Challenges* (pp. 9–13). Amsterdam: Elsevier Science Bv.

Monostori, L., Kadar, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., … Ueda, K. (2016). Cyber-physical systems in manufacturing. *Cirp Annals-Manufacturing Technology, 65*(2), 621–641.

Moreira, F., Ferreira, M. J., & Seruca, I. (2017). Digital Transformation - a New Challenge for Higher Education: A Curriculum Proposal. *International Conference of Education*.

Mukhopadhyay, S., & Bouwman, H. (2019). Orchestration and governance in digital platform ecosystems: A literature review and trends. *Digital Policy, Regulation and Governance, 21*(4), 329–351.

Muller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How smes approach business model innovations in industry 4.0. *Technol Forecast. Social Change, 132*, 2–17.

Nerur, S., Rasheed, A., & Natarajan, V. (2008). The intellectual structure of the strategic management field: an author co-citation analysis. *Strat. Manage. J., 29*, 319–336.

Nissen, V., & Seifert, H. (2018). Digital Transformation in Business Consulting-Status Quo in Germany," in: V. Nissen (ed.). *Digital Transformation of the Consulting Industry: Extending the Traditional Delivery Model,* Berlin: Springer-Verlag Berlin, pp. 153-190.

Nissen, V., Seifert, H., & Blumenstein, M. (2015). *"Virtualisierung Von Beratungsleistungen: Qualitätsanforderungen, Chancen Und Risiken Der Digitalen Transformation in Der Unternehmensberatung Aus Der Klientenperspektive," Handbuch der Unternehmensberatung* (25th ed.). Berlin): Erich Schmidt Verlag.

Nissen, V., Seifert, H., & Blumenstein, M. (2018). A Method to Support the Selection of Technologies for the Virtualization of Consulting Services. In: V. Nissen (ed.). *Digital Transformation of the Consulting Industry: Extending the Traditional Delivery Model,* Berlin: Springer-Verlag Berlin, pp. 243-274.

North, K., Aramburu, N., & Lorenzo, O. J. (2020). Promoting digitally enabled growth in Smes: A framework proposal. *Journal of Enterprise Information Management, 33*(1), 238–262.

Oesterreich, Thuy Duong, & Teuteberg, Frank (2016). Understanding the implications of digitisation and automation in the context of industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry, 83*, 121–139.

Osareh, F. (1996). Bibliometrics, citation analysis and co-citation analysis: a review of literature I. *Libri, 46*, 149–158.

Pagani, M. (2013). Digital business strategy and value creation: Framing the dynamic cycle of control points. *MIS Quarterly, 37*(2), 617–632.

Park, Y., & El Sawy, O. A. (2013). The Value of Configurational Approaches for Studying Digital Business Strategy. In P. C. Fiss, B. Cambre, & A. Marx (Eds.), *Configurational Theory and Methods in Organizational Research* (pp. 205–224). Emerald Group Publishing Ltd: Bingley.

Parker, G., & Van Alstyne, M. (2014). Platform strategy. *SSRN Electronic Journal*.

Pavlou, P., & Sawy, O. (2006). from it leveraging competence to competitive advantage in turbulent environments: The case of new product development. *Info. Sys. Research, 17*, 198–227.

Pavlou, P. A., & El Sawy, O. A. (2010). The "Third Hand": It-enabled competitive advantage in turbulence through improvisational capabilities. *Information Systems Research, 21*(3), 443–471.

Peter, M., Kraft, C., & Lindeque, J. (2020). Strategic action fields of digital transformation: An exploration of the strategic action fields of Swiss Smes and large enterprises. *Journal of Strategy and Management, 13*, 160–180.

Pihir, I., Tomicic-Pupek, K., & Tomičić Furjan, M. (2019). Digital Transformation playground: Literature review and framework of concepts. *Journal of Information and Organizational Sciences, 43*, 33–48.

Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., De Amicis, R., … Vallarino, I. (2015). Visual computing as a key enabling technology for Industrie 4.0 and industrial internet. *IEEE Computer Graphics Applications, 35*(2), 26–40.

Pritchett, G. (2014). Value Proposition Design: How to Create Products and Services Customers Want. *Central European Business Review* (3:4), pp. 52-52.

Qin, J., Liu, Y., & Grosvenor, R. (2016). A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. In A. Nassehi, & S. Newman (Eds.), *Sixth International Conference on Changeable* (pp. 173–178). Elsevier Science Bv: Agile, Reconfigurable and Virtual Production, Amsterdam.

Rai, A., Pavlou, P., & Du, S. (2012). Interfirm it capability profiles and communications for cocreating relational value: Evidence. *Management Information Systems Quarterly, 36*, 233–262.

Rajnai, Z., Kocsis, I., & Ieee (2018). *Assessing Industry 4.0 Readiness of Enterprises*. New York: Ieee.

Ray, G., Muhanna, W. A., & Barney, J. B. (2005). Information technology and the performance of the customer service process: A resource-based analysis. *Mis Quarterly, 29*(4), 625–652.

Rigby, D. K., Sutherland, J., & Takeuchi, H. (2016). Embracing agile how to master the process that's transforming management. *Harvard Business Review, 94:5*, pp. 41-+.

Ritala, P., Golnam, A., & Wegmann, A. (2014). Coopetition-based business models: The case of Amazon. Com. *Industrial Marketing Management, 43*(2), 236–249.

Ross, J. W., Sebastian, I. M., & Beath, C. M. (2017). How to develop a great digital strategy. *Mit Sloan Management Review, 58*(2), 7–9.

Sanchez, M. A. (2017). A framework to assess organizational readiness for the digital transformation. *Dimension Empresarial, 15*(2), 27–40.

Schmidt, R., Zimmermann, A., Mohring, M., Nurcan, S., Keller, B., and Bar, F. 2016. "Digitization - Perspectives for Conceptualization," in: A. Celesti and P. Leitner (eds.). *Advances in Service-Oriented and Cloud Computing,* Berlin: Springer-Verlag Berlin, pp. 263-275.

Schuh, G., Anderl, R., Gausemeier, J., ten Hompel, M., and Wahlster, W. 2017. "Industrie 4.0 Maturity Index," *Managing the digital transformation of companies. Munich: Herbert Utz*).

Schuh, G., Potente, T., Wesch-Potente, C., Weber, A. R., & Prote, J. P. (2014). Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0. In K. Windt (Ed.), *2nd Cirp Robust Manufacturing Conference* (pp. 51–56). Amsterdam: Elsevier Science Bv.

Seifert, H., & Nissen, V. (2018a). Crowd Workplace-a Case Study on the Digital Transformation within It- and Management-Consulting. In: V. Nissen (ed.). *Digital Transformation of the Consulting Industry: Extending the Traditional Delivery Model,* Berlin: Springer-Verlag Berlin, pp. 299-321.

Seifert, H., & Nissen, V. (2018b). Virtualization of Consulting Services: State of Research on Digital Transformation in Consulting and Future Research Demand. In: V. Nissen (ed.). *Digital Transformation of the Consulting Industry: Extending the Traditional Delivery Model,* Berlin: Springer-Verlag Berlin, pp. 61-73.

Setia, P., Venkatesh, V., & Joglekar, S. (2013). Leveraging digital technologies: How information quality leads to localized capabilities and customer service performance. *MIS Quarterly, 37*(2), 565–A564.

Shiau, W.-L., & Dwivedi, Y. K. (2013). Citation and co-citation analysis to identify core and emerging knowledge in electronic commerce research. *Scientometrics, 94*(3), 1317–1337.

Singh, A., Kumar, B., Singh, G., Mohan, A. (2017). Digital Image Watermarking: Concepts and Applications. In: *Medical Image Watermarking*. pp. 1-12.

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*, 265–269.

Spiess, P., Karnouskos, S., Guinard, D., Savio, D., Baecker, O., De Souza, L. M. S., & Trifa, V. (2009). Soa-Based Integration of the Internet of Things in Enterprise Services. In *international conference on web services* (pp. 968–975).

Spil, T., Pris, M., & Kijl, B. 2017. "Exploring the Big Five of E-Leadership by Developing Digital Strategies with Mobile, Cloud, Big Data, Social Media, and the Internet of Things," in: Z. Ndaba and T. Mokoteli (eds.). *Proceedings of the 5th International Conference on Management, Leadership and Governance,* Nr Reading: Acad Conferences Ltd, pp. 408-417.

Suomalainen, T., Kuusela, R., & Tihinen, M. (2015). Continuous planning: An important aspect of agile and lean development. *International Journal of Agile Systems and Management, 8*(2), 132–162.

Svadberg, S., Holand, A., & Breunig, K. (2019). Beyond the hype: A bibliometric analysis deconstructing research on digitalization. *Technology Innovation Management Review, 9*, 38–50.

Tamm, T., Seddon, P. B., Shanks, G., & Reynolds, P. (2011). How does enterprise architecture add value to organisations? *Communications of the Association for Information Systems, 28*, 141–168.

Taylor, S. 2019. 2019 Digital Transformation Market Trends Report. Webtorials.

Tomáková, H., & Nisler, J. (2017). Bpmn as a Quality Tool for the Efficient Functioning of the Company. IBIMA 2017.

Tseng, M.-L., Tran, T. P. T., Ha, H. M., Bui, T.-D., & Lim, M. K. (2021). Sustainable industrial and operation engineering trends and challenges toward industry 4.0: A data driven analysis. *Journal of Industrial and Production Engineering*, 1–18.

Uhl, A., & Lars, G. (2014). Digital Enterprise Transformation: A Business Driven Approach to Leveraging Innovative It.

Van Alstyne, M. W., Parker, G. G., & Choudary, S. P. (2016). Pipelines, platforms, and the new rules of strategy. *Harvard Business Review, 94:4*, pp. 54-+.

Vial, Gregory (2019). Understanding digital transformation: A review and a research Agenda. *The Journal of Strategic Information Systems, 28*(2), 118–144.

Wan, Xing, Cenamor, Javier, Parker, Geoffrey, & Van Alstyne, Marshall (2017). Unraveling platform strategies: A review from an organizational ambidexterity perspective. *Sustainability, 9*(5), 734. https://doi.org/10.3390/su9050734

Wang, N., Liang, H., Jia, Y., Ge, S., Xue, Y., & Wang, Z. (2016). Cloud computing research in the is discipline: A citation/co-citation analysis. *Decision Support Systems, 86*, 35–47.

Warner, K., and Wäger, M. 2018. "Building Dynamic Capabilities for Digital Transformation: An Ongoing Process of Strategic Renewal," *Long Range Planning* (52).

Weill, P., & Woerner, S. L. (2015). Thriving in an increasingly digital ecosystem. *Mit Sloan Management Review, 56*(4), 27–34.

Werth, D., Greff, T., & Scheer, A.-W. (2016). Consulting 4.0 – Die Digitalisierung Der Unternehmensberatung. *HMD Praxis der Wirtschaftsinformatik, 53*(1), 55–70.

Woodard, C. J., Ramasubbu, N., Tschang, F. T., & Sambamurthy, V. (2013). Design capital and design moves: The logic of digital business strategy. *Mis Quarterly, 37*(2), 537–564.

Zhang, M. 2010. "Social Network Analysis: History, Concepts, and Research," in: B. Furht (ed.). *Handbook of Social Network Technologies and Applications,* Boston, MA: Springer US, pp. 3-21.

Zhu, K., & Kraemer, K. L. (2005). Post-adoption variations in usage and value of E-business by organizations: Cross-country evidence from the retail industry. *Information Systems Research, 16*(1), 61–84.

Zimmermann, A., Buckow, H., Gros, H., Nandico, O. F., Piller, G., & Prott, K. (2011). Capability Diagnostics of Enterprise Service Architectures Using a Dedicated Software Architecture Reference Model. In *IEEE International Conference on Services Computing* (pp. 592–599).

Zimmermann, A., Schmidt, R., Jugel, D., & Mohring, M. 2016a. "Adaptive Enterprise Architecture for Digital Transformation," in: A. Celesti and P. Leitner (eds.). *Advances in Service-Oriented and Cloud Computing,* Berlin: Springer-Verlag Berlin, pp. 308-319.

Zimmermann, A., Schmidt, R., Jugel, D., Sandkuhl, K., Schweda, C., Mohring, M., & Bogner, J. (2016). Decision Case Management for Digital Enterprise Architectures with the Internet of Things. In I. Czarnowski, A. M. Caballero, R. J. Howlett, & L. C. Jain (Eds.), *Intelligent Decision Technologies 2016* (pp. 27–37). Pt Ii, Cham: Springer International Publishing Ag.

Zimmermann, A., Schmidt, R., Sandkuhl, K., Wissotzki, M., Jugel, D., & Mohring, M. (2015). Digital Enterprise Architecture - Transformation for the Internet of Things. *Enterprise Distributed Object Computing*, 130–138.

Xiaoteng Zhu is a PhD candidate of Management Information Systems in the School of Economics and Management at Jiangsu University of Science and Technology. Her research interests focus on IT use, digital transformation, information management, and social network analysis.

Shilun Ge is Chair Professor of MIS in the School of Economics and Management at Jiangsu University of Science and Technology. His research has focused on issues of enterprise modeling, enterprise data model, and IT project management. He received his PhD in the School of Economics and Management at Nanjing University of Science and Technology. He has authored and co-authored 3 books and more than 100 papers.

Nianxin Wang is a professor of Management Information Systems in the College of Economics and Management at Jiangsu University of Science and Technology. He received his Ph.D. from Southeast University of China. His current research interests include cloud computing management, IT business value, business-IT alignment, IT use, and crowdfunding. His research has been appeared or accepted in such journals as Information Systems Research, Journal of Management Information Systems, Journal of the Association for Information Systems, and Decision Support Systems. He is serving as senior editor for Information Technology & People, and on the editorial board of Internet Research.