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Exploring the Development Trajectory of Digital Transformation

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Abstract

Digital transformation (DT) has become a critical focus in both academia and industry. However, its rapid evolution complicates our understanding of its core concepts and developmental patterns. Understanding the development path of DT is crucial for both scholars and practitioners because it provides a structured view of how the field has progressed over time. This study employs main path analysis (MPA), a citation-based scientometric method, to systematically review and trace the intellectual trajectory of DT research over the past 30 years. Drawing on 1790 academic articles from the Web of Science database, the study identifies key influential works and maps the primary citation paths that shape the field. The analysis reveals three major developmental phases of DT research—engagement, enablement, and enhancement—each characterized by distinct thematic and conceptual shifts. Furthermore, five emerging research trends are uncovered: reinventing digital innovation affordance, value-creation paths of DT, synergistic DT with business and management practices, disciplinary boundaries of DT, and digital leadership. Understanding the intellectual trajectory and emerging trends of DT helps practitioners anticipate technological shifts and align transformation efforts, guiding decision-makers in effectively managing their DT processes. Also, these findings provide a structured framework for understanding the evolution of DT and offer valuable directions for future research in information systems and digital innovation.

Keywords: digital transformation; main path analysis; digital innovation; systematic review

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Academic Editor: Zongjun Wang

Received: 3 May 2025
Revised: 5 July 2025
Accepted: 8 July 2025
Published: 10 July 2025

Citation: Wang, P.-S.; Chou, T.-C.; Chen, J.-R. Exploring the Development Trajectory of Digital Transformation. *Systems* **2025**, *13*, 568. https://doi.org/10.3390/systems13070568

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1. Introduction

The accelerating wave of digitalization driven by both industry and academia is catalyzing continual innovation in emerging technologies such as artificial intelligence (AI) while simultaneously facilitating the rapid and large-scale deployment of digital and smart technologies across the business landscape. As digital technologies fundamentally alter the operational dynamics of industries, organizations are compelled to reconfigure their strategic and organizational models [1]. In this context, the pursuit of digital technology innovation and transformation has become an imperative for organizational survival. DT is commonly defined as organizational change that is triggered and shaped by the widespread diffusion of digital technologies [2]. This definition emphasizes that the transformative impact lies not in the technology itself but in how it reconfigures organizational structures and practices. However, this definition is not universally accepted, and various academic disciplines have appropriated and reinterpreted the concept to fit their theoretical

frameworks [3]. For instance, Vial defines DT as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [4]. A common thread among these definitions is the understanding that DT entails a fundamental redefinition of an organization's business model, rather than mere functional improvements.

Recent developments have further complicated the DT landscape. One notable catalyst has been the COVID-19 pandemic, which has accelerated digitization and DT, particularly in small and medium-sized enterprises (SMEs) and higher education institutions. For example, Cong et al. demonstrate how the pandemic enhanced SMEs' resilience by compelling technology adoption [5], often due to constraints on owners' cognitive capacity and the necessity of operational continuity during lockdowns. Similarly, Rupeika-Apoga, Petrovska, and Bule [6] argue that the crisis enabled fundamental changes in SME strategies, promoting long-term value creation. Nurhas and Aditya [7] observe that educational institutions were likewise forced to transform their operational and pedagogical models, further evidencing the pervasiveness of DT. Beyond organizational concerns, DT research has expanded to examine its broader societal implications. Recent studies have addressed how DT affects social inclusion [8], sustainability [9], and higher education [7]. The broader societal, ethical, economic, political, and technological implications of digitalization remain in flux, rendering empirical observation and theoretical generalization particularly challenging [10].

These developments underscore the need for continued theoretical refinement and empirical investigation into the evolving roles and consequences of DT across sectors and societies. For example, Tan et al. emphasize the necessity for enhanced theoretical and empirical inquiry into how digital platforms and ecosystems emerge, evolve, converge, diverge, and renew over time [11]. Nevertheless, the expanding volume of literature necessitates a systematic approach to comprehend its ongoing evolution. Accordingly, Sandberg, Holmström, and Lyytinen [12], for example, conducted an empirical study demonstrating how the digitization of product platforms induces organizational phase transitions, marking a shift from a platform-centric logic to an ecosystem-oriented organizing logic. Similarly, systematic reviews conducted by Hanelt and Bohnsack [1] and Gutierriz, Ferreira, and Fernandes [13], based on 279 and 167 articles, respectively, provide foundational insights.

These prior contributions have substantially advanced the understanding of DT. However, such reviews may not fully capture the structural interconnections of knowledge diffusion and the latent transformation patterns engendered by digital technologies. This will hinder our understanding of digital transformation. Apparently, the challenges associated with DT are multifaceted. Indeed, scholars and practitioners continue to debate the scope and essence of DT [2,14], while others highlight the conceptual ambiguity that persists in defining the term [15]. Furthermore, Brunetti et al. argue that successful DT demands strategic initiatives that span multiple domains, including the cultivation of an innovation-oriented culture, the development of digital competencies (e.g., education, talent, and culture), as well as robust infrastructure, advanced technologies, and supportive ecosystems [16]. Yet the complexity of this transformation remains problematic. According to the World Economic Forum, although 87% of companies anticipate that DT will disrupt their industries, only half consider themselves adequately prepared [17]. Reflecting this tension, Hovorka and Mueller [10] note that "the language of transformation and of becoming is suggestive that we are going some-when but have not yet arrived".

Based on the discussion above, from both practical and academic perspectives, it is clear that a more comprehensive and broad understanding of the concept and evolution of DT is necessary. However, a thorough analysis of the developmental path of DT scholarship is still missing, highlighting the need for a systematic review that maps its progress and

pinpoints emerging trends. The goal of this study is to enhance scholarly understanding of the evolutionary path of DT through scientometric analysis while also developing practical frameworks for organizations. This study aims to answer the following research questions to gain a comprehensive view of the DT literature:

RQ1. Which key studies have significantly influenced the development of the DT literature?
RQ2. What are the emerging themes and novel contributions in the DT research domain?

To investigate these questions, this study compiles and analyzes 1790 peer-reviewed articles related to DT. It applies two scientometric methods—key-route MPA and multiple global MPA—to trace the developmental trajectory of DT research over the past decades. MPA is a well-established analytical technique used to extract the principal intellectual structure of a research field by mapping citation networks [18]. Through this method, the study identifies critical citation pathways, turning points, and landmark contributions in the DT literature. The current study argues that understanding the intrinsic nature of DT literature draws on the concepts of complex adaptive systems (CASs), where citation networks reveal emergent properties, path dependencies, and evolutionary dynamics. This reflects how interrelated elements (articles, concepts) form a unified whole influenced by its environment (e.g., technological advancements, societal needs).

The structure of this paper is as follows: Section 2 outlines the methodology, including the application of key-route and multiple global MPA. The subsequent sections present the main findings, followed by a discussion and concluding remarks.

2. Research Methodology

2.1. The Concept of a Citation Network

This study adopts the MPA methodology, supported by specialized software tools, to systematically examine the development trajectory of DT research. The research process comprises four distinct stages, as outlined in Table 1. MPA, first introduced by Hummon and Doreian [19], is a citation-based analytical method predicated on the notion that knowledge is disseminated through citation relationships from earlier to later scholarly works. Main path analysis is a bibliometric method, a type of systematic literature review [20], that identifies the most influential and central pathways of knowledge development within a citation network. Generally, systematic literature reviews (SLRs) aim to collect, identify, and critically analyze the most relevant articles for inclusion in the analysis, while citation network analysis selects based on citations to explore the processes of knowledge creation, transfer, and development [21].

In contrast, SLR focuses on the content of selected relevant publications, whereas MPA emphasizes the citation relationships among these publications, revealing how knowledge has evolved through citation flows [19]. Accordingly, the core objective of MPA is to identify the most influential publications across different temporal stages that form the intellectual backbone of a research domain [21]. The method has been widely employed in diverse research contexts to map developmental trajectories such as knowledge diffusion [22], technology evolution [23], and technical pathways [24].

Conceptually, Hummon and Doreian [19] defined the flow of citations within a network as a series of search paths composed of links (citations) and nodes (articles). They introduced the "traversal count" metric to quantify the importance of each link based on its frequency of occurrence across all possible paths in the network. The underlying assumption of MPA is that researchers within the same academic community tend to cite one another in an effort to position their work within the existing body of knowledge, thereby enabling the tracing of intellectual development over time.

From a technical standpoint, MPA facilitates the extraction of a research domain's essential intellectual structure by distilling large and complex citation networks into a

manageable set of core citation paths [25]. This process significantly reduces informational complexity and enables the identification of pivotal works and evolutionary patterns in the scholarly discourse. From a systemic perspective, the DT literature corpus is explicitly defined as a bounded knowledge system comprising four constitutive subsystems: (1) a structural subsystem (citation network topology), (2) a functional subsystem (knowledge flows via traversal count), (3) an evolutionary subsystem (temporal phase transitions), and (4) a computational subsystem (path-tracking search algorithm). This system perspective enables MPA to map structural pathways, quantify diffusion intensity, and track evolutionary shifts.

Table 1. MPA method (adapted from [26–28]).

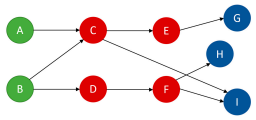
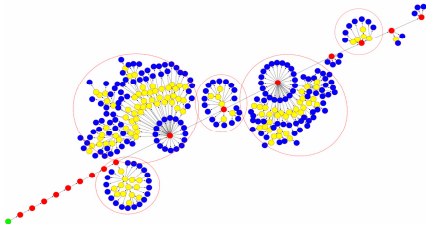
(1) The Concept of a Citation Network	
A network's sequence of links and nodes as search paths.	
Source nodes (in green) are the nodes that are cited while referring to no other nodes.	
Intermediate nodes (in rad) are nodes that are citing and cited by others.	
Sink nodes (in blue) are nodes that are citing others, but not cited.	
(2) Data Collection and Filtering	
Research target.	See Table 2 for the search strategy and keywords used, and Figure 1 for the data screen flow diagram.
Design a set of query.	
Search in the database.	
(3) Traversal Weight	
Search Path Count (SPC): A citation link's SPC refers to the number of times the link is traversed when one explores all the possible citation chains from all the sources to all the sinks in a citation network. To determine the SPC for a specific link, one must enumerate all potential citation chains that originate from all the sources and conclude at all the sinks.	The study used search path link count (SPLC) analysis to identify the most influential publications within the selected discipline, highlighting key studies that have significantly shaped the field's development. The SPLC algorithm is detailed in Ref. [26].
Search Path Link Count (SPLC): A citation link's SPLC is the number of times the link is traversed when running through all possible citation chains from all the ancestors of the tail node (including itself) to all the sinks. To obtain the SPLC for a specific link, one needs to enumerate all the possible citation chains that originate from all the ancestors of the tail node (including itself) and terminate at all the sinks. There are apparently many more citation chains to enumerate.	
Search Path Node Pair (SPNP): SPNP adds further complications, namely the number of times the link is traversed when exploring all possible citation chains from the ancestors of the tail node (including itself) to the descendants of the head node (including itself). Therefore, to obtain the SPNP, one must enumerate all possible citation chains that originate from the ancestors of the tail node (including itself) and conclude at the descendants of the head node (including itself).	
(4) Path-Tracking Search Algorithm	
Local main path method (LMP): LMP helps identify the important roots of the current active ideas. In this method, the search process begins at a source and makes the locally best choice when selecting the next stop until a sink is encountered.	For RQ1, to trace the evolution of research within the discipline, key-route MPA was conducted, mapping the field's developmental trajectory over time. Comprehensive visualization details for the key-route MPA are provided in Ref. [26]. For RQ2, multiple global MPA was applied to uncover emerging trends, providing insights into the future direction of research in this area.
Global main path method: The GMP helps discover the overall significant path. This method identifies the citation chains with the highest overall traversal weights.	
Key-route main path method (KRMP): The KRMP guarantees that the top citation links are included in the paths. In this method, the key-route search algorithm begins with a seed link, usually the link with the highest traversal weight. It then searches forward until a sink is reached and backward from the tail node until a source is found. Multiple global MPA (MGMPA): MGMPA determines the main research path, extending the number of developmental trajectories under study and making them more comprehensive.	

Table 2. Search strategy and keywords used.

Database	**Web of Science Index: Social Sciences Citation Index (SSCI) or Science Citation Index Expanded (SCI-EXPANDED).**
Search Strategy	TS = ((("Digital*") AND ("Innovation" or "Transformation" or "Disruption" or "servitization" or "servitisation")) or ("Digitalization" or "Digitalisation") NOT ("Review"))
Document Type	Article or Early Access or Review Article
Search Area	Information Science Library Science
Time Span	From 1994 to 2025

The "*" is a truncation symbol used to retrieve multiple word variants (e.g., "Digital" captures "digitalization," "digitization," and "digital").

2.2. Data Collection and Filtering

Table 2 presents the search strategy and key terms employed in this study. A critical principle underlying MPA is the construction of a comprehensive dataset that captures the full scope of relevant scholarly work while systematically excluding irrelevant content. To this end, the data for this study were retrieved from the Web of Science (WoS) Core Collection, specifically from the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI), ensuring the inclusion of high-quality academic publications across both technological and managerial disciplines.

The data collection process followed a multi-step procedure. First, a review of the established literature and prior review studies in the domain of DT (e.g., Vial [4], Sambamurthy and Zmud [29]) was conducted to extract a preliminary list of frequently used keywords. Building upon the query formulation strategy proposed by Porter and Youtie [30], a pilot search query was constructed. This initial query was refined through iterative review of titles and abstracts of relevant articles in the field to ensure both coverage and relevance.

Subsequently, the final search strategy was developed by narrowing the keyword list, which allowed for a more precise filtering of the literature. The temporal range of the search spanned from 1 January 1994 to 31 January 2025. Although the initial coverage began in 1994, the decision to emphasize literature from 2000 onward was based on the significant shift in digital technology applications during the post-dot-com era, which marked a transition from e-commerce-centric models to broader inter-organizational DTs.

Citation metadata for each article was meticulously collected from the WoS database. The final dataset comprised 1790 peer-reviewed articles, which form the basis of the citation network used in this MPA. This curated dataset is fundamental to tracing the intellectual structure and evolution of the DT research field. Notably, a non-targeted search across all WoS categories yielded over 56,000 articles, which presented challenges in terms of data manageability and relevance. To address this, the search was restricted to the Information Science & Library Science category. This constraint ensured thematic alignment with the study's focus while maintaining the analytical tractability of the dataset. The final sample of 1790 articles thus represent a focused and relevant corpus for conducting robust MPA. The data screen flow diagram is shown in Figure 1.

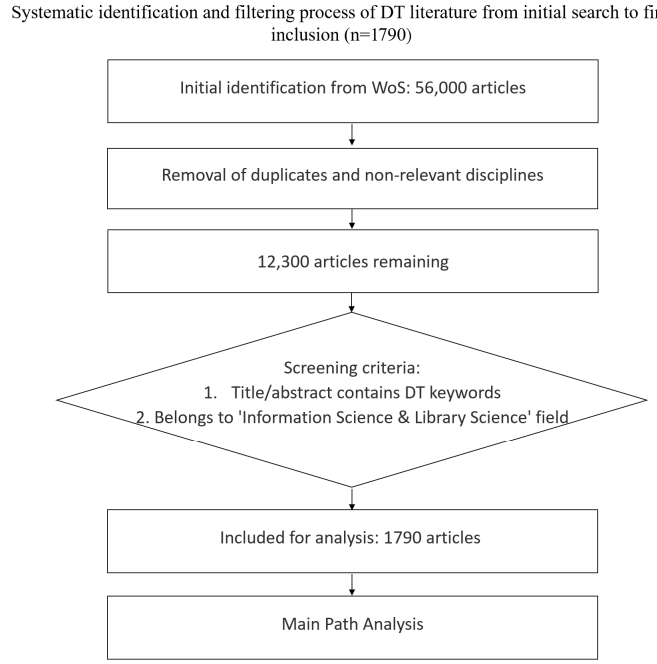


Figure 1. Data screen flow diagram.

2.3. Traversal Weight

As outlined by Liu and Lu [27], MPA consists of two primary steps: (1) transforming a binary citation network into a weighted network in which the weight of each link reflects its significance, and (2) applying a search algorithm to extract the main path that represents the intellectual backbone of the domain. In the first step, the analysis of the citation network was conducted using Pajek, a widely adopted software package developed for the analysis and visualization of large-scale network data [31].

Following the methodological framework established by Hummon and Doreian [19], three types of traversal weights are commonly used to quantify the significance of citation links: Search Path Link Count (SPLC), Search Path Node Pair (SPNP), and Node Pair Projection Count (NPPC). However, Batagelj [32] later introduced an additional metric, Search Path Count (SPC), and noted that NPPC is generally unsuitable for large-scale networks due to its computational inefficiency. To generalize these traversal methods, Batagelj [32] proposed the term SPX to encompass SPLC, SPNP, and SPC. Among these, SPLC has been identified as the most effective approach for detecting influential connections in citation networks, due to its robustness and ability to highlight critical structural links [28]. Therefore, this study adopts the SPLC metric to compute traversal weights and assign relative significance to each citation link within the DT literature network. This weighted structure serves as the foundation for identifying the most influential citation pathways through the subsequent application of main path algorithms. Therefore, for this study, traversal weights were calculated using Pajek with the SPLC algorithm under default normalization [32].

2.4. Path-Tracking Search Algorithm

This study employed the Key-route Main MPA method to ensure that the most significant citation links within the network were comprehensively captured [27]. The key-route MPA approach is designed to identify critical intellectual trajectories by selecting citation links with the highest traversal counts. The key-route MPA employed in this study is a refined main path approach. The process begins by determining a key route based on traversal weight, after which the analysis is extended in two directions: forward—from the end node of the key route toward a sink (representing the most recent or terminal

contributions)—and backward—from the starting node of the key route to a source (representing the earliest or foundational studies) [26]. A key advantage of this method is its ability to preserve the most influential citation links across multiple citation sequences, thereby highlighting the structural core of knowledge diffusion [33]. This structure reveals not only linear progressions of thought but also divergent–convergent patterns, illustrating how multiple research lines evolve independently before merging into shared intellectual developments. For this study, key-route analysis in MainPath software selected seed links from the top 15 highest traversal counts, consistent with Liu, Lu, and Ho's [28] recommendations for balancing path coverage and noise reduction.

In addition to key-route MPA, this study incorporates Multiple Global MPA to explore diverse research sub-trajectories. As emphasized by Liu and Lu [34] in the context of Data Envelopment Analysis (DEA), the global main path method facilitates a more nuanced understanding of research field evolution by enabling the identification of multiple simultaneous pathways. Multiple global MPA thus supports the discovery of emerging themes and subfields within the broader DT literature, depending on the number of main paths selected. To operationalize these methods, the MainPath 480 software was utilized. This software enables the calculation of traversal weights, construction of citation networks, and extraction of both key-route and multiple global main paths, thereby forming the basis of the citation trajectory analysis conducted in this study.

3. Results

3.1. Growth Trend of DT Papers

The volume of scholarly publications in the field of DT has steadily increased over time, as depicted in Figure 2. This upward trend reflects a sustained and growing interest in the topic. The findings of this study are consistent with prior research suggesting that DT has gained substantial prominence over the past decade. Scholars increasingly acknowledge DT as an ongoing and evolving process that continues to influence and reshape individual behavior, organizational practices, and broader societal structures [35,36]. Based on the observed trajectory, it is reasonable to anticipate that research activity in this domain will continue to grow, with significant expansion likely to persist through 2030 if current trends hold.

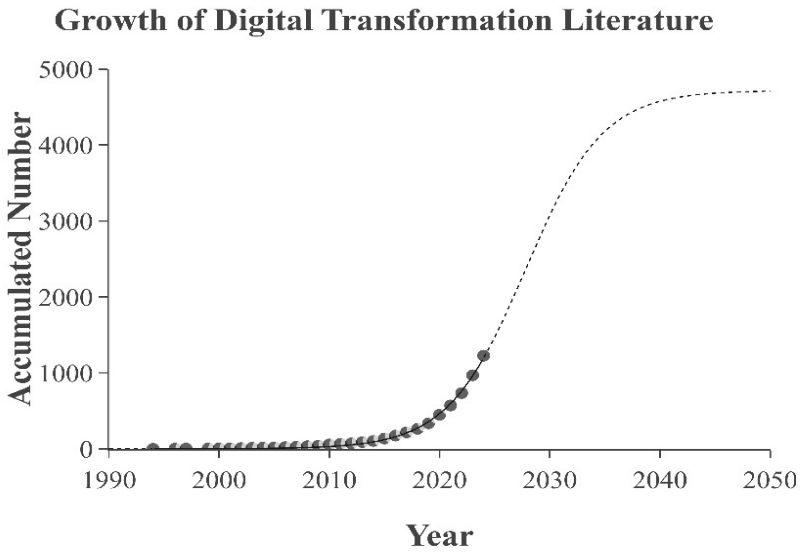


Figure 2. Growth trend of the DT literature.

The analysis reveals that the Key-route 15 main paths comprise a concentration of highly significant citation links, while paths with lower traversal counts are excluded from

the resulting network. Table 3 presents the 15 citation links with the highest traversal counts, which were selected as seed links for constructing the main path network in this study. These links are regarded as the most influential because they represent critical conduits through which foundational and transformative ideas have been transmitted across the DT literature.

Table 3. The top 15 highest traversal links.

Count	SPLC (Traversal Counts)	Links (From $\geq$ To)
1	4,796,460	Yoo2010 => YooHL2010
2	3,393,620	Wheeler2002 => SambamurthyBG2003
3	3,313,885	YooHL2010 => HenfridssonB2013
4	3,223,890	LyytinenR2003a => Yoo2010
5	3,051,061	SambamurthyZ2000 => Wheeler2002
6	2,709,928	SelanderHS2013 => HenfridssonMS2014
7	2,571,216	SvahnML2017 => FM9004_2_NambisanLMS2017
8	2,219,856	FM9004_2_NambisanLMS2017 => Vial2019
9	2,131,760	SambamurthyBG2003 => YooHL2010
10	2,063,040	HenfridssonB2013 => SelanderHS2013
11	1,968,101	SambamurthyZ2000 => LyytinenY2002
12	1,898,968	HenfridssonMS2014 => SvahnML2017
13	1,744,150	ElsawyMPP2010 => HenfridssonB2013
14	1,710,220	SambamurthyBG2003 => PavlouE2010
15	1,696,810	SambamurthyZ2000 => SambamurthyBG2003

Collectively, these frequently traversed citation paths delineate the intellectual trajectory of DT research and highlight the pivotal publications that have shaped the field. Accordingly, the set of articles identified along this main path can be interpreted as the core knowledge base underpinning the development of DT as a research domain. For further detail, Table 4 provides a comprehensive description of each node along the main path, including the publication titles and corresponding authors.

Table 4. The most influential publication of DT research on IS studies.

Labels	Title of Literature	Refs.
SambamurthyZ2000	Research commentary: The organizing logic for an enterprise's IT activities in the digital era—A prognosis of practice and a call for research	Sambamurthy and Zmud [29]
LyytinenY2002	Research commentary: The next wave of Nomadic computing	Lyytinen and Yoo [37]
Wheeler2002	NEBIC: A dynamic capabilities theory for assessing net-enablement	Wheeler [38]
SambamurthyBG2003	Shaping agility through digital options: Reconceptualizing the role of information technology in contemporary firms	Sambamurthy, Bharadwaj, and Grover [35]
LyytinenR2003a	The disruptive nature of information technology innovations: The case of Internet computing in systems development organizations	Lyytinen and Rose [36]
YooHL2010	The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research	Yoo, Henfridsson, and Lyytinen [39]

Table 4. *Cont.*

Labels	Title of Literature	Refs.
Yoo2010	Computing in Everyday Life: A Call for Research on Experiential Computing	Yoo [40]
PavlouE2010	The "Third Hand": IT-Enabled Competitive Advantage in Turbulence Through Improvisational Capabilities	Pavlou and El Sawy [41]
ElsawyMPP2010	Seeking the Configurations of Digital Ecodynamics: It Takes Three to Tango	El Sawy and Malhotra [42]
HenfridssonB2013	The Generative Mechanisms of Digital Infrastructure Evolution	Henfridsson and Bygstad [43]
SelanderHS2013	Capability search and redeem across digital ecosystems	Selander, Henfridsson, and Svahn [44]
HenfridssonMS2014	Managing technological change in the digital age: the role of architectural frames	Henfridsson, Mathiassen, and Svahn [45]
NambisanLMS2017	Digital Innovation Management: Reinventing Innovation Management Research in a Digital World	Nambisan and Lyytinen [46]
SvahnML2017	Embracing Digital Innovation in Incumbent Firms: How Volvo Cars Managed Competing Concerns	Svahn, Mathiassen, and Lindgren [47]
Vial2019	Understanding digital transformation: A review and a research agenda	Vial [4]
BaiyereST2020	Digital transformation and the new logics of business process management	Baiyere, Salmela, and Tapanainen [48]
WesselBOCJ2021	Unpacking the Difference Between Digital Transformation and IT-Enabled Organizational Transformation	Wessel and Baiyere [49]
CastilloBLB2021	Impact of Social Media on the Firm's Knowledge Exploration and Knowledge Exploitation: The Role of Business Analytics Talent	Castillo López, Llorens Montes, and Braojos Gómez [50]
BenitezACE2022	Impact of digital leadership capability on innovation performance: The role of platform digitization capability	Benitez and Arenas [51]
GongYZ2023	The too-much-of-a-good-thing effect of digitalization capability on radical innovation: the role of knowledge accumulation and knowledge integration capability	Gong, Yao, and Zan [52]
BhattiGAMS2024	The impact of digital platforms on the creativity of remote workers through the mediating role of explicit and tacit knowledge sharing	Bhatti and Gavurova [53]
MajumdarrDHBP2024	Linking digital transformational leadership, symmetrical internal communication with innovation capability: a moderated mediation model	Majumdarr and Dasgupta [54]
MeleCSC2024	Revisiting the idea of knowledge-based dynamic capabilities for digital transformation	Mele and Capaldo [55]
LiuZ2025	The role of digital resilient agility: how digital capability incompatibility affects knowledge cooperation performance in project network organizations	Liu and Zhang [56]

This section presents the principal developmental trajectories of DT research. As depicted in Figure 3, arrows indicate the direction of knowledge flow, while the thickness of each line represents the corresponding Search Path Link Count (SPLC) value, consistent

with the top 15 highest traversal links detailed in Table 3. A thicker line denotes a more influential citation pathway within the network.

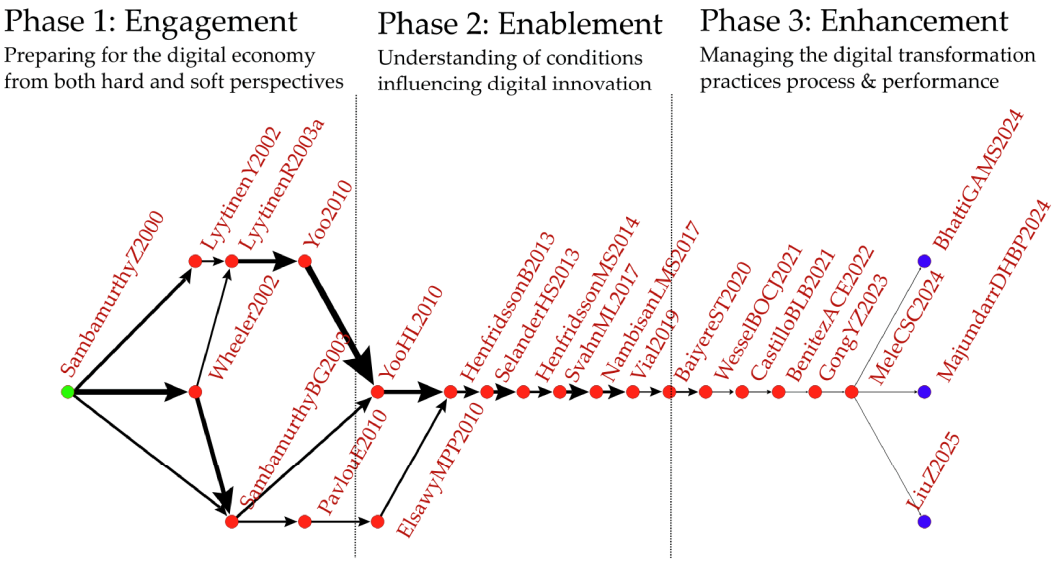


Figure 3. Main path of DT studies.

In the following subsections, we provide concise summaries of the scholarly contributions found along the main paths, with particular emphasis on the most traversed (i.e., top linked) papers. Notably, many of these high-impact publications originate from leading journals in the field of Management Information Systems (MIS), including *Information Systems Research* (*ISR*), *MIS Quarterly*, *the Journal of Information Technology*, and the *Journal of Strategic Information Systems* (*JSIS*). These outlets have played a pivotal role in shaping DT scholarship's intellectual foundation and evolution.

The top three citation links with the highest traversal densities along the main path are attributed to Yoo [40], Wheeler [38], and Yoo, Henfridsson, and Lyytinen [39]. Among these, Yoo [40] exhibits the highest knowledge flow link density, signifying this study's centrality and frequent citation within the DT literature. This study introduces a schematic framework for experiential computing, highlighting how digital technologies reshape everyday human experiences and interactions. Wheeler [38] contributes the Net-Enabled Business Innovation Cycle (NEBIC) model, which offers a strategic perspective on how organizations can leverage digital networks to enhance their capacity for customer value creation. Yoo, Henfridsson, and Lyytinen [39] further advance the theoretical landscape by proposing a comprehensive conceptual framework that articulates the emerging organizing logic of digital innovation. Their work outlines a research agenda for digital strategy and addresses the development and governance of enterprise-level information technology infrastructures.

Collectively, these foundational studies have played a pivotal role in shaping the early development of DT research. They provide conceptual clarity and strategic direction that continue to influence subsequent inquiry and scholarly discourse in the field.

3.2. The Development Trajectory of DT

Digital technologies have progressed at an unprecedented pace, outstripping all prior waves of innovation in both scale and impact. As a result, enterprises are increasingly compelled to reconfigure their information technology (IT) capabilities, infrastructure, management practices, and strategic models to remain competitive in the digital landscape.

To delineate the intellectual evolution of the DT literature, this study applies the MPA approach and classifies the primary research trajectories into three distinct phases:

- Engagement Phase—this phase emphasizes organizational readiness for participation in the digital economy, encompassing both hard capabilities (e.g., technological infrastructure) and soft capabilities (e.g., culture, leadership, and digital skills).
- Enablement Phase—research in this phase focuses on identifying and understanding the structural and contextual conditions that facilitate digital innovation, including organizational configurations, platform ecosystems, and strategic alignment.
- Enhancement Phase—the final phase addresses the implementation, management, and evaluation of DT practices, with particular attention to performance outcomes, continuous adaptation, and value realization.

3.2.1. Phase 1: Engagement—Preparing for the Digital Economy from Both Hard and Soft Perspectives

The bursting of the dot-com bubble in 2000 marked a pivotal transition in the trajectory of digital technology adoption, as attention shifted from speculative Internet ventures toward enterprise-oriented applications. In the early stages of this transition, the conceptualization of the Internet and its application within organizational contexts remained underdeveloped and ambiguous. As noted by Sambamurthy, Bharadwaj, and Grover [35], it became increasingly clear that information technology (IT) assumed a fundamentally different and more strategic role within firms. This recognition catalyzed a paradigm shift within the Information Systems (IS) discipline, prompting both scholars and practitioners to reevaluate the essence and function of digital technologies. A seminal work that catalyzed this shift is the study by Sambamurthy and Zmud [29], which is a foundational node on the main path of the DT literature. The authors conceptualized IT activities in firms not as isolated operational tools but as integral components of platform logic—a structurally complex and capability-oriented architecture enabling scalable and dynamic enterprise systems.

Following this, two major research streams emerged. The first stream focuses on Internet-based computing and the evolving architectural features of digital technologies. Key contributions in this stream include works by Lyytinen and Yoo [37], Lyytinen and Rose [36], Yoo [40], and Yoo, Henfridsson, and Lyytinen [39]. These studies investigate how digital technologies diverge from traditional ISs in terms of their architectural flexibility, ubiquity, and user-centric design. Lyytinen and Yoo [37] identified three foundational characteristics of digital technologies—mobility, digital convergence, and mass scale—as central enablers of nomadic information environments. Lyytinen and Rose [36] introduced the notion of disruptive IT innovation, positing that Internet-based computing represents a form of architectural innovation built upon global infrastructures. Building upon this, Yoo [40] advanced the concept of experiential computing, where digital technologies embedded in everyday objects reshape user experience through ubiquitous interaction. Expanding further, Yoo, Henfridsson, and Lyytinen [39] proposed a layered modular architecture, which integrates four loosely coupled layers—devices, networks, services, and content—to reflect the structural complexity of modern digital ecosystems.

The second stream emphasizes capability-building through digital networks, with influential contributions from Wheeler [38], Sambamurthy, Bharadwaj, and Grover [35], and Pavlou and El Sawy [41]. This body of work centers on the firm's ability to strategically select and deploy digital technologies in alignment with dynamic environmental conditions. Wheeler [38] introduced the Net-Enabled Business Innovation Cycle (NEBIC) model, emphasizing capabilities such as the selection of emerging technologies and their alignment with market opportunities to enhance customer value. Sambamurthy, Bharadwaj, and

Grover [35] further identified three core organizational capabilities—agility, digital options, and entrepreneurial alertness—through which IT investments drive strategic renewal. Pavlou and El Sawy [41] contributed the concept of improvisational capabilities, referring to a firm's ability to spontaneously reconfigure existing resources to address unanticipated challenges and opportunities in turbulent environments.

In summary, this initial phase of DT research reflects a growing organizational interest in the internal adoption of digital technologies. The academic focus during this period centered on understanding the dual importance of hard digital architectures and soft organizational capabilities. Successful DT is not merely about adopting new technologies; it embodies a systemic organizational change that relies on the alignment and interaction of multiple interdependent components. Firms must develop new capabilities to master DT practices, where elements such as digital adoption (the implementation and usage of digital tools and platforms), digital drive (the internal motivation and leadership commitment), digital literacy, and digital culture (the shared values, beliefs, and norms) interact synergistically to shape overall performance outcomes. Scholars sought to redefine the conceptual boundaries of digital architecture and identify the core capabilities required to compete effectively in an increasingly digital economy.

3.2.2. Phase 2: Enablement—Understanding the Patterns of Conditions Influencing Digital Innovation

Building upon the foundation laid by Sambamurthy, Bharadwaj, and Grover [35] who conceptualized IT as a generator of digital options, the second developmental stage of DT research marks a shift in focus from the internal organizational context to the external dynamic environment. During this phase, scholarly attention moved toward enabling digital innovation within broader inter-organizational and industry-level contexts. Although enabling digital innovation had become a central concern, early research lacked clarity regarding how it unfolds at the industry level and which external conditions shape it.

To address this research gap, scholars such as Pavlou and El Sawy [41] and Henfridsson and Bygstad [43] introduced the configurational approach, which posits that combinations of conditions, rather than isolated factors, are the primary determinants of innovation outcomes. This perspective also acknowledges equifinality—the possibility that multiple configurations can lead to the same desired result [33]. Following this logic, El Sawy and Malhotra [42] examined the interplay between environmental turbulence, dynamic capabilities, and IT systems, highlighting how these elements interact as a cohesive ecosystem. Henfridsson and Bygstad [43] contributed by analyzing the contingent causality behind digital infrastructure evolution, focusing on the dynamic patterns that shape infrastructural change over time. In parallel, Selander, Henfridsson, and Svahn [44] introduced a pluralistic strategy for non-focal actors, suggesting that actors should not commit to a single digital ecosystem but instead engage across multiple ecosystems to maximize innovation potential.

Building on Alexander's theory of patterns [57], Henfridsson, Mathiassen, and Svahn [45] proposed a network-of-patterns architecture, enabling firms to better respond to technological change and manage digital-era products more effectively. Later, Svahn et al. extended this work by examining the inherent tensions in digital innovation—such as those between specific and generic functionality—emphasizing how issues of capability, focus, collaboration, and governance are systemically interdependent [47]. Lastly, Nambisan and Lyytinen [46] argued that the relationship between innovation processes and outcomes is inherently complex and dynamic, particularly in digitized environments. They proposed a conceptual shift from traditional innovation models toward a dynamic problem–solution pairing approach, as also discussed by Von Hippel and Von Krogh [58].

In summary, this phase of DT research transitioned from surface-level examinations of digital innovation to deeper explorations of the patterns and configurations of conditions that shape it. Researchers in this stage sought to reconceptualize digital innovation by uncovering the complex, systemic influences that govern it, thereby identifying strategic opportunities for firms to proactively seize innovation within dynamic digital environments.

3.2.3. Phase 3: Enhancement: Managing the DT Practice Process and Performance

After nearly two decades of scholarly development, the third stage of DT research has shifted toward achieving a comprehensive understanding of its nature and implications, with the aim of facilitating more effective implementation processes. This phase places particular emphasis on managerial factors and organizational capabilities, which has attracted substantial academic interest. For instance, Vial [4] highlights the structural changes and organizational barriers that complicate DT initiatives. Baiyere, Salmela, and Tapanainen [48] advocate for a reexamination of traditional management frameworks, arguing that long-held assumptions may no longer hold in the context of business process transformation. Similarly, Wessel and Baiyere [49] distinguish between digital and IT-enabled organizational transformation, exploring how organizational identity interacts with and influences each process.

From a capabilities perspective, Benitez and Arenas [51] emphasize the importance of digital leadership capability as a driver of successful transformation, while Gong, Yao, and Zan [52] investigate the complex relationship between digitalization capability and radical innovation performance. These studies reflect the growing recognition that managerial competence and organizational readiness are critical enablers of DT, underscoring the increasing relevance of translating digital strategies into actionable business practices. In addition, two notable studies emphasize the role of knowledge in DT. Castillo López, Llorens Montes, and Braojos Gómez [50] identify social media as a disruptive technology that significantly enhances the processes of knowledge exploration and exploitation. Meanwhile, Mele and Capaldo [55] explore knowledge-based dynamic capabilities, suggesting that traditional approaches to knowledge management must be reconfigured in response to digital technologies. Interestingly, these articles appear near the end nodes of the key-route main path, denoted in blue in the citation network visualization. Although end-node articles often cite earlier influential works, they are not necessarily representative of the most central contributions to the field, but rather they may signal emerging directions for future research.

In summary, DT research can be categorized into three distinct phases, as shown in Figure 4. Phase 1 focuses on preparing organizations for the digital economy by integrating digital infrastructures and computing technologies into internal IT systems. Phase 2 concentrates on identifying configurational patterns and external contingencies that enable digital innovation across ecosystems and platforms. Phase 3 centers on enhancing managerial capabilities and organizational environments to fully realize the value of DT in business practice. Each phase represents a progressive deepening of the theoretical and practical understanding of DT, reflecting the field's maturation over time. DT also addresses the evolution of business digital systems and their trigger mechanisms. The current study observed that Phase 1 positions systems as infrastructure tools that precede capability interplay. Infrastructure saturation is the most significant mechanism to trigger Phase 1 into ecosystem reconfiguration. Accordingly, the digital system in Phase 2 can be characterized as interconnected platforms. When the platform facilitates intra-organizational value co-creation, the function of knowledge management triggers the DT into Phase 3, characterizing digital systems as intelligent networks.

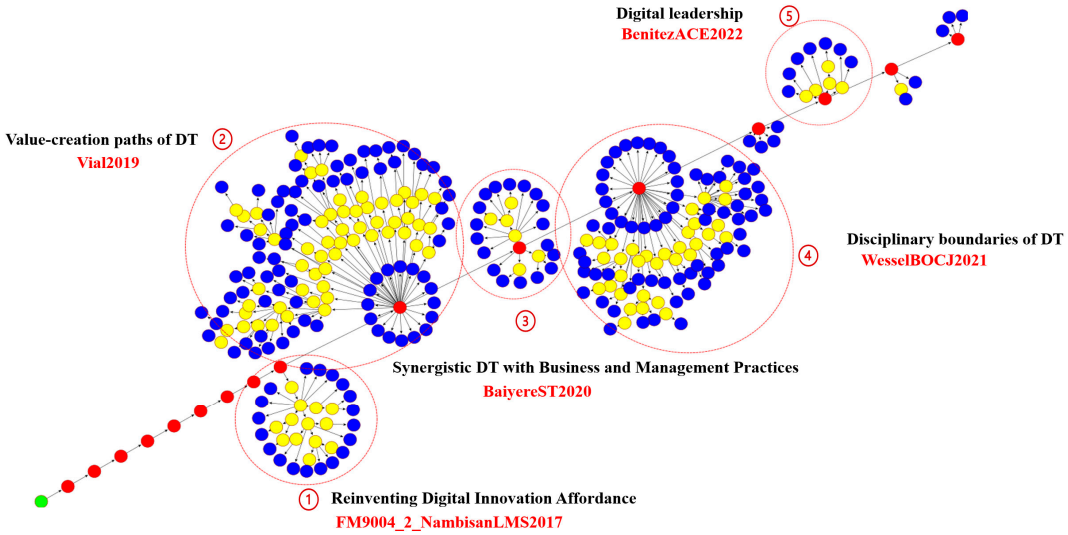


Figure 4. Multiple global MPA of DT studies.

3.3. Trend Research in DT

The evolving trajectory of DT research was further analyzed through the multiple global main path method, as proposed by Liu, Lu, and Ho [25]. This technique enables the identification of multiple significant citation paths within the broader citation network, thereby revealing both historical and contemporary clusters of scholarly work. By tracing these diverse pathways, the analysis uncovers the key thematic areas, influential authors, and seminal contributions that have shaped the intellectual development of the DT field. As illustrated in Figure 4, each cluster represents a distinct sub-theme within DT research. To systematically interpret the meaning of these clusters, the titles, abstracts, and keywords of the articles within each cluster were closely examined. This examination allowed for the extraction of dominant concepts and patterns, which were subsequently categorized into five overarching thematic groups:

1. Reinventing digital innovation affordance.
2. Value-creation paths of DT.
3. Synergistic DT with business and management practices.
4. Disciplinary boundaries of DT.
5. Digital leadership.

The subsequent sections provide an in-depth discussion of key publications and representative contributions within each thematic group, corresponding to the labeled clusters in Figure 4. To facilitate traceability, the code of the initial paper in each cluster is indicated directly beneath the corresponding theme label in the figure. This integrated approach not only reveals how the DT literature has evolved across thematic dimensions but also provides insight into the emerging directions of future research.

3.3.1. Reinventing Digital Innovation Affordance

The concept of digital innovation (DI) has rapidly expanded alongside the widespread adoption of digital technologies, making its effective management a critical enabler of DT. As emphasized by Nambisan and Lyytinen [46], the shift from traditional innovation to digital innovation represents a pivotal opportunity—one that organizations must actively seize. Increasingly, research in this area has moved beyond simply articulating the potential benefits of DI, focusing instead on how organizations can actualize these opportunities through strategic capability development and implementation. The capacity

to both identify and enact innovation opportunities is essential for realizing the full value of digital innovation.

To deepen theoretical understanding in this domain, Nambisan and Lyytinen [46] introduced four novel theorizing logics, designed to enhance the explanation of innovation processes and outcomes within digitally dynamic environments. Complementing this perspective, Henfridsson and Nandhakumar [59] proposed the value spaces framework, conceptualized as an evolving network of digital resources that supports the creation and capture of value in digital innovation ecosystems. Further advancing the discourse, Wang [60] underscored the importance of analyzing digital innovation ecosystems in order to better manage the complex interplay between digital technologies and innovation activities.

This cluster of research moves beyond the "fashion stage" of digital innovation and provides a robust intellectual foundation for subsequent research streams. These technologies not only enable new modes of value creation and problem-solving but also challenge traditional assumptions about creativity, automation, and human–machine collaboration. For example, generative AI is reshaping innovation possibilities across industries by transforming how ideas are generated, solutions are developed, and products are designed. However, generative AI can be misused to create deepfakes, spam, or automated misinformation, posing a significant challenge for firms.

In particular, it significantly informs later clusters that advocate for the reconceptualization of digital innovation and transformation, as well as the integration of DT into business and management domains. These theoretical advancements collectively contribute to a more nuanced and actionable understanding of how digital innovation operates in contemporary organizational and inter-organizational contexts.

3.3.2. Value-Creation Paths of DT

The discourse on DT within the enterprise domain has evolved into a comprehensive discussion encompassing both digital innovation and digital strategy. However, Vial [4] offers a broader conceptualization by framing DT as a process through which digital technologies introduce disruptions, thereby prompting organizations to enact strategic responses aimed at reconfiguring their value-creation pathways. This emphasis on the transformation of value creation has extended beyond the private sector and garnered increasing attention within the field of public administration.

In particular, researchers have begun to explore how DT practices are being adopted and adapted by public sector institutions. Gong, Yang, and Shi [61] underscore that DT has emerged as a strategic imperative for governments, necessitating the development of organizational flexibility to effectively navigate transformation and enhance both service quality and operational efficiency. Similarly, Pittaway and Montazemi [62] highlight how public agencies are leveraging digital technologies to restructure organizational frameworks and modernize public service delivery processes. However, they also note that the success of such initiatives hinges on acquiring the requisite organizational knowledge to manage the complexities of disruptive change in public sector contexts.

This cross-sectoral diffusion of DT research reflects the growing recognition that DT is not only a business concern but also a public governance challenge, demanding adaptive strategies, institutional learning, and innovation capacity across both domains.

3.3.3. Synergistic DT with Business and Management Practices

This research cluster comprises studies that examine the synergistic integration of DT with core business and management practices. In their investigation of business process management (BPM), Baiyere, Salmela, and Tapanainen [48] sought to understand how DT reshapes the traditional logics underlying BPM. Their findings indicate that sustaining and

adapting business processes in the face of continuous organizational change requires the adoption of new process logics that are better suited to digital environments. For example, the authors highlight the emergence of infrastructural flexibility enabled by a novel Internet of Things (IoT) platform, which was intentionally designed to co-evolve with evolving business processes.

In a broader effort to synthesize the DT literature, Kraus and Durst [63] conducted a comprehensive mapping of the thematic evolution of DT research within business and management fields. They propose a synergistic framework that aligns existing DT scholarship with foundational management theories and practices, thereby offering a structured pathway for integrating DT into organizational strategies and operational models.

Collectively, these studies underscore the importance of reconciling DT initiatives with established business practices, advocating for adaptive frameworks that accommodate the dynamic interplay between technology and management. For example, integrating generative AI into green knowledge management—such as using AI to generate, synthesize, and disseminate sustainability-related insights—requires not only technological readiness but also strategic alignment with organizational values, environmental goals, and green knowledge-sharing practices. This highlights the need for organizations to develop green knowledge management capabilities and adapt their managerial structures and cultural norms to effectively harness the potential of advanced digital tools for sustainable innovation.

3.3.4. Disciplinary Boundaries of DT

As Wessel and Baiyere [49] have noted, both Information Systems (IS) scholars and practitioners continue to grapple with the conceptual boundaries and implications of DT. In response to this ambiguity, the present cluster comprises studies that seek to differentiate DT from conventional IT-enabled transformation, with a particular focus on conceptual clarity. Two critical distinctions between these forms of transformation were identified: DT leverages digital technologies to (re)define an organization's value proposition, whereas IT-enabled transformation utilizes digital technologies primarily to support existing value propositions, and DT is associated with the emergence of a new organizational identity, while IT-enabled transformation tends to reinforce or enhance the existing organizational identity.

Expanding on this conceptual agenda, Hund and Wagner [64] offer a revised definition and framework for digital innovation, arguing that prevailing conceptualizations fail to fully account for the dynamic and systemic nature of innovation in digital contexts. Similarly, Piccoli, Rodriguez, and Grover [65] contribute to this discourse by introducing the construct of digital resources, distinguishing it from more traditional constructs such as IT resources and IT-enabled resources, thereby clarifying the unique affordances and strategic potential of digital assets. Together, these contributions aim to sharpen the theoretical underpinnings of DT and foster a more nuanced understanding of how digital technologies differ in function and impact from earlier IT innovations.

3.3.5. Digital Leadership

The final cluster focuses on the emerging theme of digital leadership, emphasizing its pivotal role in enabling successful DT. Benitez and Arenas [51] make a significant theoretical contribution to the Information Systems (IS) literature by developing the concept of digital leadership capability. Their findings reveal that digital leadership enhances a firm's innovation performance by facilitating the digitalization of its platform infrastructure, thus enabling more agile and responsive operations. Building on this line of inquiry, Yao and Tang [66] argue that effective DT permeates all functional areas of an organization,

introducing both new opportunities and leadership challenges. Their study presents an innovative empirical measurement of both digital leadership and DT and confirms a positive relationship between the two—demonstrating that digital leadership serves as a critical enabler of transformation initiatives. Collectively, these studies highlight that beyond technological investments, leadership capabilities play a decisive role in steering organizations through the complexities of DT, and in ensuring that technological change is effectively translated into strategic and operational benefits.

4. Conclusions

4.1. Discussion of Results

DT is essential for all businesses and has fundamentally changed how they operate and deliver customer value. This study offers a comprehensive examination of the development trajectory of DT through the application of MPA. By analyzing 1790 scholarly articles over three decades, the research reveals the intellectual backbone of the DT literature and identifies the most influential studies shaping the field. Using key-route and multiple global MPA techniques, we uncover three distinct evolutionary phases of DT research: engagement, enablement, and enhancement. The engagement phase emphasizes the foundational reconfiguration of digital architectures and organizational capabilities; the enablement phase focuses on uncovering the dynamic patterns and contextual conditions that influence digital innovation; and the enhancement phase explores the managerial practices and strategic competencies necessary to realize effective DT in practice.

In this study, we addressed two research questions: RQ1 and RQ2. Using the key-route MPA, we identified 24 influential papers that have shaped the DT literature. The full list of these impactful papers is presented in Table 4, which relates to RQ1—pertaining to key research studies that influence the development of the DT field. Additionally, we answered RQ2 using multiple global MPA to identify the main focus areas and important contributions within each paper. Our analysis highlights popular sub-themes in the DT literature, including five key thematic trends identified through the multiple global MPA: reinvention of digital innovation affordance, value-creation paths of DT, synergistic DT with business and management practices, disciplinary boundaries of DT, and digital leadership. This approach is essential for understanding the current state of the field and forecasting its future.

The evolving landscape of DT research reveals a dynamic interrelationship among the five emerging themes, starting from how digital technologies continually reshape the possibilities for organizational action and enabling new forms of interaction, coordination, and value creation. As organizations increasingly pursue the synergistic integration of DT with business and management practices, they adapt and co-evolve their strategic, operational, and organizational capabilities. Consequently, the disciplinary boundaries of DT have become increasingly porous, blending insights from information systems, strategic management, organizational behavior, and innovation studies. Within this context, the evolution of digital leadership emerges as a critical response to the complexities introduced by digitalization. Digital leadership evolves in tandem with the expanding affordances of digital technologies and the increasing need to bridge cross-disciplinary knowledge in shaping value-driven transformation.

These themes not only reflect the diversification and maturation of the DT field but also highlight critical areas for future inquiry. As digital technologies continue to evolve, understanding how organizations adopt, adapt, and lead through DT will remain a central concern in information systems and management research. Additionally, we observe that digital transformation will affect organizations in various ways as technology progresses. That is why some scholars (e.g., Sony and Naik [67]) see digital transformation

as a sociotechnical process that merges social and technical elements working together toward a shared goal. Specifically, when digital transformation occurs in the AI field, ethical issues become a vital concern for all companies. For example, Borau [68] states that "the use of female AI agents, such as vocal assistants, chatbots, and robots, is on the rise, but the indiscriminate feminization of these AI agents poses novel ethical concerns about their impact on gender relations in society." While digital technologies offer great potential for innovation and efficiency, they also introduce new risks and vulnerabilities at social, organizational, and individual levels.

4.2. Implication

This study makes significant contributions to the DT literature by providing a comprehensive and systematic analysis of three decades of scholarly work. Unlike prior reviews that focus narrowly on specific aspects or rely on limited datasets, this research employs MPA to uncover the most influential studies within a complex citation network. By identifying key thematic trends and shifts in the development of DT research, the study offers valuable insights into the evolving nature of the field. The findings enhance our understanding of how DT scholarship has progressed and where promising avenues for future inquiry lie. Ultimately, this review serves as a foundational resource for new scholars seeking to grasp the current state of DT research and identify critical gaps and opportunities for future exploration.

For practitioners, the engagement–enablement–enhancement progression offers a systematic roadmap: (1) Engagement emphasizes hybrid infrastructures (e.g., IoT platforms + skills) to manage transformation risks; (2) Enablement applies configurational patterns to align ecosystem partnerships with innovation opportunities; and (3) Enhancement builds digital leadership to coordinate technological and organizational change [51,69]. This process turns DT into an adaptive learning system.

Furthermore, the findings of this study are highly useful for systems management practices in several ways: (1) Phase-based framework linkage: Clearly connects the three research phases (engagement–enablement–enhancement) to organizational digital transformation (DT) management practices. (2) Systems perspective integration: Describes organizations as complex adaptive systems that require phased capability development. (3) Actionable guidance: Offers concrete examples of how each phase influences strategic decisions, such as digital infrastructure investment during the engagement phase.

4.3. Study Limitations and Future Work

This study also has certain limitations. First, MPA primarily relies on citation information, which may lead to the exclusion of discontinuous concepts or disruptive innovations in the development of DT [70] and underrepresents seminal works that become "assumed knowledge" through indirect influence pathways. Second, the analysis is based solely on the Web of Science (WoS) database, so does not include articles from other sources [71]. This creates boundary permeability constraints that restrict the integration of gray literature and practitioner reports, which are vital in fast-changing DT domains within our knowledge system framework (Section 2.2). In addition, from a systems theory perspective, citation counts (traversal weights) represent one type of link or flow within the knowledge system but may not capture all nuances of influence (e.g., the impact of seminal works that become "assumed knowledge" and are less directly cited later, or the influence of practitioner reports and gray literature in a fast-moving field like DT). Consequently, the ability to comprehensively trace the developmental trajectory is constrained.

We acknowledge the potential limitation of using data filtered exclusively under the "Information Science & Library Science" category. As Paul and Criado [20] point out,

"many researchers and academics tend to select perhaps the most well-known bibliographic database, WoS. Relying mainly on Scopus to conduct a systematic literature review may yield an extensive list of references that could even exceed the word limits set by many journals." Accordingly, we have not conducted a cross-database comparison in the current study, which may lead to possible disciplinary bias and have implications in interpreting the main paths identified. For example, when considering the DT literature corpus defined as a bounded knowledge system, the fact that Scopus includes a larger number of engineering journals and conference proceedings than WoS can significantly influence research visibility, bibliometric analysis, and the perceived impact of scholarly output in the engineering and technology fields. The WoS focus may underrepresent interdisciplinary knowledge flows. Future studies should employ cross-platform validation to mitigate disciplinary bias.

This study used Pajek and MainPath 480 software to analyze citation networks and main paths. However, we recognize a key methodological limitation: both tools are closed-source and provide limited access to their algorithmic settings. We did not make any modifications or apply custom settings to the software; instead, we relied on the default configurations provided by the tools. As a result, we could not adjust or disclose specific configurations such as edge-weight normalization, traversal rules, or pruning thresholds. Additionally, because the software operates as a black box, we were unable to perform sensitivity analyses to assess how parameter changes might affect the citation paths. While the software manuals offer general guidance on their analytical frameworks, the lack of transparency in certain settings limits reproducibility and robustness checks. We see this as a constraint of the current study and recommend that future research consider using open-source or customizable tools to enable more thorough methodological validation.

While enhanced visualizations with interactive, metric-driven figures could further improve the analytical depth and user engagement of our findings, the current study is limited in this area due to technical constraints and software limitations. Future research could overcome this limitation by incorporating advanced visualization platforms or web-based interfaces to allow for more dynamic exploration of the results.

Our methodology also shares the limitations of citation-based analysis, potentially excluding interdisciplinary perspectives. Future DT research should implement ethical auditing of knowledge-mapping tools to mitigate algorithmic bias, as seen in public sector inclusion challenges [8,62].

Author Contributions: Conceptualization, T.-C.C.; methodology, T.-C.C., P.-S.W. and J.-R.C.; data collection, P.-S.W. and J.-R.C.; analysis and interpretation of results, T.-C.C. and J.-R.C.; writing—draft manuscript preparation, P.-S.W. and J.-R.C.; writing—review and editing, T.-C.C. and P.-S.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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