Diffusion of Innovations in the Digital Age: Trends, Hotspots, and Research Frontiers (1990–2025)

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ABSTRACT:

This study conducts a bibliometric review of Diffusion of Innovations (DOI) research in the digital age, drawing on 404 publications indexed in Scopus from 1990 to 2025. Using performance indicators, co-authorship analysis, and keyword co-occurrence mapping, it identifies long-term trends, influential contributors, thematic clusters, and research frontiers. Results reveal a sharp increase in DOI-related publications after 2010, peaking in 2024, with the United States as the leading contributor, while Malaysia, India, and China emerge as critical regional hubs. Thematic evolution shows a progression from early concerns with ICT adoption and the digital divide to organizational adoption models (TAM, TOE, UTAUT), and more recently, to emerging frontiers such as artificial intelligence, generative AI, ChatGPT, and blockchain.

This study provides one of the most comprehensive syntheses of DOI research across three decades, demonstrating its adaptability to digital transformation contexts. The findings offer insights for scholars advancing DOI theory, policymakers shaping digital innovation strategies, and practitioners managing technology adoption in complex ecosystems, while highlighting future opportunities in generative and immersive technologies.

Keywords: Diffusion of Innovations (DOI), Digital Transformation, Bibliometrics Analysis, Emerging Technologies, Innovation Adoption.

Introduction:

The Diffusion of Innovations (DOI) theory was first introduced in 1962 and later refined in subsequent editions [1, 2]. It has for decades served as a foundational framework for understanding how innovations spread among individuals, organizations, and societies. Its five stages of knowledge, persuasion, decision, implementation, and confirmation have guided empirical research across domains such as communication, education, health, and agriculture [2, 3]. In the field of information systems and organizational studies, DOI has also been extensively synthesized and applied [4]. In the digital age, this framework has gained renewed significance as the mechanisms of innovation diffusion have become faster, more complex, and increasingly shaped by technology [5]. Emerging technologies such as artificial intelligence (AI), robotic process automation (RPA), blockchain, and digital platforms are transforming industries and institutional practices, prompting fresh scholarly interest in the applicability of DOI theory [6-8]

In response to accelerating digital transformation, DOI theory has been widely adopted to analyze how organizations and individuals engage with new technologies [5]. It plays a central role in understanding the adoption behaviors of individuals and organizations in rapidly evolving digital ecosystems. At the same time, DOI has often been integrated with complementary models such as the Technology Acceptance Model (TAM) [9], the Technology–Organization–Environment (TOE) framework [10], and the Unified Theory of Acceptance and Use of Technology (UTAUT) [11], demonstrating its adaptability in digitally mediated contexts. Despite this renewed prominence, the literature remains fragmented, particularly in how DOI has been adapted and integrated with other models in digital contexts.

Despite its enduring relevance, gaps remain in the literature. Although DOI continues to be widely cited and applied, existing reviews are typically sector-specific or narrative in nature, with many focusing on areas such as healthcare or e-learning [3, 12, 13]. These reviews provide limited clarity on how DOI's theoretical core has expanded or adapted in response to digital-age dynamics. While bibliometric attempts exist, they often address innovation adoption broadly rather than specifically by DOI, leaving gaps in mapping its intellectual development [14, 15]. Broader adoption reviews, such as those examining UTAUT [16] and AI adoption [17], similarly point to the fragmented and cross-disciplinary nature of adoption scholarship. Thus, there remains a need for a comprehensive bibliometric synthesis that systematically maps the intellectual development and applications of DOI in the digital age.

This paper aims to provide a comprehensive bibliometric review of DOI-related research from 1990 to 2025, with an emphasis on digital transformation and emerging technologies. The specific objectives are:

- To trace the publication trends and geographical distribution of DOI research in the digital age.
- To identify the most influential authors, journals, institutions, and countries in this research domain.
- To uncover the thematic clusters and intellectual structures of DOI research as they relate to digital innovation.
- To highlight emerging topics and research frontiers that define the contemporary landscape of DOI applications.

Therefore, this study is guided by the following research questions:

1. What are the publication and geographical distribution trends in DOI research from 1990 to 2025?
2. Who are the most influential contributors (authors, journals, institutions, and countries) in DOI research?
3. What thematic clusters and intellectual structures characterize DOI-related studies in digital innovation contexts?
4. Which topics are emerging as new frontiers in the application of DOI theory to digital transformation?

The remainder of this paper is organized as follows. Section 2 reviews the origins and core concepts of DOI theory, its application in digital innovation, and identifies gaps in the literature. Section 3 outlines the methodological approach, including data sources, search strategy, data cleaning, and tools employed for bibliometric analysis. Section 4 presents the results of performance analysis, science mapping, and the identification of emerging research frontiers. Section 5 integrates the discussion and conclusion, interpreting the findings in relation to theoretical debates, outlining contributions and implications, and suggesting directions for future research.

1) Literature Review:

Despite its broad application, prior reviews are often narrative or domain-specific, focusing mainly on healthcare, education, or information systems, and thus fail to provide a comprehensive, cross-disciplinary synthesis of the field. This fragmentation highlights a critical gap in the literature.

2.1 Origins and Core Concepts of DOI Theory

The DOI theory was initially introduced in 1962 to explain how agricultural practices spread among farmers [1]. Since then, it has developed into one of the most influential frameworks for understanding the adoption of innovations across diverse fields, including communication, marketing, education, health informatics, and organizational studies [3, 4]. DOI highlights that innovation adoption is not merely a technical decision but a socially embedded process shaped by interpersonal communication, organizational culture, and broader institutional environments [2, 12].

Several conceptual pillars define DOI theory. One of the most widely cited contributions is the set of perceived attributes of innovations, namely relative advantage, compatibility, complexity, trialability, and observability. These attributes explain why some innovations spread faster than others, since technologies that are perceived as advantageous, compatible with existing practices, simple to use, amenable to limited experimentation, and visible in their results are more likely to be adopted [2, 10]. In addition to perceived attributes, DOI identifies four fundamental elements of diffusion: the innovation itself, the communication channels through which information flows, the time dimension that captures the pace of adoption, and the social system that provides the institutional and cultural context. Together, these elements emphasize that diffusion is both an individual cognitive act and a collective social phenomenon [18].

Roger (2003) further conceptualized adoption as a temporal process, captured in the innovation–decision framework. This process comprises the stages of knowledge, persuasion, decision, implementation, and confirmation, which together describe how individuals and organizations progress from initial awareness of an innovation to its routinization in practice. The framework underscores the dynamic and iterative nature of adoption, showing that decisions are subject to reinforcement, reconsideration, and contextual influence [3].

Through these interrelated constructs, DOI offers a comprehensive explanation of how innovations spread across different settings. Its adaptability has allowed it to bridge micro-level perspectives, such as individual perceptions of technology, with macro-level dynamics, such as organizational structures and social networks. This theoretical flexibility explains why DOI remains one of the most widely cited frameworks in technology adoption research [4, 12] and why it continues to provide explanatory value in contexts characterized by rapid technological change.

2.2 DOI Theory in the Context of Digital Innovation

The rapid advance of digital technologies has revitalized scholarly interest in the DOI theory. As organizations confront challenges of digital transformation, disruptive technologies, and

information system adoption, DOI has provided an analytical lens for understanding the conditions under which technologies are adopted, resisted, or institutionalized [19]. Recent research illustrates its applicability to a range of emerging technologies. For example, Xu, et al. [6] employed DOI to investigate longitudinal patterns of AI adoption in organizational settings, while Abdalla, et al. [20] applied the framework to examine the uptake of Generative-AI (Gen-AI) tools such as ChatGPT among students in business and management education. In the field of blockchain, Chhina, et al. [21] demonstrated how DOI can explain adoption barriers and enablers in emerging economies, highlighting institutional and infrastructural challenges. Similar perspectives have been applied to robotic process automation, where DOI has been used to analyze organizational determinants of adoption and usage [7]. In cloud computing, DOI has been combined with complementary perspectives to capture both individual and organizational adoption behavior [19].

In parallel, DOI has increasingly been hybridized with other theoretical frameworks to account for the layered realities of digital transformation. Integrations with the TAM [9], the TOE framework [10], and the UTAUT [11] illustrate efforts to extend DOI by incorporating contextual and organizational factors. Such theoretical pluralism reflects the recognition that innovation adoption in digital contexts is shaped not only by individual perceptions but also by technological infrastructures, institutional logics, and environmental contingencies.

2.3 Gaps in the Literature and the Need for a Bibliometric Perspective

Although the DOI theory has been widely applied across multiple domains, existing reviews remain fragmented in scope and limited in analytical depth. Much of the review literature is either narrative in orientation or sector-specific, with a concentration on healthcare, education, and information systems [3, 4, 13]. These works have provided valuable insights into adoption processes within particular contexts but offer little clarity on the broader theoretical trajectory of DOI across disciplines.

In recent years, scholars have employed bibliometric and science mapping methods to examine innovation adoption and digital innovation more generally [14, 15]. While such studies illuminate the intellectual structure of innovation research, they do not focus explicitly on DOI as a theoretical framework. As a result, how DOI has evolved, adapted, and been applied in the digital age remains underexplored. This lack of integrative synthesis makes it challenging to discern dominant themes, emerging frontiers, and the extent to which DOI continues to provide explanatory power in technology-driven environments.

A bibliometric perspective is well-suited to address this gap. Unlike narrative reviews, bibliometric methods systematically analyze publication and citation patterns to identify influential authors, institutions, and journals, as well as thematic clusters and intellectual linkages [22]. Applying these techniques to DOI-related research from 1990 onwards, a period marked by the global spread of digital technologies, offers the opportunity to consolidate fragmented findings, trace thematic evolution, and highlight underexplored domains. Such a synthesis not only contributes to theoretical consolidation but also provides a roadmap for future research, ensuring that DOI remains a relevant and adaptive framework for studying digital transformation and emerging technologies.

Table 1 summarizes the most influential review studies of DOI theory across different domains. While these reviews provide valuable insights within their respective sectors, they are either narrative or conceptual in orientation and remain limited in scope. None provides a comprehensive bibliometric synthesis of DOI research in the context of digital transformation and emerging technologies.

Table 1: Summary of Existing Review Studies on DOI Theory, 1995–2025

Domain	Type of Review	Representative References	Key Features and Limitations
Healthcare and Health Services	Systematic review	Greenhalgh et al. (2004)	Comprehensive synthesis of DOI in health service organizations. Provides implementation insights but is limited to the healthcare sector.
Public Health	Narrative review	Dearing & Cox (2018)	Summarizes DOI principles and applications in health policy and practice. Valuable for conceptual clarity but not systematic.
Education and E-learning	Narrative review	Şahin (2006)	Reviews DOI applications in educational technology. Sector-specific and lacks broader generalization.
E-health/ Medical Informatics	Literature review	Zhang et al. (2015)	Uses DOI to explain patient acceptance of e-health technologies: narrow focus and limited cross-sector relevance.
Information Systems	Integrative review	Jeyaraj et al. (2006)	Synthesizes IT/IS adoption literature and includes DOI as a key framework. Broad but not exclusively focused on DOI's theoretical evolution.
Innovation Management	Critical review	MacVaugh & Schiavone (2010)	Critiques DOI's limitations in complex settings and proposes integrative models. Highlights theoretical gaps rather than empirical synthesis.
Sociology/ General Theory	Conceptual review	Wejnert (2002)	Integrates models of innovation diffusion into a conceptual framework. A strong theoretical orientation, but with limited empirical application.
Innovation Adoption	Bibliometric review	van Oorschot et al. (2018)	Maps the intellectual structure of innovation adoption literature. Focuses on adoption research broadly rather than DOI specifically.
Digital Innovation	Bibliometric review	Alaassar et al. (2025)	Examines digital innovation research using bibliometric methods. Provides methodological insights but does not center on DOI.

Source: Compiled by the Author Based on Literature Review.Methods

To address this gap, the study adopts a bibliometric approach, which enables systematic mapping of publication trends, influential contributors, thematic evolution, and emerging research frontiers.

3.1 Search Strategy and Data Source

To systematically examine how DOI theory has been applied within the context of emerging information technologies, a structured bibliometric search was conducted using the Scopus database. Scopus was chosen for its extensive disciplinary coverage, reliable citation tracking, and compatibility with bibliometric tools [23]. The search strategy followed PRISMA guidelines for systematic reviews [24, 25] and was informed by recent bibliometric studies in information systems and innovation research [26]. The query targeted the fields of Article Title, Abstract, and Keywords (TITLE-ABS-KEY), which most directly reflect a publication's core content and research intent. The search combined theoretical terms associated with DOI (e.g., "diffusion of innovation", "DOI theory") with digital and emerging technology terms (e.g., artificial intelligence (AI), information and communication technology (ICT), automation, blockchain, cloud computing).

To maintain focus and comparability, the dataset was confined to peer-reviewed journal articles and reviews published in English between 1990 and 2025. The disciplinary scope was limited to social sciences, computer science, business, and engineering, reflecting the primary domains in which DOI has been applied to digital transformation and emerging technologies. Reliance on Scopus ensured comprehensive and standardised coverage of indexed journals. These delimitations provided a rigorous and thematically focused dataset. The final search, conducted on 8 May 2025, yielded an initial corpus of 404 records. No manual screening was applied, in order to minimise subjective bias and to preserve reproducibility [22].

3.2 Data Collection

The bibliographic data were exported from Scopus in CSV format, which included standard metadata: document title, author(s), source title, publication year, author affiliations, keywords (author and indexed), abstracts, and reference lists. Citation counts and Digital Object Identifiers (DOIs) were also retained. The 35-year range was selected to capture both foundational and recent contributions and to allow for the identification of longitudinal trends in DOI theory research across technological domains.

3.3 Data Cleaning and Harmonization

Before initiating the bibliometric analysis, a critical preprocessing phase was undertaken to ensure the accuracy, consistency, and interpretability of the dataset. Bibliographic metadata retrieved from Scopus often contain inconsistencies in author names, institutional affiliations, country nomenclature, and keyword usage, which, if uncorrected, can distort co-authorship mapping, institutional productivity assessment, and thematic clustering.

To address these issues, a two-step cleaning and harmonization procedure was applied using BiblioMagika [27] and OpenRefine [28]. These tools were employed to standardize author names, institutions, countries, and keywords, thereby ensuring consistency in subsequent analyses.

Through this integrated preprocessing workflow, the dataset was refined to minimize redundancy, reduce noise, and enhance analytical validity. The harmonized data provided a robust foundation for constructing networks, analyzing trends, and exploring thematic structures within the bibliometric framework.

3.4 Tools

This study employed a suite of bibliometric tools to evaluate research performance and visualize the intellectual and conceptual landscape of DOI-related scholarship. BiblioMagika was used for performance analysis, reporting key indicators such as Total Publications (TP), Number of Cited Publications (NCP), Total Citations (TC), Citations per Publication (C/P), and h-, g-, and m-indices at the author level. For institutions and countries, only TP, TC, and C/P were reported to ensure appropriate interpretation. These metrics provided insights into research productivity,

citation impact, and scholarly influence across different units of analysis.

VOSviewer (v1.6.20) was employed for keyword co-occurrence analysis, enabling the identification of thematic clusters and the mapping of the field's conceptual structure [29]. Its visualization functions highlighted relationships among frequently co-occurring terms and revealed both established topics and emerging trends.

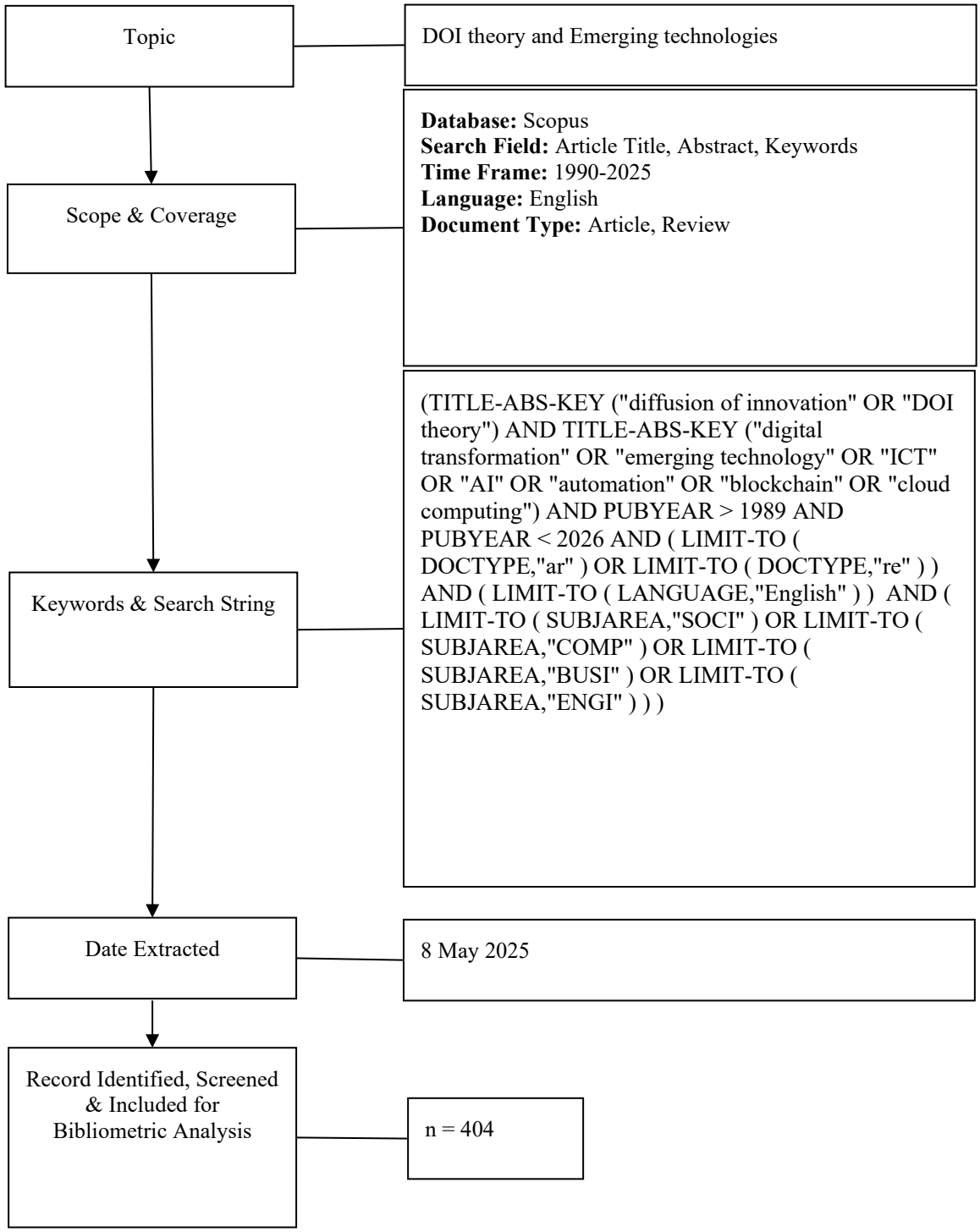

Figure 1. Flow diagram of the search strategy.
Source: [24, 26]

RESULTS

This section presents the findings of the bibliometric analysis. The results are organized into descriptive performance indicators and science mapping outputs to capture both publication trends and the intellectual structure of DOI research.

4.1 Performance Analysis

This section presents a performance analysis of DOI-related research from 1990 to 2025. It examines publication trends, authorship patterns, institutional contributions, country-level outputs, and source titles to provide a comprehensive overview of the field's growth and distribution.

a. Publication Trends

Figure 2 illustrates the annual publication output and citation dynamics of research related to the DOI. Publication activity rose gradually after 2005 and accelerated sharply after 2015, reaching a record 67 papers in 2024. Citation peaks, however, occurred in earlier years (2006, 2007, 2013, and 2021), reflecting the long citation half-life of seminal works and the disproportionate influence of a few highly cited studies.

The decline in citations from 2023 onward is consistent with citation latency [30, 31], as newer works have had limited time to accumulate impact. Taken together, the figure shows that DOI scholarship is expanding in scale but remains shaped by episodic intellectual breakthroughs, underscoring Rogers' (2003) observation that diffusion is often driven by influential opinion leaders rather than sheer volume of contributions.

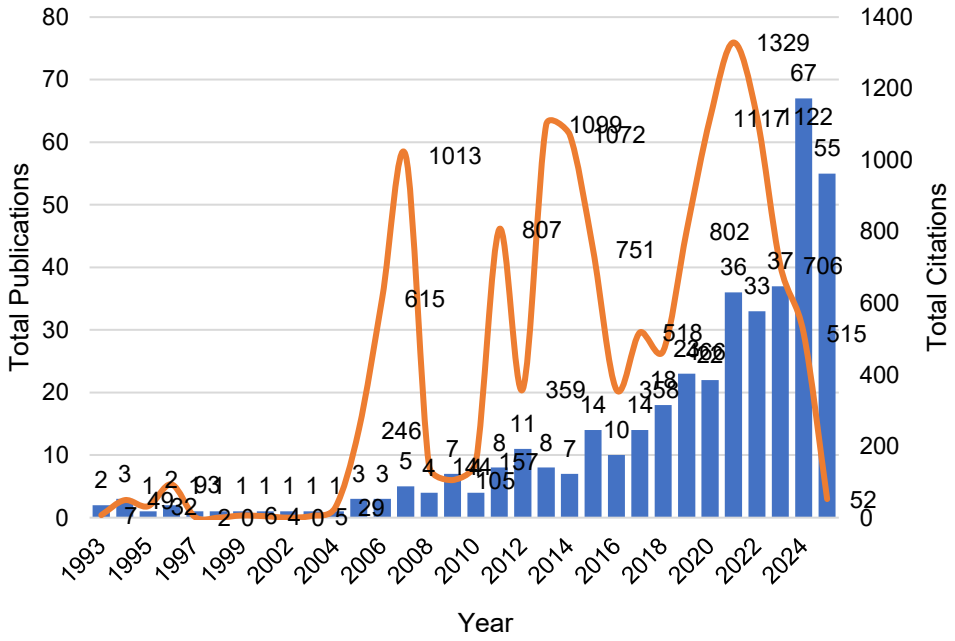

Figure 2. Total Publications and Citations by Year
Source: Generated by the author(s) using biblioMagika®[27]

b. Publications by Authors

Table 2 presents the top ten most productive authors in the field of DOI theory as applied to emerging technologies, assessed by total publications (TP), citation impact, and bibliometric indices. All listed authors have published at least two articles, with six producing three each, indicating a modest but consistent body of work in this domain.

In terms of influence, Wamba, Samuel Fosso (TBS Business School, France) is the most impactful contributor, with the highest total citations (TC = 210), citations per publication (C/P = 70.00), and a strong m-index (0.750). The use of h-, g-, and m-indices follows established bibliometric measures[32-34]. Bhardwaj, Amit

Kumar (India), Ali, Omar (Kuwait), and Shrestha, Anup (Australia) also demonstrate considerable visibility, each exceeding 150 citations and maintaining C/P values above 55. Alzahrani, Ahmed Ibrahim (Saudi Arabia) and Rana, Nripendra P. (Qatar), despite having only two publications, record exceptionally high C/P ratios of 92.00 and 89.00, respectively, showing that even limited outputs can exert a notable impact. By contrast, authors such as Athambawa, Aiman (Malaysia), and Odeh, Mahmoud (Jordan) record lower citation counts, which may reflect more recent or niche contributions. Overall, this author-level analysis highlights not only patterns of productivity but also the disproportionate influence a small group of scholars can exert in shaping DOI-related discourse. The geographical diversity of affiliations, spanning Africa, the Middle East, Asia, Europe, and Australia, further illustrates the global diffusion of DOI research in digital and emerging technology contexts.

Table 2. Most Productive Authors

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	h	g	m
Mbatha, Blessing	University of South Africa	South Africa	3	3	53	17.67	3	3	0.200
Ali, Omar	American University of the Middle East	Kuwait	3	3	167	55.67	3	3	0.375
Tseng, Ming-Lang	Asia University	Malaysia	3	3	40	13.33	3	3	1.000
Bhardwaj, Amit Kumar	Thapar Institute of Engineering and Technology	India	3	3	187	62.33	3	3	0.500
Shrestha, Anup	University of Southern Queensland	Australia	3	3	167	55.67	3	3	0.375
Wamba, Samuel Fosso	TBS Business School	France	3	3	210	70.00	3	3	0.750
Odeh, Mahmoud	Zarqa University	Jordan	2	1	18	9.00	1	2	0.250
Alzahrani, Ahmed Ibrahim	King Saud University	Saudi Arabia	2	2	184	92.00	2	2	0.222
Rana, Nripendra P.	Qatar University	Qatar	2	2	178	89.00	2	2	0.500
Athambawa, Aiman	Management and Science University	Malaysia	2	2	12	6.00	2	2	0.500

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; h=h-index; g=g-index; m=m-index.
Source: Generated by the author(s) using biblioMagika®[27]Publications by Institutions

Table 3 lists the most productive institutions in DOI-related research, each contributing at least five publications. Malaysian universities dominate the list, with Universiti Utara Malaysia, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, and Universiti Teknologi MARA accounting for a combined total of 37 papers. Among them, Universiti Teknologi Malaysia stands out not only for productivity (TP = 10) but also for its strong citation performance (TC = 358; C/P = 35.80), suggesting that its contributions are both frequent and influential. This concentration reflects Malaysia's strategic

emphasis on digital innovation and the diffusion of technology in academic research.

Beyond Malaysia, several global institutions exhibit high-impact, low-volume profiles. Michigan State University (USA) recorded only five publications but achieved the highest citation average (C/P = 47.80), indicating the presence of highly influential studies. Similarly, Aalborg University (Denmark) and Monash University (Australia) demonstrate strong citation metrics relative to output, while the Hong Kong Polytechnic University shows comparable performance in the Asian context. These patterns highlight a distinction between institutions driving research volume and those contributing seminal, widely cited work, both of which are essential to the intellectual development of DOI theory.

Table 3. Most productive institutions with minimum of five publications

Institution Name	Country	TP	TC	C/P
Universiti Utara Malaysia	Malaysia	11	121	11.00
Universiti Teknologi Malaysia	Malaysia	10	358	35.80
Universiti Kebangsaan Malaysia	Malaysia	9	106	11.78
Universiti Teknologi MARA	Malaysia	7	28	4.00
Aalborg University	Denmark	6	138	23.00
University of Pretoria	South Africa	6	89	14.83
University of South Africa	South Africa	6	105	17.50
Hong Kong Polytechnic University	Hong Kong	5	98	19.60
Monash University	Australia	5	114	22.80
Michigan State University	United States	5	239	47.80

Notes: TP=total number of publications; TC=total citations; C/P=average citations per publication
Source: Generated by the author(s) using biblioMagika®[27]

c. **Publications by Countries**

Table 4 highlights the leading countries in DOI-related research, ranked by total publication output. The United States clearly dominates with 94 publications and the highest citation volume (TC = 4,830), resulting in a strong C/P of 51.38. The United Kingdom, despite fewer publications (TP = 28), achieves the highest citation impact (C/P = 92.21), indicating a more petite but exceptionally influential body of work. Canada also demonstrates a high-impact, low-volume profile with an average of 79.70 citations per paper, underscoring the presence of seminal contributions.

Such national-level patterns are consistent with prior bibliometric findings on cross-country publication and collaboration dynamics [35]. In contrast, Malaysia, India, and China demonstrate high publication volumes with growing scholarly

visibility, collectively contributing over 110 papers. Malaysia, in particular, shows strong institutional involvement, though with a comparatively lower C/P of 19.16, reflecting a focus on research volume. India and China balance productivity with moderate citation performance, each registering around 800 to 989 citations, reflecting their expanding roles in global innovation research. The presence of countries from Asia, North America, Europe, and Africa signifies the global diffusion of DOI theory, with different national profiles emphasizing either productivity, impact, or a balance of both.

Table 4. Top 10 Countries contributed to the publications

Country	TP	TC	C/P
United States	94	4830	51.38
Malaysia	50	958	19.16
India	32	989	30.91
China	29	800	27.59
Australia	29	770	26.55
United Kingdom	28	2582	92.21
South Africa	21	511	24.33
Canada	20	1594	79.70
France	15	697	46.47
Turkey	13	304	23.38

Notes: TP=total number of publications; TC=total citations; C/P=average citations per publication
Source: Generated by the author(s) using biblioMagika® [27].

d. Publications by Source Titles

Table 5 presents the top five source titles contributing to the DOI-related literature, indicating both volume and impact of publication. Information Development ranks highest in terms of output, with eight publications, all of which are cited, resulting in a consistent C/P and C/CP of 36.00 and an h-index of 6. Similarly, Technological Forecasting and Social Change maintains a balance between productivity (TP = 7) and strong citation performance (C/P = 40.00), reflecting its prominence as a venue for forward-looking research on innovation diffusion in technological contexts.

Sustainability (Switzerland), although tied for fourth in output (TP = 5), records the highest average citations per publication (C/P = 44.60) and the highest m-index (0.800), indicating both short-term influence and potential for lasting impact. Technology in Society and Education and Information Technologies also contribute meaningfully, with citation metrics that affirm their role as reputable outlets for DOI scholarship. These findings suggest that DOI-related research is being disseminated through interdisciplinary journals, particularly those positioned at the intersection of technology, society, and policy, highlighting the broad relevance of DOI theory across academic domains. These findings are consistent with bibliometric guidelines emphasizing the role of source titles in shaping intellectual domains [22].

Table 5. Most active source titles

Source Title	TP	TC	C/P	h
Information Development	8	288	36.00	6
Education and Information Technologies	7	116	16.57	4
Technological Forecasting and Social Change	7	280	40.00	6
Technology in Society	5	100	20.00	4
Sustainability (Switzerland)	5	223	44.60	4

Notes: TP=total number of publications; TC=total citations; C/P=average citations per publication; h=h-index
Source: Generated by the author(s) using biblioMagika®[27]

4.2 Science Mapping

Co-occurrence analysis of author keywords is a widely used bibliometric technique for uncovering the thematic structure of a research field [36]. In this study, VOSviewer was used to generate a co-occurrence network in which nodes represent keywords and links indicate their co-occurrence across documents [37]. Frequently co-occurring keywords denote conceptual proximity, which makes it possible to infer thematic clusters and identify the intellectual organization of a research domain [38]. This approach provides a visual map of how topics within DOI research interrelate and evolve.

The analysis employed the full counting method, with a threshold of five minimum occurrences, thereby reducing the initial pool of 1,149 author keywords to 41. Keyword co-occurrence used full counting with a minimum occurrence threshold of 5 to balance interpretability and coverage; robustness checks with thresholds of 4 and 6 yielded similar cluster configurations[39, 40]. This filtering ensured analytical clarity by focusing on terms with substantive representation. Node size reflects keyword frequency, link thickness indicates the strength of co-association, and distinct colors represent clusters. The resulting network highlights both the breadth and the depth of author-defined research priorities in DOI-related studies.

Cluster 1 (Blue): Digital Innovation and Transformation

This cluster encompasses research focused on digital transformation, technological modernization, and national-level adoption contexts. The prominence of terms such as digital transformation (22 occurrences), emerging technologies (16), and industry 4.0 reflects efforts to understand how digital diffusion reshapes organizations and policies. Early studies addressed issues of the digital divide, including rural broadband access [41] and sustainable internet use in Malaysia [42], alongside conceptual and policy debates on what constitutes the "digital divide"[43] and how diffusion unfolds in ICT policy contexts [44]. More recent work shifts toward strategic, sectoral, and national views of digital transformation, such as enterprise-focused syntheses of digital innovation [45], public-sector transformation frameworks at the national level [46], and Industry 4.0–driven transformation in supply chains [47, 48]. Regional studies further illustrate how national and cultural contexts shape diffusion mechanisms [49]. Together, these works demonstrate DOI's utility for analyzing both persistent inequalities and newer waves of organizational/national digital modernization.

Cluster 2 (Teal): Organizational and Social Implementation

Cluster 2 reflects research on technology adoption in organizational and governmental settings, with particular attention to developing countries and professional domains. Frequently occurring terms such as ICT, SMEs, and e-government emphasize the practical application of DOI in enterprise innovation and public sector modernization. Recent studies demonstrate how DOI is integrated with complementary models such as UTAUT and operationalized through survey-based, quantitative approaches, including structural equation modelling (SEM). For example, Aamir, et al. [50] analyzed multisided platforms from the perspective of travel agents, while Ayyash and Salah [51] examined AI adoption in Palestinian universities, illustrating organizational readiness and resource constraints in higher education. Wagner, et al. [52] investigated AI adoption in medical education, linking professional competences and trust with diffusion outcomes, whereas Colvin and Benjamin [53] studied the adoption of AI avatars by therapists, highlighting sociotechnical and ethical factors. Methodological contributions, such as recommender system adoption modeling [54], further demonstrate the prevalence of SEM in operationalizing DOI attributes. This cluster thus captures an evolving strand of DOI research that links individual attitudes with broader concerns regarding organizational and policy adoption.

Cluster 3 (Green): Diffusion of Innovation Core

At the center of the network is the theoretical core of DOI research. The largest node, diffusion of innovation (197 occurrences), anchors this cluster and connects foundational concepts with contemporary applications [2]. Keywords such as blockchain, supply chain management, and institutional theory show how DOI has been adapted to new technological and organizational domains. For example, Moraes, et al. [55] applied DOI to explain blockchain adoption in supply chains, while Asante Boakye, et al. [56] highlighted adoption enablers in small-business supply-chain finance, and Akbari, et al. [47] discussed supply-chain digital transformation in the context of Industry 4.0. Institutional perspectives on diffusion and technology adoption are reflected in recent studies [50, 57]. The inclusion of social media demonstrates DOI's application to consumer technologies [54], while research on technology adoption in higher education [51]signals its continued relevance across domains.. This cluster highlights DOI's dual role as a theoretical foundation and a practical tool for analyzing adoption in evolving digital ecosystems.

Cluster 4 (Purple): Cloud and Education-Oriented Adoption

Cluster 4 focuses on adoption research in infrastructural and educational environments, particularly cloud computing (50 occurrences) and educational technology. Central to this cluster are the TOE framework (45) and TAM, which are frequently integrated with DOI to capture both individual and organizational determinants of adoption. Oliveira, et al. [19] provided one of the foundational analyses of cloud adoption across manufacturing and service sectors, while Rohani and Hussin [58] extended the discussion to higher education through a framework for university technology transfer offices. Earlier work, such as Alshamaila, et al. [59] and Wu, et al. [60], illustrated adoption dynamics in SMEs and supply chain infrastructures, establishing cloud computing as a fertile site for DOI-based inquiry. More recent contributions have advanced this line of research: Kumar, et al. [61] examined cloud adoption and organizational agility in SMEs using SEM, Tella, et al. [62] applied DOI to ICT adoption in libraries, and Qashou, et al. [63]investigated mobile cloud computing in higher education. In addition, infrastructural perspectives have been highlighted by studies of technology adoption in large-scale projects [64]. Together, these works demonstrate how DOI is applied in conjunction with complementary frameworks to explain adoption in education and infrastructure, showing both continuity with earlier models and responsiveness to contemporary digital transformation.

Cluster 5 (Yellow): AI and Generative Technologies

This cluster represents the most rapidly emerging research frontier. Anchored by artificial intelligence (58 occurrences), it also includes gen-AI and ChatGPT, marking the rise of generative technologies in DOI-related studies. These keywords are associated with recent publication years, confirming their novelty and future relevance. Radhakrishnan, et al. [65] examined how organizations progress in their AI adoption journey, while Al-Dhaen, et al. [66] emphasized responsible AI in healthcare contexts. Fang, et al. [67] linked AI adoption to digital transformation in supply chain management. Building on these developments, Russo [68] analyzed the complexity of generative AI (Gen-AI) adoption in software engineering, and Wagner, et al. [52] demonstrated the relevance of DOI to AI adoption in digital health. Applications extend further to higher education [53] and therapy [51]. The co-occurrence of big data and IoT links this cluster to broader digital transformation themes, but the emphasis on generative models signals a new trajectory for DOI applications. Unlike earlier clusters that focus on infrastructure or behavioral intention, this cluster addresses disruptive innovations that raise issues of trust, ethics, and governance. It highlights DOI's capacity for extension but also its need for hybridization with other frameworks when dealing with frontier technologies.

Cluster 6 & 7 (Light Green & Light Yellow): Peripheral and Emerging Topics

The final clusters represent smaller but noteworthy areas of DOI research. Cluster 6 emphasizes developing countries, educational technology, and trust, highlighting sociotechnical studies that focus on digital inequality and adoption in low-resource settings. Ayyash and Salah [51] examined AI adoption in Palestinian universities, illustrating how resource constraints and institutional contexts shape diffusion. Issues of trust and educational applications are reflected in studies on Gen-AI in learning environments [69, 70], which highlight how student perceptions and acceptance mediate adoption outcomes. Cluster 7, defined by the keyword virtual reality, indicates a niche but emerging strand of research. Although marginal in current DOI scholarship, VR exemplifies the exploratory edge of DOI applications. Studies such as Abdul Waheed and Panneerselvam [71] on VR adoption in secondary education, Park, et al. [72] on consumer use of VR in sports, and Jin and Ryu [73] on AI–VR convergence in metaverses illustrate how immersive technologies intersect with DOI, trust, and digital inequality. Together, these works show how VR, while still peripheral, is becoming a fertile testing ground for extending DOI into frontier contexts.

The co-occurrence analysis reveals both consolidation and diversification in DOI-related scholarship. Foundational constructs such as diffusion of innovation, adoption, and ICT continue to anchor the field, while thematic clusters on cloud computing, AI, ChatGPT, and blockchain highlight the extension of DOI into new digital frontiers. The frequent integration of DOI with models such as TAM, TOE, and UTAUT underscores its interdisciplinary adaptability, enabling multi-level analyses of individual, organizational, and institutional factors. Overall, the science mapping analysis demonstrates that DOI research in the digital age is characterized by a stable theoretical core and dynamic expansion into emerging technologies, confirming both the continuity and the adaptability of the diffusion framework.

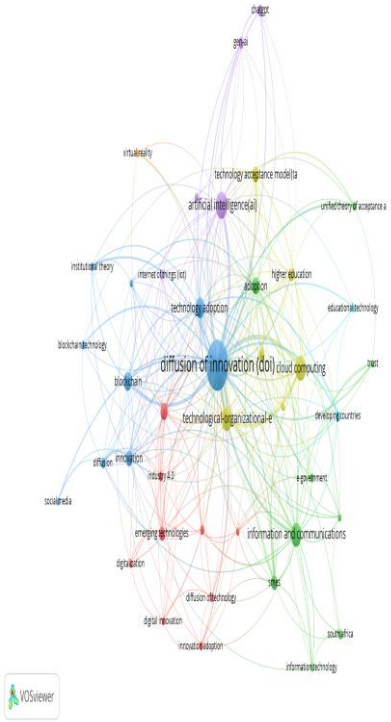

Figure 4. Network visualization of the co-occurrence analysis of author keywords
Source: Generated by the author(s) using VOSviewer (van Eck & Waltman, 2014)

4.3 Emerging Frontiers

The overlay visualization in Figure 5 uses a color gradient (blue to yellow) to illustrate the temporal evolution of keywords in the DOI literature. Keywords shaded in blue represent earlier contributions (pre-2016), while those in yellow correspond to more recent research trends (post-2022).

Early Period (2010–2016): Foundational and Contextual Themes

The early phase of DOI scholarship focused heavily on foundational concepts and regional applications. Keywords such as diffusion of technology (2014.7), digital divide (2015.7), information and communications technology (ICT) (2015.6), and developing countries (2016) reflect a concern with technological inequality and access, particularly in Global South contexts such as Malaysia, South Africa, and Brazil. These studies grounded the theoretical application of DOI in developmental policy, infrastructure, and

socio-economic disparities. For example, Mkhize, et al. [74] applied a DOI perspective to evaluate the usage of learning management systems in open and distance education, while Oliveira, et al. [19] analyzed the determinants of cloud computing adoption in organizations. Work on cloud adoption in education [75] and national innovation foresight in Brazil [76] further demonstrates how infrastructural capacity and policy initiatives condition diffusion processes.

Middle Phase (2017–2021): Institutionalization and Model Integration

From 2017 onward, research began shifting toward institutional factors and modeling approaches. Concepts like innovation, cloud computing, technology adoption, and adoption itself were widely discussed around 2019–2020. The emergence of frameworks such as TAM, TOE, and UTAUT, along with methods like structural equation modeling, reflects methodological maturation and a growing interest in explaining adoption behaviors empirically. Domains such as SMEs, higher education, and e-government became prominent fields of application. Representative studies include Perdana, et al. [77], who examined blockchain diffusion through competing discourses, and Bhatti, et al. [78], who analyzed information security adoption in IT outsourcing from a DOI perspective. Higher education adoption was explored by Jayasundara [79] in the context of e-books, while studies from developing countries highlight contextual challenges, including ICT solutions for healthcare in South Africa [80] and determinants of cloud-based e-learning adoption in Nigeria [81].

Recent Period (2022–2024): AI, Generative Tech, and Digital Innovation

The most recent research trajectory is strongly oriented toward advanced digital technologies and their implications. Emerging keywords such as gen-AI (2024.4), ChatGPT (2024.3), AI (2023.6), digital transformation (2023.5), blockchain (2022.7), and big data (2022.4) represent a significant thematic pivot toward intelligent, data-driven, and generative systems. This suggests that DOI theory is now being applied to understand the adoption and diffusion of highly dynamic, disruptive technologies in both organizational and societal contexts. Recent works, Russo [68] analyzed the complexity of Gen-AI adoption in software engineering, while Smit, et al. [82] integrated DOI with the TOE framework to explain AI adoption in sociotechnical systems. Research on consumer technologies, such as recommender systems [54], and student perspectives on GenAI in education [69] highlights DOI's role in shaping behavioral and trust-related outcomes. Broader digital innovation and transformation themes are addressed by Campagna and Bhada [45], who reviewed strategic adoption at the enterprise level. Collectively, these works demonstrate how DOI is being applied to frontier technologies, where issues of governance, ethics, and organizational readiness are paramount.

This temporal mapping reveals the progressive deepening and broadening of DOI theory's application. Initially focused on foundational access and development issues, the research has evolved to incorporate theoretical refinement, empirical validation, and technological sophistication. The emergence of AI and generative technologies as dominant keywords highlights a shift from understanding why people adopt to how they interact with, personalize, or co-create technological change. Overall, this evolution demonstrates DOI theory's theoretical resilience and adaptability. Its integration with behavioral models (TAM, UTAUT), organizational frameworks (TOE), and emerging technologies (AI, blockchain, gen-AI) shows that it continues to offer a robust lens for analyzing adoption patterns in increasingly complex and dynamic innovation environments.

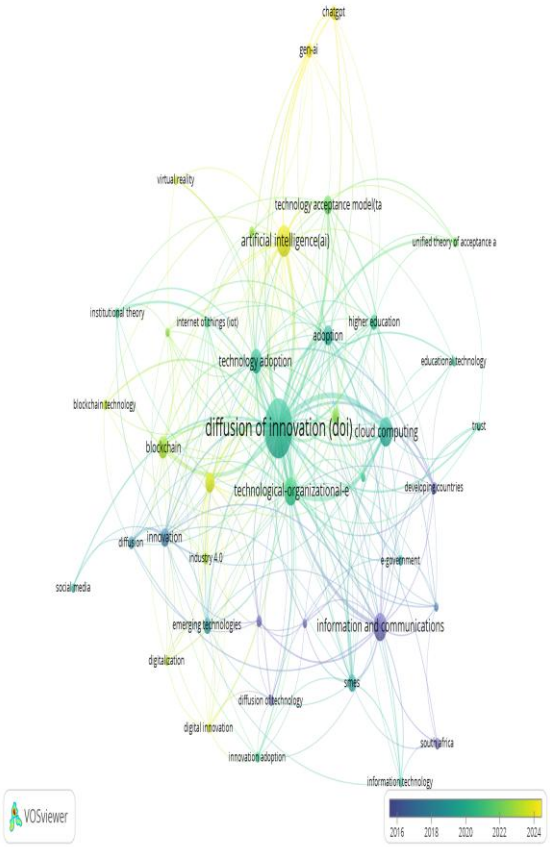

Figure 5. Overlay visualization of the co-occurrence analysis of author keywords
Source: Generated by the author(s) using VOSviewer (van Eck & Waltman, 2014)

2) DISCUSSION AND CONCLUSION

The findings of this study offer comprehensive insights into the evolution of DOI research in the digital age. The bibliometric trends confirm steady growth since 2010, reaching a peak in 2024, and illustrate the geographical diversification of scholarship. While the United States continues to dominate in terms of productivity and citations, emerging economies such as Malaysia, India, and China have become important hubs, reflecting the globalization of DOI-related research. This resonates with the broader observation that diffusion research evolves cumulatively across societies and highlights the increasing relevance of DOI for contexts outside the Global North (e.g., [42, 49].

In terms of influential contributors, the results reveal that a small group of authors and institutions exerts disproportionate impact. Scholars such as Wamba, Bhardwaj, and Ali, and institutions such as Universiti Teknologi Malaysia and Michigan State University, have produced widely cited works. Journals like Technological Forecasting and Social Change and Information Development serve as leading outlets. This concentration of influence reflects the role of opinion leaders in diffusion processes, suggesting that academic dissemination itself follows the dynamics of innovation. To avoid over-reliance on a limited set of actors, future research should encourage cross-institutional and cross-regional collaborations that foster greater diversity and inclusivity.

Thematic mapping further clarifies the intellectual structure of DOI scholarship, revealing six clusters that span digital transformation, organizational and social implementation, the theoretical core of DOI, cloud and education-oriented adoption, AI and generative

technologies, and peripheral emerging topics. These clusters show that DOI's innovation attributes remain central to adoption studies, but they are increasingly combined with complementary frameworks such as TAM, TOE, and UTAUT [19, 82]. Such integration demonstrates the adaptability of DOI theory and its capacity to capture complex, multi-level dynamics in digital transformation.

The analysis of emerging frontiers highlights a strong pivot toward disruptive technologies, including AI, Gen-AI, ChatGPT, blockchain, and immersive technologies. Studies such as Russo [68] on Gen-AI adoption in software engineering, Tantivejakul, et al. [69] on student perceptions of Gen-AI in education, and Abdul Waheed and Panneerselvam [71] on VR adoption in schools illustrate how DOI is being applied at the frontier of technological innovation. These works show DOI's continuing utility for framing adoption drivers. However, they also reveal their limitations in addressing trust, governance, and ethical regulation, signaling the need for hybrid models that integrate sociotechnical and ethical perspectives.

Taken together, these findings confirm the theoretical resilience of DOI while underscoring the need for continuous adaptation and adjustment. Theoretically, this study demonstrates that DOI remains relevant but increasingly functions as a flexible framework that must be extended through integration with organizational and contextual models. Methodologically, it contributes a cross-disciplinary bibliometric synthesis that consolidates fragmented strands of research. Practically, it highlights the implications for policymakers and practitioners, particularly in supporting digital adoption in emerging economies and designing strategies that reflect DOI attributes such as relative advantage, compatibility, and complexity [41, 51].

The study has certain limitations. First, the reliance on selected terminologies and specific keywords may have excluded works framed under alternative expressions, especially in emerging domains. Second, the disciplinary scope was intentionally limited to social sciences, computer science, business, and engineering, which may have overlooked relevant contributions from adjacent fields such as health sciences or communication studies. Third, the exclusive use of Scopus ensured consistency and comparability but excluded publications indexed in other databases. While these boundaries restrict coverage, they also reflect deliberate design choices that ensured rigor, coherence, and focus. Future research could address these limitations by expanding keyword strategies, including a broader set of disciplines, triangulating with additional databases, and complementing bibliometric mapping with qualitative or mixed-method approaches to deepen interpretive insights.

In conclusion, this bibliometric synthesis consolidates three decades of DOI research in digital contexts, tracing its trajectories from foundational studies on digital inequality to recent explorations of generative technologies. By illuminating past developments and future frontiers, it provides a roadmap for scholars, policymakers, and practitioners to engage with the opportunities and challenges

diffusion in an era increasingly shaped by disruptive and generative technologies.

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