

Mapping Research Trends In Information Infrastructure: A Bibliometric Review of Computer Science And ICT (2013–2023)

Pemetaan Trend Penyelidikan Dalam Infrastruktur Maklumat: Tinjauan Bibliometrik Sains Komputer dan ICT (2013–2023)

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ABSTRACT

This study presents a comprehensive bibliometric analysis of research trends in information infrastructure (Infostructure) within the Computer Science and Information and Communication Technology (ICT) domains, covering publications from 2013 to 2023. Utilising the Scopus database, 1179 articles were systematically analysed through keyword searches, using VOSViewer for mapping publication trends, keyword co-occurrence, and citation analysis. The findings reveal key research clusters, including network and communication technologies, data management, security and privacy, and digital transformation, with China, Russia and the United States leading in contributions. A notable increase in publications was observed from 2020 onwards, signaling a growing interest in Infostructure's role in digital transformation. While the study focused on English language articles, future research should consider expanding to broader datasets and interdisciplinary perspectives. This research provides a valuable foundation for understanding Infostructure's evolution over the past decade. It offers insights for future studies supporting emerging technologies such as IoT, AI, and blockchain.

Keywords: Bibliometrics Analysis, Research Trends, Literature Review, Infostructure, Information Infrastructure

ABSTRAK

Kajian ini membentangkan analisis bibliometrik yang komprehensif mengenai trend penyelidikan dalam infrastruktur maklumat dalam bidang Sains Komputer dan Teknologi Maklumat dan Komunikasi (ICT), merangkumi penerbitan dari tahun 2013 hingga 2023. Kajian ini menggunakan pangkalan data Scopus, 1179 artikel dianalisis secara sistematik

melalui carian kata kunci, menggunakan VOSViewer untuk memetakan trend penerbitan, kekerapan kata kunci, dan analisis sitasi. Penemuan ini mendedahkan kluster penyelidikan utama adalah termasuk teknologi rangkaian dan komunikasi, pengurusan data, keselamatan dan privasi, serta transformasi digital, dengan China, Rusia dan Amerika Syarikat mendahului dalam senarai sumbangan terbanyak penerbitan. Peningkatan ketara dalam penerbitan didapati dari tahun 2020 menandakan minat yang semakin meningkat terhadap peranan infrastruktur maklumat dalam transformasi digital. Walaupun kajian ini menumpukan pada artikel dalam Bahasa Inggeris, penyelidikan akan datang haruslah mempertimbangkan kepada set data yang lebih luas dan perspektif pelbagai disiplin. Penyelidikan ini menyediakan asas yang penting untuk memahami evolusi infrastruktur maklumat sedekad yang lalu. Ia menawarkan pandangan untuk kajian masa depan yang menyokong teknologi baru seperti IoT, AI, dan blockchain.

Kata kunci: Analisis Bibliometrik, Trend Penyelidikan, Kajian Literatur, Infostruktur, Infrastruktur Maklumat

INTRODUCTION

Information infrastructure, or Infostructure, is an online and digital-based system facility that supports information interchange in digitization activities for organizations, governments, and societies. It consists of the information technology (hardware and software) components, including the technology platforms within national, regional, or local boundaries that help organizations to have an infrastructure for communication networks, allowing the flow of information to be primarily in place (Eliwa et al., 2022). Information infrastructure is essential for the functioning of modern organizations, serving as the backbone for various processes and activities (Shaburov & Alekseev, 2022). It also shapes access to information, exercises political power, and drives business operations (Ayodele, 2020). In addition, effective operations for organizations require reliability, flexibility, and compatibility with the information infrastructure (Sun et al., 2024). Adapting to new environments and business demands is necessary to address fast-moving technology innovations. In the digital era that has been defined by over-expectations from "high technology," especially during the last two decades of computing, advanced information infrastructure management and maintenance are both essential to success, and they also reveal how vital these technologies have become for making organizations perform better.

Information and conventional infrastructure or physical infrastructure attributes differ. The physical infrastructure tends to be oriented toward physical facilities provided by the government or organization, like roads, bridges, and utilities. In contrast, the Infostructure is about digital resources that must be in place for an Information System to work (Alvarez, 2017). Infostructure includes networks, data centers, security systems, and other hardware and software for managing information systems (Mouratidis et al., 2023; Shaburov & Alekseev, 2022). Moreover, information infrastructure plays a vital role in supporting the security of information systems and safeguarding data from unauthorized access or alterations (Erokhin et al., 2023). Information systems are at the heart of the information age, serving as the fundamental vehicle for information utility delivery and underpinning entire organizations, large or small. Moreover, tremendous advancements in Information systems, the Internet of Things (IoT), mobile applications, and artificial intelligence (AI) have popularized a massive number of hardware and software components to be used in large networks, necessitating complex information infrastructures providing information exchange and delivery (Rahman et al., 2019; Zakaria et al., 2020).

Infostructure consists of information, communication and technology (ICT) elements that have various advantages and are applied in disaster management, city resource management, and critical information infrastructure. It is defined as integrating information content and ICT infrastructure, promoting information sharing through a coordinated approach (Latif et al., 2016). In disaster management, Infostructure ensures timely and effective responses by providing quality information to support agency decision-making (Latif et al., 2017). Additionally, city resources, information infrastructure, and ICT superstructure are needed in a smart city development framework focusing on its information systems and technology architecture (Achmad et al., 2018). Moreover, in critical information infrastructure, no compromising in ensuring security and reliability requires a systematic approach to cybersecurity practices for utilities (Kumar et al., 2020; Maksimova et al., 2022). Therefore, enabling a coordinated information-sharing and infrastructure that sustains critical decision-making processes is crucial for disaster response and smart city operations to bolster the security and reliability of services needed to continue serving communities.

LITERATURE REVIEW

Recent research on Information infrastructure in computer science and ICT is a growing area of research. In this study, various fields are explored, ranging from studies on technical integration and management of information systems to strategic use behavior within specific sectors. For example, (Weiss et al., 2000) research highlighted the critical role of IT in various fields, emphasizing the technologies enabling the collection, storage, processing, and transmission of information using computer systems, software, hardware, and network facilities. Another paper investigated using ICT with organizational infrastructure to improve performance outcomes in construction projects, proposing a method for evaluating this alignment (Eliwa et al., 2022). Meanwhile, (Kulugh et al., 2022) introduced the cybersecurity resilience measurement model for critical national information infrastructure. The study revealed that 35% of organizations exhibit optimized resilience, while 10% show initial and weak resilience to show the importance of cybersecurity in information infrastructure. Mouratidis et al. (2023) research on Cyber Incident Handling Modeling Language (CIHML) to improve Incident Handling processes in a critical information infrastructure. The research can help operators identify, evaluate, and model cyber incidents in essential information systems and mitigate cyber-attacks. The study by Bhaiyat & Sithungu (2022) delved into the emergence of the Industrial Internet of Things (IIoT) and its cyber security issues within critical information infrastructure. These research strands hint at a new awareness that information infrastructure is vital to organizational efficacy, safety, and resilience across all sectors. There has also been a growing interest in ensuring all appropriate technologies and processes are necessary to deliver across various government capabilities integrated with business processes, including working towards research on ICT architectures and robust security solutions for protecting information infrastructures of national security.

However, previous studies have not explored bibliometric analysis combined with mapping methods in Infostructure within Computer and ICT over the last decade. This study examines research progress in this field from 2013 to 2023 using VOSviewer to map developments and identify emerging research topics, serving as a foundational step in pinpointing research focus areas for future research references. Bibliometric data analysis has become one of the alternative research areas of literature review that many authors are working on. The analysis capability of the Bibliometrics technique allows research publications' metadata to be visualized in line with the development of existing research. The visualization of data is called mapping. Researchers commonly use several mapping and visualization tools: VOSViewer,

CiteSpace, Bibliometrix, Gephi, and Sci2 (UIC, 2023). This research employs VOSViewer as the preferred data mapping and visualization as it is free to use and has the capabilities to perform bibliometrics mapping, including co-authors maps, citations maps, co-citations maps, bibliographic coupling maps, and co-occurrence maps (D. F. Al Husaeni & Nandiyanto, 2022; D. N. Al Husaeni & Nandiyanto, 2022).

This study's main objective is to thoroughly examine the information infrastructure research domain in computing and ICT. It will help to understand the most recent emerging technologies and research trends within the framework, specifically focusing on scholarly articles published from 2013 to 2023. The examination employs Bibliometrics as a statistical technique to assess the fundamental elements addressed in these articles. The Bibliometric statistical approach is used to analyse and evaluate the prevalence of evolving trends in a particular research area (Hao et al., 2018; Mustapha et al., 2021). Besides, it can quantify the research dimension, assess the dominant areas of study, and predict future directions of research activity (Bornmann, 2008; Abbas et al., 2020; Alsharif et al., 2021). The study employs Scopus online repository analysis with several popular research articles and integrated analytical functions to report abstracts in pictorial forms. The subsequent steps can export the exploration results from the Scopus Database to other applications like the VOSviewer for further analysis and synthesis.

Research Objectives

This paper aims to conduct a bibliometric analysis to understand the research trends and developments in the information infrastructure of the Computer Science and Information and Communication Technology (ICT) domains. By analysing publication patterns, keyword co-occurrence, and citation data, this study seeks to identify emerging research trends, influential authors, and key areas of interest that have shaped the field over the past decade. The primary objective is to address the following research questions:

1. What have been the publication trends in Infostructure within Computer Science and ICT over the last decade?
2. Who are the most cited authors and journals in the infostructure research area, specifically within the computer and ICT domains, and what is the framework of their research?
3. Which countries have been the most productive in contributing to research on Infostructure in Computer Science and ICT platforms?
4. What are the most common research keywords related to Infostructure in the Computer Science and ICT fields, and what are the latest research trends?

METHODOLOGY

This research employs a Bibliometrics analysis approach proposed by Kushairi & Ahmi (2021). The Bibliometrics analysis methods require a systematic approach to ensure a comprehensive collection and analysis of relevant literature. The research flow (as illustrated in Figure 1) outlines the steps, starting with identifying a clear topic scope and using a vigorous search strategy, followed by meticulous data collection, extraction, and screening processes.

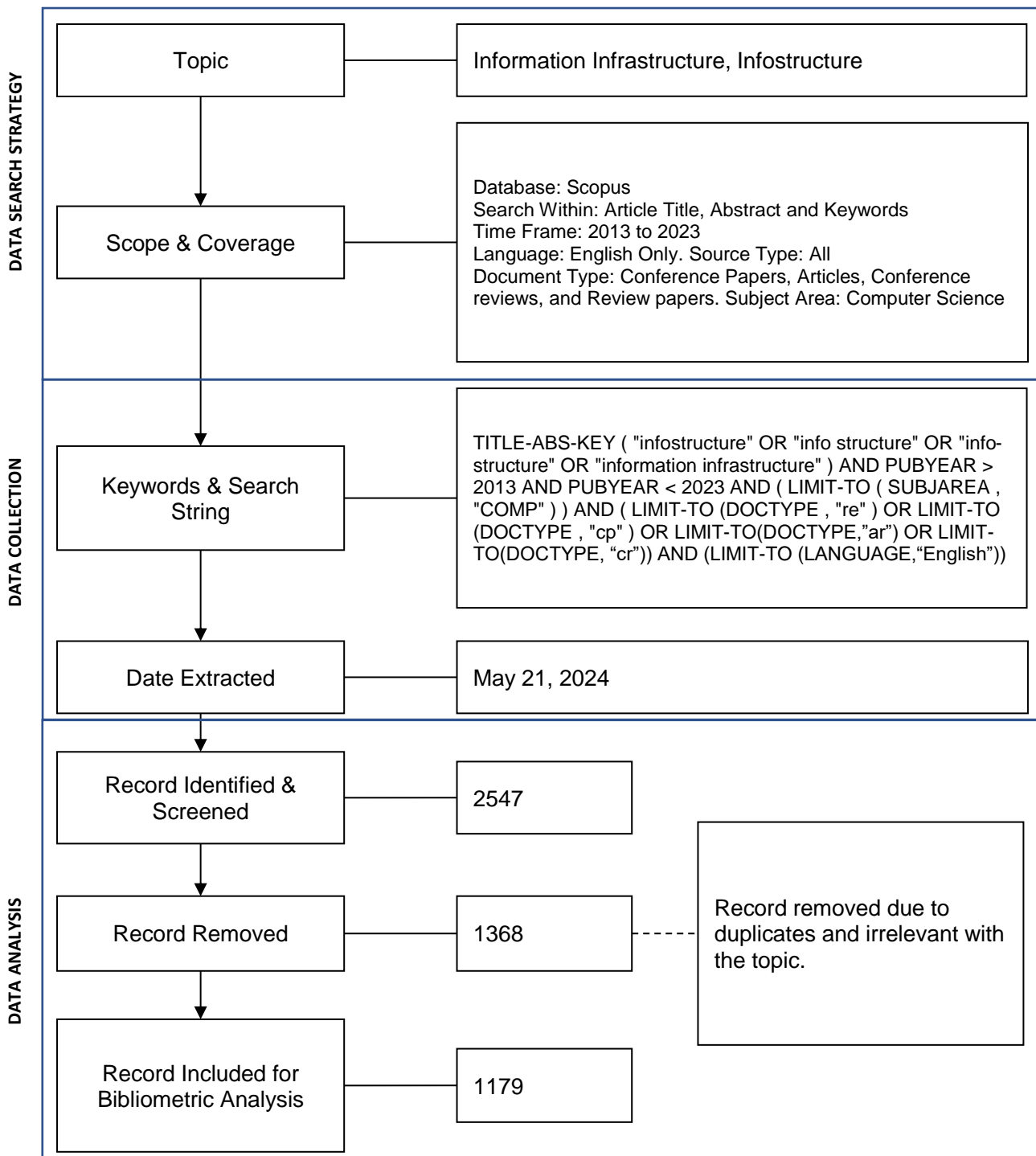


FIGURE 1. Flow diagram of the search strategy
Source: (Kushairi & Ahmi, 2021)

DATA SEARCH STRATEGY

The Scopus database was the primary source for gathering relevant publications for analysis. The search focused on publications from 2013 to 2023 to capture the most recent developments in Information Infrastructure. The search terms included variations such as "infostructure," "info structure," "information infrastructure," and related keywords, ensuring that a wide range of literature was captured. A keyword string was developed to cover title, abstract, and keyword fields in Scopus, ensuring that all relevant literature within the specified scope was captured. Conference papers, articles, and conference reviews were included to overview the

research landscape comprehensively. The search strategy focused on the Computer Science subject area because Scopus does not provide a separate classification specifically for ICT-related topics. Although ICT is closely tied to Computer Science, its research is often dispersed across broader categories. Therefore, the limitation ensured consistency and alignment with the research scope.

DATA COLLECTION

The data utilised in this study were exclusively sourced from Scopus, a preeminent abstract and citation database renowned for its comprehensive collection of peer-reviewed scholarly literature. Hence, the research dataset encompassed a multitude of prominent journals focusing on Infostructure or information infrastructure in computer and ICT areas. This analysis has provided insights into the evolution of research interests in the stated field. Furthermore, the study employed a screening sequence to determine the search terms for article retrieval. The study was initiated by querying the Scopus database *with Infostructure, info structure, info-structure, and information infrastructure* in the title, abstract, and keywords of the Scopus search engine. The advanced search syntax is as in Table 1:

TABLE 1. Search string

Scopus	TITLE-ABS-KEY ("infostructure" OR "info structure" OR "info-structure" OR "information infrastructure") AND PUBYEAR > 2013 AND PUBYEAR < 2023 AND (LIMIT-TO (SUBJAREA, "COMP")) AND (LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cr")) AND (LIMIT-TO (LANGUAGE, "English"))
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Afterward, the search result was refined, and a few Scopus feature filtering was employed. Firstly, the publication year was set to 2013 to 2023 to get the ten-year publication. This process yielded 2547 results, which were additionally scrutinized to include only research articles in English, and books were also excluded. Then, the document types selected were Conference Papers, Articles, Conference reviews, and Review papers only. The final search string refinement included 1179 articles used for bibliometric analysis. As of May 2024, all articles from the Scopus database relating to information infrastructure were incorporated into the study.

Bibliometrics combines, alters, and examines bibliographic data on scientific publications. It includes sophisticated approaches such as document co-citation analysis and simple descriptive statistics such as journals where published, year of publication, and classification by primary author. A literature review, bibliography building, and obtaining reliable results require an iterative sequence of appropriate keywords, literature search, and analysis in this study. Additionally, to ensure the inclusion of only the best publications, articles were restricted to high-quality peer-reviewed academic journals, excluding books and conference proceedings.

DATA ANALYSIS

The bibliometrics data were analysed to reveal patterns, trends, and relationships among infostructure research through the various network analysis techniques. The research uses several types of analyses, such as co-authorship, bibliographic coupling, keyword co-occurrence, and citation mapping, through VOSviewer (version 1.6.19). Linkages were established between publications, authors, and journals using bibliographic coupling to find the best-cited and influential authors on this subject. The researcher will learn the cited area from these findings and the most appropriate research topics.

The dataset, comprising publication year, titles, authors, journals, citations and keywords, was retrieved from the Scopus database in RIS format, covering the period from 2013 to December 2023. The data were then processed through VOSviewer to generate visualized network maps using clustering and mapping techniques (Van Eck & Waltman, 2023). Visual representations, such as co-authorship networks and keyword co-occurrence maps, are critical in identifying key research themes and collaboration networks (D. F. Al Husaeni et al., 2023). Citation and co-citation analyses were performed to determine the field's most influential authors, publications, and journals.

RESULT AND DISCUSSION

1. Publication Trends in Infostructure Research within Computer Science and ICT

Figure 2 illustrates the number of scholarly articles on Infostructure in computers and ICT from 2013 to 2023, and the data indicate a general upward trend in the volume of publications. The frequency of publications has exhibited periodic growth, with a projected increase anticipated in the year 2021, suggesting growing academic and industry interest in this area. The analysis reveals that most papers were published recently between 2020 and 2021. From 2013 to 2023, the average number of publications was 107, dedicated to Computer Science and ICT infostructure. There was a slight decrease in publications in 2015 and 2016, with 93 documents. However, authors started publishing more, with 100 publications in 2017, 102 in 2018, 108 in 2019 and then jumped to 129 in 2021. The remaining papers were disseminated throughout the subsequent years, as depicted in Figure 2.

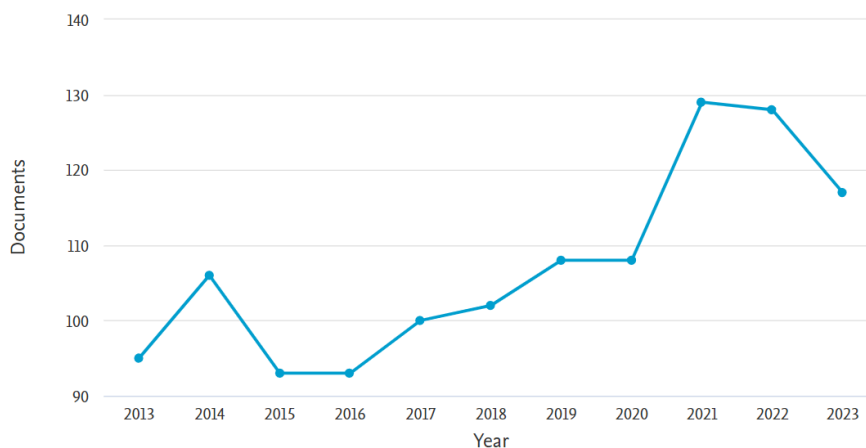


FIGURE 2. Distribution of Publication by Year

2. Analysis of Most Cited Authors, Journals, and Research Frameworks

In the content analysis for the most cited articles and journals, *'The Most Cited Articles,' 'Times Cited,' 'Sources,' and 'Theoretical Framework'* were chosen as the analysis criteria presented in Table 2.

TABLE 2. The Top 10 Highly Cited Authors and Journals on Infostructure in Computer and ICT Areas in 2013-2023

Authors	Title	Source	Theoretical Framework	Cited
Henfridsson & Bygstad (2013)	The generative mechanisms of digital infrastructure evolution	MIS Quarterly: Management Information Systems	Critical Realism	590
Ding et al. (2019)	Deep anomaly detection on attributed networks	SIAM International Conference on Data Mining, SDM 2019	Machine Learning Theory, specifically Graph Theory and Autoencoder Techniques	258
Monteiro et al. (2013)	From artifacts to infrastructures	Computer Supported Cooperative Work: CSCW: An International Journal	Socio-technical Systems Theory, Information Systems Design	177
Karasti (Karasti, 2014)	Infrastructuring in participatory design	ACM International Conference Proceeding Series	Participatory Design Theory	174
Gray et al. (Gray et al., 2018)	Data infrastructure literacy	Big Data and Society	Socio-Technical Infrastructure Theory	155
Winter et al. (Winter et al., 2014)	Beyond the organizational 'container': Conceptualizing 21st-century socio-technical work	Information and Organization	Neo-Sociotechnical Systems Theory	154
Song et al. (Song et al., 2017)	An Internet of Energy Things Based on Wireless LPWAN	Engineering	Internet of Things (IoT) Framework, specifically Energy Informatics	127
Ølnes (Ølnes, 2016)	Beyond Bitcoin enabling smart government using blockchain technology	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Distributed Ledger Technology Theory	126
Abubakar et al. (Abubakar et al., 2014)	Contractors' perception of the factors affecting building information modeling (BIM) adoption in the Nigerian construction industry	Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering	Technology Adoption and Diffusion Theory	119
Garrido-Hidalgo et al. (Garrido-Hidalgo et al., 2019)	An end-to-end Internet of Things solution for Reverse Supply Chain Management in Industry 4.0	Computers in Industry	Industry 4.0 Framework, IoT Integration	118

Table 2 shows the most productive journal concerning information infrastructure in Computers and ICT. It indicates that the most influential research in this field is published in various

reputable sources, with MIS Quarterly: Management Information Systems leading in citations, followed by significant contributions from conferences and journals such as the SIAM International Conference on Data Mining and Computer Supported Cooperative Work. The theoretical frameworks these researchers use are Critical Realism, Machine Learning Theory, Socio-technical Systems Theory, and more. This diverse representation underscores the interdisciplinary nature and broad relevance of information infrastructure research in modern digital and organizational contexts. Henfridsson and Bygstad's (2013) work on digital infrastructure evolution adopts a Critical Realism framework and is the most cited, with 590 citations. Ding et al.'s (2019) paper on deep anomaly detection has 258 citations, showing the importance of advanced computational methods in information infrastructure research. Monteiro et al. (2013) studied the transition from artifacts to infrastructures. They applied socio-technical systems theory and information systems design, receiving 177 citations and underscoring the relevance of integrating social and technical perspectives. Moreover, the distribution of the most productive journals concerning Infostructure is presented accordingly in Table 2.

On the other hand, RQ2 also investigated the number of authors with the most publications in the Infostructure in the Computer and ICT research area. In the content analysis made for the authors in the research area, most authors published articles with an average of 7 publications. Gnatyuk et al. (2020) are the authors with the most publications, contributing 15 documents, closely followed by Sydorenko (2024) and Papastergiou (2024), each with 12 and 10 publications, as shown in Figure 3. The number of publications by authors Makoveichuk (2024), Ellingsen (2024), Klievink (2024), Djordjević (2024), Kasahara (2024), Makoveichuk (2024), Mitrofanova (2024) and Polozhentsev (2024) illustrates a range of productivity among the top contributors, with several authors publishing significantly more than their peers, indicating critical figures in the research community whose work is central to advancements in this domain. Author publishing is individually counted and not represented by the whole country. In contrast, the most productive country is counted based on the overall document produced by authors based on the country.

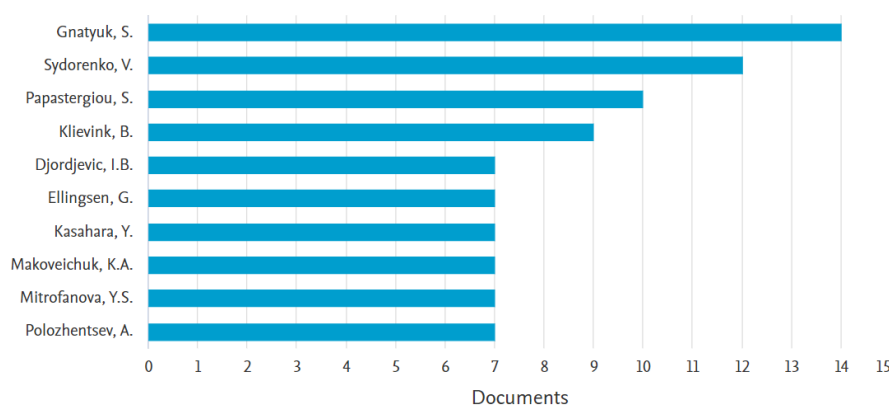


FIGURE 3. Number of Publication by Authors

3. Geographic Productivity and Regional Contributions in Infostructure Research

Figure 4 presents the rankings of the ten most productive countries regarding information infrastructure in computer and ICT research. From a national perspective, most countries/cited areas have consistently shown interest in all research topics on the information infrastructure for computer science and ICT. In contrast, different countries and regions demonstrated a

distinct inclination towards particular tendencies. The dataset's examination determined that the publications on Infostructure in the Computer and ICT area encompass 87 countries. Notably, the majority of these publications originate from China (193), followed by the Russian Federation (162), United States (141), Norway (60), United Kingdom (56), Japan (53), India and Ukraine (48), Germany (45) and Denmark (33). Italy and Malaysia also account for 33 journals, and the remaining publications are distributed among other countries, such as the Netherlands, Finland, Greece, and Australia, which have more than 20 documents.

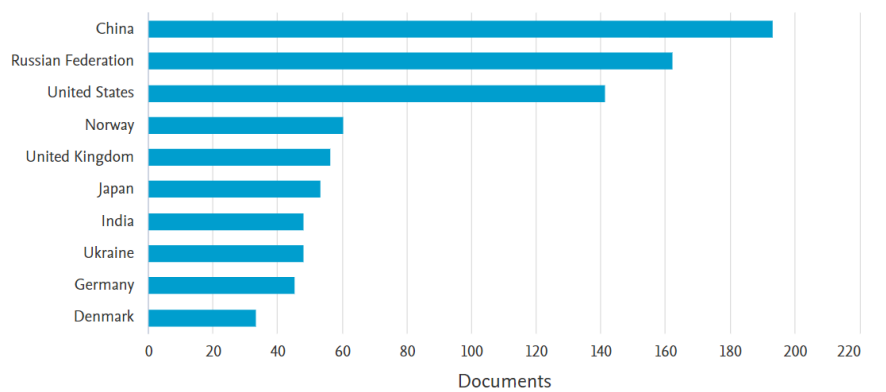


FIGURE 4. List of The Most Productive Countries in The Research Area

The analysis also reveals that the publications were written by the top 10 organizations and institutions, as shown in Figure 5. Universitetet i Oslo (Norway) leads with the highest number of documents, closely followed by the V.A. Trapeznikov Institute of Control Sciences (Russia). Both institutions have contributed significantly, each with approximately 30 publications. The National Aviation University (US) and the Russian Academy of Sciences (Russia) also show substantial contributions, each with about 25 documents. Other notable institutions include Delft University of Technology (Netherlands), Copenhagen Business School (Denmark), University of Piraeus (Greece), Peter the Great St. Petersburg Polytechnic University (Russia), University of Johannesburg (South Africa), and Kyushu University (Japan), each varying from around 5 to 20 documents. This chart highlights a diverse geographical spread of research contributions from leading educational and research institutions worldwide.

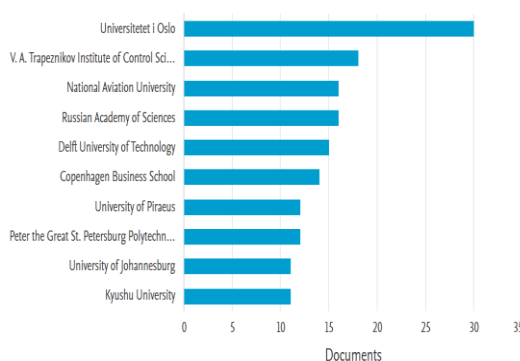


FIGURE 5. Publication types

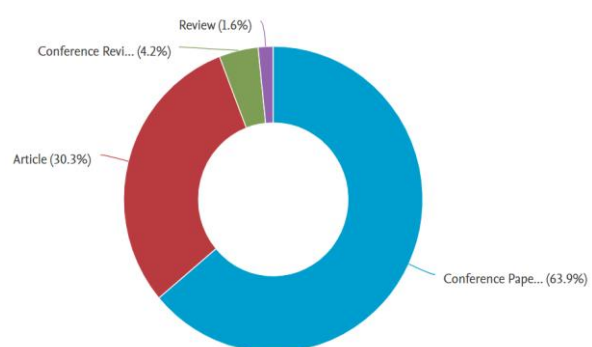


FIGURE 6. Publication by affiliations

The pie chart in Figure 6 summarizes publication types for information infrastructure research. The data revealed that most publications are conference papers, comprising 63.9%, indicating a significant preference for presenting research findings at conferences in this field. This is followed by articles, accounting for 30.3%. Reviews articles and conference reviews account for a smaller fraction, comprising 1.6% and 4.2%, respectively. This distribution suggests that

the field is active in terms of ongoing discussions and developments presented at conferences, with a substantial but lesser focus on detailed articles and reviews in academic journals.

4. Keyword Analysis and Emerging Research Trends in Infostructure

In bibliometric studies, keyword co-occurrence refers to the frequency with which two or more keywords appear together in a set of publications (Van Eck & Waltman, 2023). This technique helps to identify the relationships between research topics, uncover emerging trends, and map the knowledge structure within a particular field (Misbah et al., 2022). In this context, co-occurrence networks are created based on the frequency of different terms appearing, helping scholars understand the connections between topics and research clusters. A well-defined procedure is typically followed to conduct the keyword co-occurrence analysis. First, the researchers collect the data from reputable sources, such as the Scopus online database, often in RIS format. The data are then inputted into VOSViewer, which processes the data for mapping. In this analysis, the settings chosen included selecting "co-occurrence" as the type of analysis and applying a "full counting method." A minimum threshold for keyword occurrences is typically set; in this case, a minimum of five occurrences, with the final dataset containing 439 keywords. This approach ensures that only relevant and frequently occurring keywords are included in the analysis, which helps focus on significant research topics and avoid noise from rarely mentioned terms.

The various components of Infostructure or information infrastructure in data mapping are categorized into nine clusters. Each cluster has a different number of items, different item types, and different cluster colors. Each item in the cluster that forms a circle has a different effect on the size of the circle. The frequency with which the circle appears determines its occurrence. The larger the circle, the more frequently the keyword is used, while the smaller the circle, the less often the keyword is used (D. N. Al Husaeni & Nandiyanto, 2022).

4.1 Visualization of Information Infrastructure Research in Computer and ICT Using VOSviewer

VOSViewer can generate three different types of Visualization forms, namely Network Visualization (Figure 7), Overlay Visualization (Figure 8), and Density Visualization (Figure 9). Relationships in network visualization are represented by a network or line connecting one term to another. The network visualization in Figure 7 illustrates clusters of related keywords, each represented by different colours, indicating various subfields within information infrastructure research. Larger nodes and thicker lines represent more frequent co-occurrences, signifying the centrality of those keywords within the research domain. The most prominent cluster (in red) is centered around "information infrastructures," showing solid connections to terms such as "healthcare," "blockchain," and "government data processing." Another notable cluster (in orange) relates to cybersecurity topics, emphasizing the importance of "network security," "cyber-attacks," and "data protection." Other clusters focus on themes such as the Internet of Things (IoT), smart cities, and information services, indicating diverse research interests within the digital infrastructure domain.

Figure 7 illustrates a complex and interconnected field where main keywords like "cybersecurity," "information management," and "digital transformation" play pivotal roles. The visualization shows dense clustering around key technological domains such as "smart power grids," "5G mobile communication systems," and "Internet of Things (IoT)," showing the critical integration of advanced technologies in modern information infrastructures.

identify 15 new research trends based on the cluster items and their relationships. The VOSViewer mapping with the co-occurrence of keywords reveals distinct clusters of research trends within the field of information infrastructure. By identifying 15 distinct research trends, the analysis uncovers the intricate relationships between various concepts across different domains.

The first cluster falls under Network and Communication Technologies. It stresses the need for communication networks as the communication network landscape is evolving with the advent of 5G, IoT, and the advancement in wireless communication technologies. Modern information infrastructures rely on these technologies and allow data transmission and processing in real-time across sectors, proving the importance of innovation in bandwidth optimization and network layers (ASM, 2020). Another vital trend, Data Management, and Processing reflects the broader significance of big data, distributed systems, and data integration for handling large volumes of information. The continuing rise in the use of cloud technologies and metadata systems indicates that there is a need for more effective data storage and retrieval techniques in several domains (Aladwan et al., 2020).

The current major trend is Security and Privacy, fuelled by growing cyber-attacks, data breaches, and privacy issues. However, this trend reaffirms the efforts to introduce new innovative strategies to encrypt, control access, and assess vulnerabilities of various information infrastructures against new security threats (Božić et al., 2019; Sahri et al., 2014). In addition, Infrastructure and Systems research is important for understanding cloud computing, critical infrastructure as well and global information infrastructure as essential infrastructures behind large-scale systems (e.g., healthcare, public administration, and energy management) (Alharbi et al., 2016; Lau et al., 2021).

Energy and efficiency refers to integrating smart grids and renewable energy management systems, which signifies a shift towards sustainable energy solutions propelled by advancements in energy transmission and utilization technologies. This trend reflects broader efforts to enhance the efficiency of energy infrastructures while reducing environmental impacts (Gurina, 2023; Lau et al., 2021). In parallel, Software and Systems Engineering continues to be a prominent field, focusing on human-computer interaction, fault tolerance, and software reliability, ensuring that information systems are robust and capable of handling complex operational demands (Johnson & Vlachokryiakos, 2024; Shivers et al., 2019).

The Economic and Development trend shows the intersection between economic growth, international trade and technological innovation. Significant investments in digital infrastructure and international collaborations are adopted by developing countries, particularly (Johnson & Vlachokryiakos, 2024; Sun et al., 2024), through adopting the ecosystems and infrastructure systems for promoting socio-economic advancement. Healthcare and Medical informatics research is growing within the healthcare sector; the use of electronic health records, e-health, and medical informatics in healthcare delivery and management to improve the healthcare delivery system (Kiplimo, 2018).

Additionally, research into information infrastructure's legal and policy frameworks satisfies legal and regulatory aspects of information infrastructure, ensuring that policies regarding standards, legislation, and frameworks are consistent with technological advancement and social demands (Rangu et al., 2023). It has started to be known as a multidisciplinary trend in education and research where e-learning, educational systems, and comparative study fuel

innovations in that knowledge is spread, and research is conducted on various disciplines (Qazi et al., 2024; Sharif Nia et al., 2024).

The strategic route of Digital Transformation and Innovation is essential to lead the technological improvement in different industries. Digital transformation from traditional systems to digital platforms and technology transfer innovations are evidence of the shift to more efficient and automated processes in the industrial sectors (Masrianto et al., 2022; Pisoni, 2021). Meanwhile, social networking – including social media and online collaboration – remains important for providing global communication and collaboration and creating new channels for research in digital interaction and connectivity (Basri, 2020; Hong et al., 2023).

Furthermore, trends in Hardware and Technology have been identified, highlighting the importance of antennas, microstrip antennas, and wireless communications as the foundation for prominent technological inventions. It focuses on hardware development, which is critical to improving the performance of communication systems (Yadav et al., 2019). Aviation and Transportation research aims to solve critical and civil aviation information and address secure and efficient transportation systems (Gnatyuk et al., 2020; Ukwandu et al., 2022). Finally, the cluster on other Applications and Systems brings trends in industrial management, Industry 4.0, and supply chain management, which requires large-scale systems and project management to provoke the operational easement in various fields such as farming and manufacturing (Bhaiyat & Sithungu, 2022; Ribeiro et al., 2021).

The following table consolidates various research clusters, highlighting their trends and associated cluster items.

TABLE 4. Research Cluster, Items, and Research Trends

No	Research Trends	Cluster	Color	Concepts of Items
1	<i>Network and Communication Technologies</i>	6	Red	5G, algorithms, bandwidth, communication infrastructure, communication satellite, complex networks, mobile telecommunications, network architecture, network layers, optical communication, quality of service, satellite communication, software-defined networks, telecommunications networks, wireless communication, wireless local area networks, wireless telecommunications, Internet of Things (IoT)
2	<i>Data Management and Processing</i>	1,2,3,6	Red, Green, Blue, Light Blue	big data, data integration, data processing, database systems, distributed database systems, distributed information, information systems, metadata, multidimensional signal processing, signal processing
3	<i>Security and Privacy</i>	4, 7, 8, 9	Yellow, Orange, Brown, Dark Brown	access control, cyber-security, data privacy, denial-of-service attack, encryption, information security, information security management, mobile security, personal information, privacy, resilience, risk, risk analysis, risk assessment, risk management, risks management, security incident, security of data, security standards, situational awareness, vulnerabilities, vulnerability
4	<i>Infrastructure and Systems</i>	1, 7, 8	Red, Orange, Brown	cloud-based, cloud-computing, critical infrastructure, critical information infrastructure, embedded systems, global information infrastructure, ICT infrastructures,

				infrastructure, infrastructure construction, information infrastructure, public works, SCADA systems
5	<i>Energy and Efficiency</i>	6	Light Blue	electric power transmission, energy, energy efficiency, energy utilization, smart grid, smart power grids
6	<i>Software and Systems Engineering</i>	9	Dark Brown	fault tolerance, human-computer interaction, quality control, software design, software reliability, systems engineering, ubiquitous computing, user interfaces
7	<i>Economics and Development</i>	5	Purple	economic development, ecosystems, investments, international trade, developed countries, developing countries
8	<i>Healthcare and Medical Informatics</i>	1	Red	healthcare sectors, e-health, electronic health records, medical informatics, health information systems
9	<i>Legal and Policy Frameworks</i>	5	Purple	conceptual frameworks, design principles, frameworks, laws and legislation, standards, policy
10	<i>Education and Research</i>	1,3,5	Red, Blue, Purple	e-learning, educational systems, research questions, case studies, comparative analysis, literature reviews, mapping, surveys, new approaches, personnel training
11	<i>Digital Transformation and Innovation</i>	3	Bue	digital economy, digital platforms, digital technologies, digital transformation, innovation, technology transfer
12	<i>Social and Networking</i>	5	Purple	social media, social networking (online), collaboration
13	<i>Hardware and Technology</i>	6, 8	Light Blue, Brown	hardware, antennas, microstrip antennas, microwave antennas, slot antennas
14	<i>Aviation and Transportation</i>	7	Orange	aviation, civil aviation, critical aviation information
15	<i>Miscellaneous Applications and Systems</i>	2,3,5,7	Green, Blue, Purple, Orange	industrial management, industrial internet of things, industry 4.0, large-scale systems, life cycle, maintenance, management, multi-agent systems, project management, supply chains, supply chain management, agriculture

In conclusion, the keyword co-occurrence analysis reveals a diverse range of interconnected research trends, each contributing to the broader understanding of information infrastructure and its applications across industries. These findings reflect the field's multidisciplinary nature, highlighting key areas where future research and innovation will likely emerge.

Figure 8 depicts the geometry of the visualization overlay, which helps understand temporal trends in research topics. In this form of visualization, we can see the year the most keyword research was conducted, starting in 2016 and continuing to 2020 and above at the latest. It suggests that topics such as "cybersecurity," "information security," "e-learning," "digital transformation," and the Internet of Things," among others, have been areas of concentrated research interest, particularly highlighted in more recent years. In addition, recent advancements and concerns in technology and security have driven much of the research in information infrastructure. The emphasis on "smart power grids" and "cyber-attacks" reflects an ongoing adaptation to evolving technological threats and the integration of new technologies into everyday systems.

digital transformation, investigating how organizational practices and information infrastructures can co-evolve to support innovation (Johnson & Vlachokryiakos, 2024).

CONCLUSION

This bibliometric analysis is a comprehensive study of the research trends and significant developments in information infrastructure in computers and ICT. The research also reveals a rising interest among academia, especially seen through the increasing number of papers published mainly in 2020 and 2021, as they were the years of 5G, IoT, and digital transformation. The analysis revealed critical research areas, such as network and communication technologies, data management, security and privacy, and digital transformation, contributing to the changing knowledge of information infrastructures. The results demonstrate that research in this domain is interdisciplinary, building its ideas on top of technological, organizational, and social frameworks to address the multiparadigmatic nature of contemporary information systems. Furthermore, the latter shows the rising need for cybersecurity and resilience in managing critical infrastructure, mainly due to growing cyber threats. Inferences are made from the analysis to analyze the field's contributions to academia and industry by identifying influential authors, journals, and regions. Future studies will necessitate further analysis of emerging paradigms of novel technologies, such as blockchain AI and their integrated core infrastructure, and the discovery of even more efficient algorithmic frameworks for optimal security and scale. Despite the study's limitations, based on its reliance on specific bibliographic databases, a more inclusive analysis could enhance the understanding of information infrastructure from varying sectors and regions. This analysis offers researchers and practitioners a holistic way to grapple with the changing information infrastructure.

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