ANALYSIS OF GLOBAL RESEARCH TRENDS IN THE INTERNET OF THINGS (IoT) AREA WITH NETWORK MAP TECHNIQUE[1][2]

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ABSTRACT| The Internet of Things (IoT) has emerged as a transformative technology paradigm that connects billions of devices, enabling seamless communication and data exchange. The study used the Web of Science Core Collection database to uncover global research trends in the IoT. The data in the study were visualized using the VOSviewer software, and bibliometric analysis was performed using the network map technique. The study aims to examine global research trends in IoT, examine IoT-related studies in social sciences, examine the status of IoT studies, especially in management and public administration, and guide researchers who aim to work on this subject. In the study, 87,397 studies on IoT between 2002 and 2022 were examined, and 1162 studies were included by limiting the studies to management and public administration. Studies were categorized and analyzed concerning fields of study, departments, years of publication, keywords, authors, and the most cited authors.

Keywords: *Internet of Things (IoT), VOSviewer, network mapping technique*
JEL Codes: *H83, O32, 033*

Scope: *Management information systems*
Type: *Research*

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NESNELERİN İNTERNETİ (IoT) ALANINDAKİ KÜRESEL ARAŞTIRMA TRENDLERİNİN AĞ HARİTASI TEKNİĞİ İLE ANALİZİ

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ÖZ | Nesnelerin İnterneti (IoT), milyarlarca cihazı birbirine bağlayan, kesintisiz iletişim ve veri alışverişi sağlayan dönüştürücü bir teknoloji paradigması olarak ortaya çıkmıştır. Bu çalışmada, IoT alanındaki küresel araştırma trendlerini ortaya çıkarmak için Web of Science Core Collection veri tabanı kullanılmıştır. Elde edilen veriler VOSviewer yazılımı ile görselleştirilip ağ haritası tekniği kullanılarak bibliyometrik bir analiz yapılmıştır. Çalışmanın amacı IoT alanında küresel araştırma trendlerini analiz etmek, sosyal bilimler alanında IoT konulu çalışmaları incelemek ve özellikle yönetim ve kamu yönetimi alanında IoT çalışmalarının durumunu inceleyerek bu konuda çalışma yapmak isteyen araştırmacılara yön göstermektedir. Çalışmada, ilk olarak 2002-2022 yılları arasında IoT konusu üzerine yapılan 87,397 adet araştırma incelenmiş daha sonra yapılan çalışmalar yönetim ve kamu yönetimi alanında sınırlandırılarak 1162 araştırma çalışmaya dahil edilmiştir. Araştırmalar çalışma alanları, anabilim dalları, yayın yılları, anahtar kelimeler, yazarlar ve en çok atıf alan yazarlar açısından kategorik olarak incelenmiş ve analiz edilmiştir.

Anahtar Kelimeler: *Nesnelerin interneti (IoT), VOSviewer, ağ haritası tekniği*
JEL Kodları*: H83, O32,033*

Alan: *Yönetim bilişim sistemleri*
Türü: *Araştırma*

1. INTRODUCTION

The Internet of Things (IoT) has emerged as a transformative force in the digital age and continues to revolutionize fields as diverse as healthcare, transportation, manufacturing, agriculture, and smart cities. Connecting tangible objects and equipping them with sensors, actuators, and network connectivity facilitates seamless data exchange and enhances intelligent decision-making. The expansion of IoT devices and applications has revolutionized our technological interactions, leading to amplified efficiency, refined resource management, and bolstered user experiences.

The dynamics of research in the IoT are increasingly varying and expanding with their evolution. The study focuses on the trends and dynamics of IoT research, which is rapidly growing and diversifying. The Web of Science Core Collection database, recognized as one of the most comprehensive and dependable sources of scientific literature, was used to compile a vast database of IoT-related articles. The rationale behind selecting The Web of Science database was based on its rigorous selection process, which includes high-quality peer-reviewed publications and offers a strong foundation for analysis.

The VOSviewer software was used to visualize global research trends in the IoT field, obtained from the Web of Science database. VOSviewer is a prominent visualization tool that employs network mapping techniques to exhibit the relationships between articles, authors, and keywords, enabling the identification of research clusters, influential authors, and emerging themes. This tool was chosen for the study because it can find links across various IoT research subfields, identify and spot growing challenges, and uncover relevant research themes by examining common citation networks.

The VOSviewer tool was used to extract IoT research trend data from the Web of Science database, which was then subjected to bibliometric analysis. A potent method for analyzing scientific literature is bibliometric analysis, which enables the study of research patterns, teamwork, and intellectual structures in a certain area. Researchers can use bibliometric tools to evaluate the existing knowledge, identify successful research outcomes, and new possibilities for further studies. A bibliometric analysis was conducted to examine the evolution of research subjects, publishing patterns, and well-known authors in the IoT sector.

The goal of the investigation is to provide a thorough analysis of current research trends in the IoT while also examining key focus areas, patterns of researcher collaboration, and the development of research topics over time. The goal is to investigate how management and public administration departments interact with IoT research trends, notably within social sciences. A literature study on IoT, network visualization, network mapping, bibliometric analysis, and using VOSviewer software is described in the first part of the paper as a means of achieving this. The methodology section provides the details of the study's approach. Finally, along with the formulation of the conclusions, the findings of the analysis are presented, including worldwide research trends, significant

authors, and new research themes. The study aims to provide data for academics, practitioners, and policymakers while also contributing significantly to our understanding of the IoT research landscape by utilizing bibliometric analysis and network mapping methodologies.

2. THEORETICAL BACKGROUND

A literature review, also known as a literature search or literature review, involves a rigorous and thorough analysis of the literature relevant to a particular subject or line of inquiry. The selection, assessment, and synthesis of pertinent literature from various sources, including books, journal articles, conference proceedings, and other published and unpublished materials, are part of this process. A literature review's main goals are to provide a critical evaluation of the literature on a particular topic, identify knowledge gaps, and suggest potential directions for further studies (Goggin, 2012; Bosward et al., 2022; Momen and Pilus, 2022; Sheth, 2023). The links and interplay between IoT, network visualization, network mapping techniques, bibliometric analysis, and VOSviewer applications are examined in theliterature review. The review sheds light on how these ideas have been incorporated into academic literature and emphasizes their overall influence on diverse sectors. Examples of interdisciplinary studies utilizing interconnected concepts have also been discussed. By synthesizing key findings, methodologies, and practices, the review provides a comprehensive understanding of how interconnected elements contribute to knowledge discovery, network analysis, and visualization. The review outlines potential areas for future research and implications for practitioners.

Alam et al. (2020) studied network virtualization techniques for IoT and highlighted various short- and long-term research challenges and open issues related to adopting software-defined IoT.

Asemi and Ebrahimi (2020) conducted a thematic analysis of IoT-related articles in the Web of Science database using the HAC approach. They analyzed relevant articles from WoS published between 2002 and 2016 by performing a keyword search using the keyword IoT.

Bednarčíková (2023) investigated using IoT in business organizations worldwide using a qualitative method to analyze the existing literature and identify the most frequently used keywords and research topics related to IoT in business.

Berezivska (2023) conducted a bibliometric analysis using the Web of Science platform and VOSviewer software to examine the use of the IoT in accounting. The study uses bibliometric, structural, cluster, and graphical analyses to visualize scientists' publication activities related to using IoT in accounting.

Cabeza et al. (2020) conducted a comparative analysis on the energy

efficiency and climate impact of buildings in Web of Science and Scopus databases on energy efficiency and climate impact of buildings using the VOSviewer program to analyze similarities between articles, co-authorship, common keyword usage, and common citations.

Kulaklı and Arıkan (2023) investigated IoT research trends in business model innovation through bibliometric studies using co-word and content analysis to identify the most frequently used keywords and research topics related to IoT and business model innovation.

Liu et al. (2016) conducted an algorithmic historiography of the existing literature on IoT using network visualization. They concluded that technological advances and application potential have led to an explosion in research on the IoT in the last six years.

Marochkina and Paramonov (2021) analyzed the problems of modeling an IoT network and proposed complex equipment for high-density IoT full-scale modeling.

Novera et al. (2022) conducted a literature review on IoT in smart tourism. They found that although there has been a significant amount of research on smart tourism, a comprehensive literature review that brings together papers to examine research streams and the scope of further research has not yet been conducted.

Ramakrishnan et al. (2020) conducted a systematic review of network visualization techniques in IoT using keywords, such as cloud, network, IoT, and systematic literature review and visualization to identify relevant articles. The authors used a qualitative method to analyze the articles and identify the most commonly used network visualization techniques in the IoT.

Wang et al. (2021) conducted a bibliometric analysis of edge computing for IoT using the Web of Science Core Collection dataset and used bibliometric methods to identify the most frequently used keywords and research topics related to edge computing for IoT.

Yang et al. (2020) investigated emerging IoT technologies in smart health research by analyzing 9561 articles published in the field of IoT-based smart health research between 2003 and 2019. The authors used tools, such as CiteSpace and bibliometric methods, to visually analyze the time distribution, spatial distribution, literature co-citation analysis, and keyword analysis of articles.

Twelve studies were examined in the literature review. The reviewed studies were selected from among those that studied IoT, performed bibliometric analysis, used network mapping techniques, made use of research databases, and used software programs for analysis. The reviewed studies show that IoT, visualization, network mapping techniques, bibliometric analysis, and VOSviewer programs are widely used in scientific literature. Researchers use these tools to analyze research trends and patterns, identify research gaps, and inform future research directions. The utilization of these instruments has

significantly augmented the comprehension of the extant state of investigation of the IoT and has further facilitated the identification of prospective research trajectories from diverse vantage points. Moreover, the literature survey suggests that the IoT has yet to be approached through the prism of management science and public administration. Consequently, to address this lacuna in the literature, our study endeavors to scrutinize IoT-related research in the domain of management science and public administration and subject extant studies to bibliometric analysis through the application of the network mapping technique.

3. METHODOLOGY

The methodology section presents a comprehensive depiction of the procedures employed to scrutinize worldwide research patterns in the IoT domain using the network-mapping methodology. The methodology section summarizes the data collection process, article selection criteria, and the software used to create network maps.

IoT is a technology integrated into every field daily. It has various advantages regarding its different types, sensors, development of the technologies with which it interacts, and its potential contributions. As a result of the integration of technology into every field, research trends in this subject are increasing. The study used the Web of Science Core Collection database to retrieve articles related to IoT. Web of Science is a comprehensive and widely recognized multidisciplinary research database covering a wide range of scientific disciplines (Yu et al., 2020; Tarakcıoğlu Altınay, 2022). The search was conducted using the term "Internet of Things". From this search, 87,397 studies published on IoT between 2002 and 2022 were identified. Articles were subjected to certain criteria to ensure their relevance and quality. These studies were first restricted to management and public administration, and 1162 studies were identified. The articles were then temporally limited to the last five years, and 720 studies were categorized in terms of fields of study, departments, years of publication, keywords, authors, and most-cited authors and analyzed using bibliometric and qualitative analysis techniques.

Bibliometric analysis is a scholarly investigative approach that entails the numerical scrutiny of bibliographic information, including publication output, citation patterns, and co-authorship networks, to detect trends, patterns, and associations within a designated area of inquiry. Bibliometric analysis can be used to identify the most influential authors, institutions, and publications in a field as well as to track the evolution of research topics over time. It can also be used to identify research gaps and guide future research directions (Ben-Daya et al., 2017; Kutera, 2022; Pahlevi, 2022; Mania, 2022; Singla, 2023). The methodology typically involves using specialized software tools, such as VOSviewer, to analyze and visualize bibliographic data.

The study aimed to analyze IoT study trends in management and public

administration using a network mapping technique within the delimitation made by identifying global research trends in IoT and IoT research trends in the field of social sciences. For this purpose, VOSviewer software version 1.6.19 was used. VOSviewer software was used to create a network map and identify important research clusters and key authors (Artsın 2020; Arslan 2022). Various metrics, such as centrality measures and clustering coefficients, were calculated to assess the importance and collaboration patterns within the network. The visualization provided by the network map was used to make sense of the relationships and connections between the authors and research areas.

Network mapping methodology includes a wide range of techniques and tools used to display and analyze a network's design and connections graphically. Its practical application is evident in many domains, including computer networks, transportation systems, and social networks. This technique can be classified as either active or passive, contingent upon whether it entails the observation of network traffic or only monitoring. It can also include different mapping types, such as logical network mapping, application mapping, and vulnerability mapping. Network mapping techniques can help identify potential problems, optimize network performance, and improve network security (Mao et al., 2015; Akande et al., 2017; Gashti, 2017). In this technique, a keyword or concept is located at the center, and the subconcepts and ideas associated with this concept extend from the center into branches. The network map technique can help students better to understand concepts and relationships in the learning process. Thus, it is very useful to use this technique to visualize semantic and conceptual relationships, particularly in social sciences.

The findings from the network map are presented in the Analysis Results section. These are interpreted to understand the global research trends in the IoT field. Collaboration patterns, research focus areas, and influential authors were identified and discussed, in line with the objectives of the study. The results are compared with the existing literature and used to inform the current state and potential future directions of IoT research.

4. RESEARCH FINDINGS AND ANALYSIS RESULTS

To identify research trends in IoT, first, the word "IoT" was searched from the Web of Science Core Collection database, and 87,397 publications were found. The figure below shows the distribution of 87,397 publications according to the field analysis, document-type analysis, and publication years as shown in Figure 1 below.

Figure 1: Tree Map Showing the Area Map of the Studies
Source: Accessed from the Web of Science Core Collection database by the author.

A figure showing the distribution of 87,397 publications on IoT, accessed from the Web of Science Core Collection database, in which field they were written, is shown. According to the figure, most studies on IoT are in Electrical and Electronics Engineering. This is followed by Computer Science Information Systems, Telecommunications, Computer Science Theory Methods, Artificial Intelligence, Software Engineering, and Interdisciplinary Applications. It is concluded that research trends in IoT are concentrated in engineering fields, as shown in Figure 2 below.

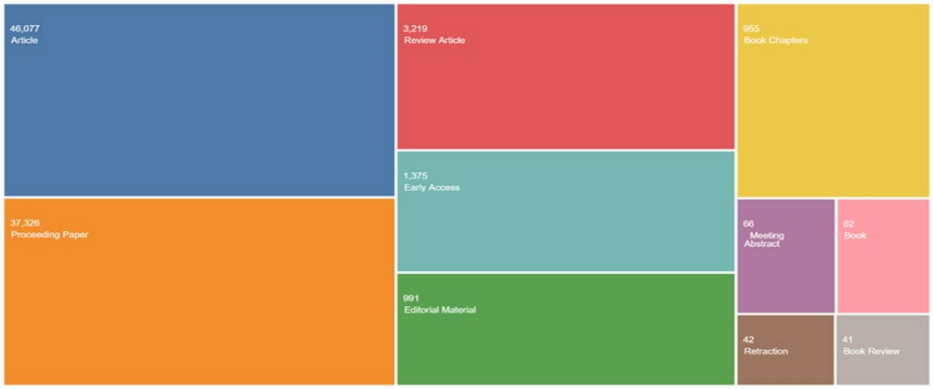
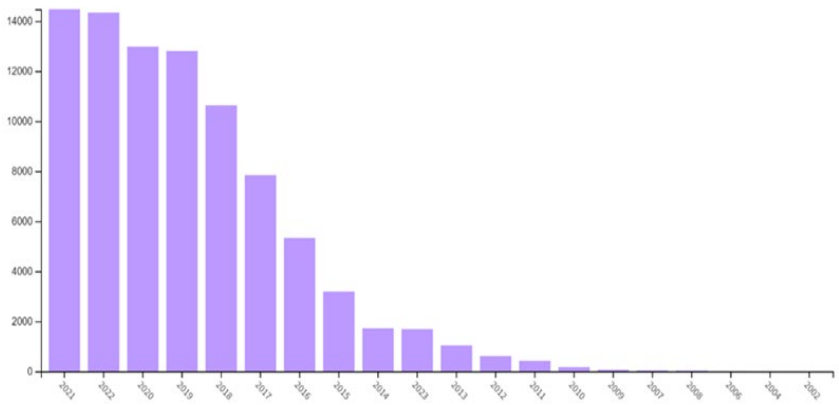


Figure 2: Tree Map Showing the Document Type Analysis of the Studies
Source: Accessed from the Web of Science Core Collection Database by the Author.

Documents, such as articles, books, book chapters, proceedings, and book reviews, were included in the studies conducted according to document type. A document-type analysis of 87,397 publications on IoT accessed from the Web of Science Core Collection database was provided. As shown in Figure 2, more than half of the studies were published as articles. It was concluded that studies on IoT were at least in the form of book reviews.



Graph 1: Distribution of Publication Years of Studies
Source: Accessed from the Web of Science Core Collection Database by the Author.

This graph was used to examine the distribution of the IoT research trends by year. The first study on the IoT was conducted in 2002. One publication was published in 2002, another in 2002, two in 2004, and six in 2006. Since 2008, interest in the IoT has increased. The number of publications increased from 616 in 2012 to 1041 in 2013, and interest in the subject increased considerably. After 2018, these studies became increasingly popular. There were 12,801 publications in 2019, 12,981 in 2020, 14,470 in 2021, and 14,338 in 2022. It is believed that the reasons for the increase in studies in IoT in recent years are the increasing use of digital technologies and given that IoT has become a multidisciplinary subject.

When Figures 1-2 and Graph 1, which emerged as a result of analyzing IoT research trends, were examined jointly, it was concluded that studies on IoT were mostly written in the field of engineering in 2021-2022. Although a large number of studies have been conducted in the field of engineering, it has been

observed that the social sciences have increased their interest in IoT, especially in the last five years. In the document-type analysis, the IoT topic was addressed the least in books and publications produced from books. This scarcity is considered to be a gap in the literature.

Of the 87,397 publications on IoT accessed from the Web of Science Core Collection database, 6271 were conducted in the field of social sciences. Considering the total number of publications, the share of social sciences in this number was small. Recently, the social sciences field has begun to be included in the IoT research trends. According to the data obtained from the Web of Science Core Collection database, the departments of Operations Research with 1436 publications, Environmental Sciences with 1208 publications, Management with 1118 publications, and Business Administration with 899 publications contributed to the IoT topic in social sciences. The public administration department contributed to IoT research trends with 45 publications. The department that contributed the least to one publication on IoT was Literature. Table 1 below shows the number of publications by management and public administration on IoT in the last five years.

Table 1: Number of IoT Studies in Management and Public Administration

	Management	**Public Administration**	**Total**
Number of Publications	**1118**	**45**	**1162**
Number of Publications in The Last 5 Years	**698**	**22**	**720**

Source: Accessed from the Web of Science Core Collection Database by the Author.

The number of studies in the field of management and public administration specified in the table above was obtained from the Web of Science Core Collection database by limiting the fields of "Management" and "Public Administration". The distribution of studies on IoT accessed from the Web of Science Core Collection database is presented in Table 1 according to management and public administration. In total, there were 1162 publications in

these two fields. Of these, 1118 were in the management field. In the field of public administration, 45 publications on the IoT were published. The research trends of the studies have been analyzed within the last five years (2018-2022). Within this limitation, it was concluded that 698 publications were published in the field of management, and 22 publications were published in the field of public administration in the last five years, covering the years 2018-2022. In the study, the VOSviewer software was used to analyze IoT research trends in management and public administration using the network map technique. The figures below include an analysis of the research trends of 720 studies on IoT in the field of management and public administration between 2018-2022 using the network map technique.

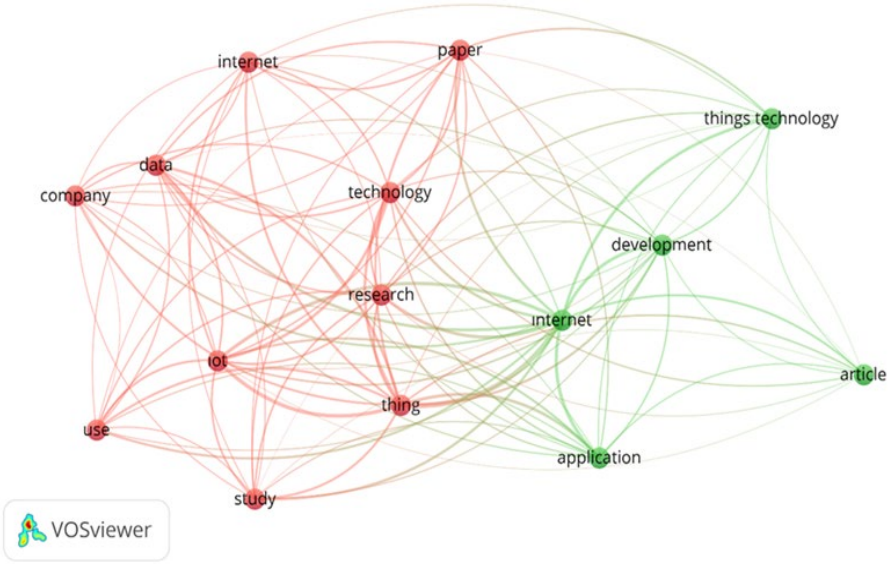


Figure 3: Network Visualization Map of Keywords Used in IoT Studies
Source: Created by the authors using VOSviewer Software.

A network visualization map graphically shows the connections between several keywords or concepts. It may be used as a tool to identify trends and connections between numerous concepts as well as to examine the connections between various themes. Before creating a network visualization map, it is important to identify the keywords or topics to be investigated further. These might be closely related to a particular topic or theme, or they could be more general notions requiring further investigation into their complexities. One such

strategy is using a force-directed graph, which inserts keywords into a two-dimensional space and then employs attractive and repulsive forces to produce a layout that represents the relationships between them. It may then emphasize certain relationships or patterns using a variety of colors, shapes, and sizes (Shannon et al., 2003). An effective tool for studying the links between various phrases and concepts and seeing patterns and connections that might not be immediately seen from a basic list or table of data is a network visualization map. An effective visual representation of the keywords in the network visualization map is created, as shown in Figure 3. The terms utilized in the IoT investigations were network-visualized, as shown in the picture. Using the network visualization approach, very frequent keywords were shown on the map (Kemeç, 2022). The network map shows that in management and public administration studies on IoT, the terms technology, Internet, data, firm, and IoT are frequently used as keywords. A density visualization map of the keywords used in IoT investigations is shown in Figure 4.

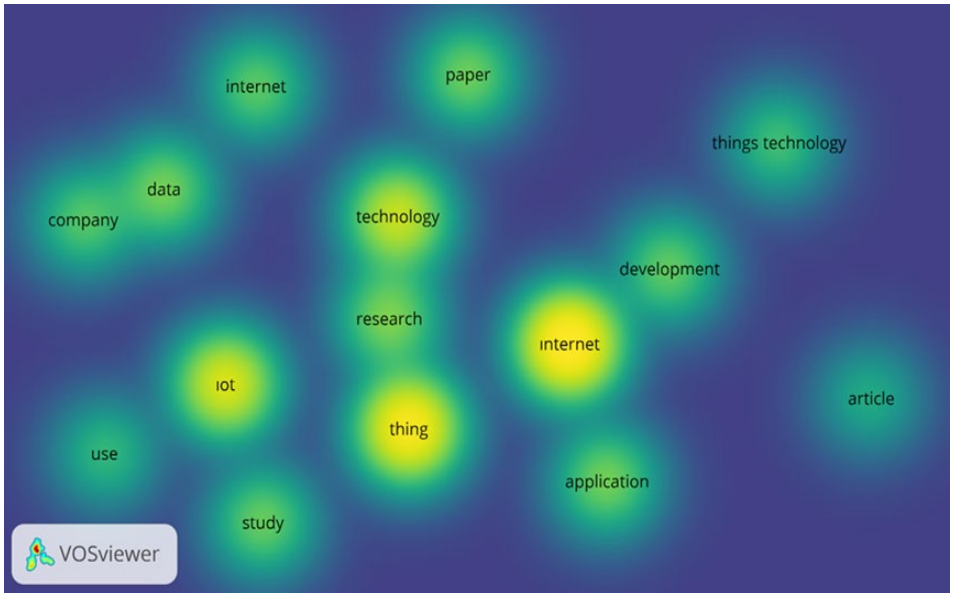


Figure 4: Density Visualization Map of Keywords Used in IoT Studies
Source: Created by the authors using VOSviewer Software.

A bibliometric software program, VOSviewer, was developed at Leiden University in the Netherlands. This program was used to map the study of global

cooperation and collaboration networks among significant writers. It is also used to depict keyword density. It can produce and display information maps with overlays, cluster types, or color-coded densities. The program has three visualization modules: network, overlay, and density. A density visualization map was used to show the frequency of keywords in a certain study region, with the size of the circle denoting frequency and the color denoting density (Wang et al., 2018; Guan et al., 2021; Zhang et al., 2022; Xiao, 2023; Braun, 2022; Zhang, 2023). The intensity view is important because each point in the network map has a different meaning in terms of the hue. This approach is important for providing a comprehensive overview and highlighting the crucial points. As the number of elements surrounding an element increases, the intensity of the color tone of the element also increases (Artsın, 2020). However, when the opposite is true, the intensity decreases. The figure above shows the intensity visualization map of the keywords used in IoT studies. The terms IoT, Internet, object, and technology are used intensively in management and public administration studies on the IoT. The next figure shows a network visualization map of the most-cited researchers in IoT research.

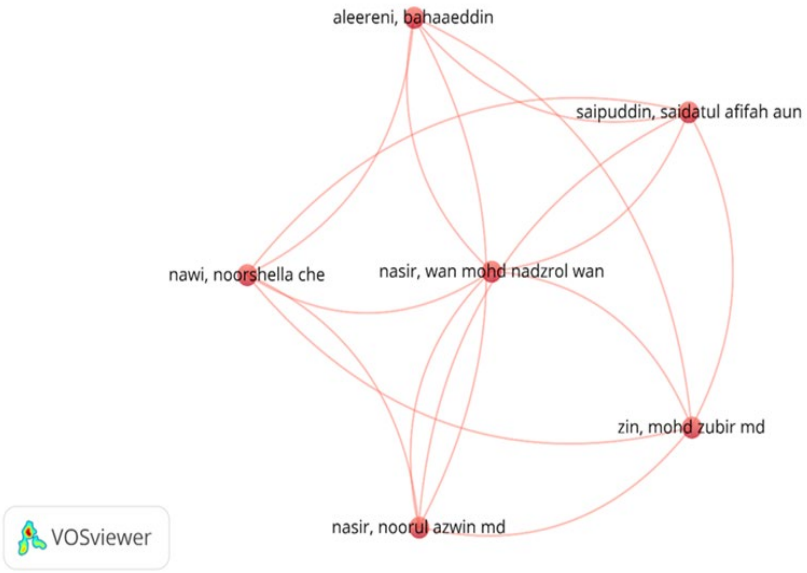


Figure 5: Network Visualization Map of the Most Cited Researchers in IoT Studies
Source: Created by the authors using VOSviewer Software.

VOSviewer software was used for bibliometric analysis and visualization of scientific literature data to create, visualize, and explore bibliometric maps of science, including co-authorship countries, bibliographic link sources, co-occurrence keyword network visualization mapping, citations, co-citations, bibliographic links, and the co-occurrence of keywords. VOSviewer was used to perform co-occurrence analyses and create visualized collaboration network maps for countries/regions, institutions, and authors. The software has been used in various fields, including health sciences and social sciences, especially for displaying large bibliometric maps in an easily interpretable manner (Ling, 2022; Pradhan and Samanta, 2022; Song, 2023; Tao, 2023). The figure above shows a network visualization map of the most cited researchers in IoT studies written in management and public administration. This network map is particularly important for researchers working or planning to work in the field of social sciences, particularly in public administration in the field of IoT. According to the network map, Nasir, Nawi, Aleereni, Saipuddin, and Zin were the most cited authors in management and public administration. It may be useful for researchers who are or will be working in the field of IoT to prioritize the work of the relevant authors in the literature review.

5. DISCUSSION AND CONCLUSION

Artificial intelligence, big data analysis, and the IoT are now widely employed across many industries because of technological advancements and the integration of digitalization. Utilization areas have grown, which has changed study patterns. We performed a thorough bibliometric analysis of the worldwide research trends in the IoT sector. Trends in IoT research were determined using the network mapping approach and a substantial dataset present in the Web of Science Core Collection database. Trends in IoT research were found using the VOSviewer software. To shed light on the existing status and potential future directions of IoT research, data visualization revealed major research themes, significant authors, and collaboration networks.

An extensive dataset from the Web of Science Core Collection database was used to examine worldwide research trends in the IoT sector using a network-mapping approach. The VOSviewer software was used to display the bibliographic data. The study concluded that there had been an ongoing rising trend in IoT research, with a notable increase in publications over the last five years. This pattern demonstrates the growing interest in IoT research advancements and the recognition of their potential influence on several industries. The investigation also revealed several critical IoT-related issues, including wireless sensor networks, cloud computing, security, and privacy.

These topics were closely connected, as several publications simultaneously covered them. Third, the analysis showed that several influential parties are involved in IoT research, including academic institutions, research organizations, and technology firms. These participants often work together, demonstrating a robust network of alliances and information exchanges in the industry. Overall, the network mapping method and VOSviewer software bibliometric study of IoT provide insightful information on the state of the field's research. These findings can guide further research paths and partnerships in this area. In addition, network mapping analysis has made it possible to identify significant trends in IoT research. The most popular topics include edge computing, sensor networks, communication protocols, security and privacy, data analytics and security. These topics cover significant difficulties and possibilities in several facets of IoT adoption and execution, reflecting the complex nature of the IoT.

IoT research has considerably benefited from the efforts of well-known authors and collaborative networks. Network mapping of keywords in management and public administration research on IoT demonstrates the widespread usage of the IoT, the Internet, objects, and technology. Although there have been several interdisciplinary studies on the IoT, it has been noted that there has been an upsurge in social science research, particularly in recent years. These investigations are still in the conceptual framework-drawing stage. The study found certain gaps and areas for further investigation, despite significant advancements. For example, further research should be conducted on effective security mechanisms and privacy-preserving strategies to manage the changing dangers in IoT systems. However, security and privacy have emerged as major concerns.

To fully realize the promise of IoT and new technologies, such as artificial intelligence, blockchain, and 5G networks, further research is needed. The IoT may benefit from bibliometric analysis to provide important insights into the research environment and trends in this area. Researchers can locate important authors, significant publications, hot subjects, and collaborative links by examining bibliographic data and creating co-authorship and co-citation networks. In conclusion, the network mapping method used in this bibliometric study offers a thorough insight into IoT research trends worldwide. The results provide valuable insights into the many research strands, significant figures, and supportive networks that have propelled advancements in this area. Researchers, decision-makers, and business professionals interested in investigating the dynamic IoT research environment and acquiring background information for further research may benefit from the bibliometric insights provided by the study.

6. STATEMENT OF CONFLICT OF INTEREST

There is no conflict of interest between the authors.

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No funding or support was used in the study.

8. AUTHOR CONTRIBUTIONS

DA, EA: The idea, Design, Concept, Interpretation
DA: Collection and/or processing of resources,literature search,empirical analysis and/or interpretation,writer
EA: Critical review, audit

9. ETHICS COMMITTEE STATEMENT AND INTELLECTUAL PROPERTY COPYRIGHTS

Ethics committee principles were complied with in the study.

10. REFERENCES

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