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A bibliometric analysis of IoT-based smart cities

A dissertation submitted in partial fulfilment of the requirements for the Bachelor of Science Honours in Information Technology

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Declaration

I Shanthan Naidu declare that:

(i) The research reported in this dissertation, except where otherwise indicated, is my original research.

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Abstract

The rapid growth of the Internet of Things (IoT) and its integration into smart cities has fuelled substantial research interest over the past decade. This study employs bibliometric analysis techniques to comprehensively explore the landscape of IoT and smart cities research, focusing exclusively on Institute of Electrical and Electronics Engineers (IEEE) articles published in English from 2013 to 2023. The Scopus database serves as the primary data source for this analysis.

The study employs three key analysis tools: VOSviewer, CiteSpace, and Microsoft Excel, to extract and visualize patterns, trends, and impactful research within this domain. VOSviewer will be utilized for co-authorship and co-citation network analysis, providing insights into collaboration dynamics among researchers and the most influential authors and institutions. CiteSpace will help identify emerging research themes, core articles, and the evolution of knowledge domains. Microsoft Excel will support quantitative analysis, enabling the examination of publication trends, citation counts, and the identification of key research clusters.

By applying these bibliometric tools to IEEE articles within the specified timeframe and language constraints, this study aims to uncover the evolution of IoT and smart cities research, prominent research clusters, and influential scholars. The findings will contribute valuable insights into the development and current state of this dynamic field, informing future research directions and facilitating interdisciplinary collaboration in the quest for smarter and more sustainable urban environments.

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List of Abbreviations

AI - Artificial Intelligence **BEMS** - Building

Energy Management Systems **CSV** - Comma-

Separated Values **FWCI** - Field-Weighted

Citation Impact

GDPR - General Data Protection Regulation

HVAC - Heating, Ventilation, and Air Conditioning

ICCCA - International Conference on Computing, Communication and Automation

ICCIKE - International Conference on Computational Intelligence and Knowledge Economy

ICT - Information and Communication Technology

IEEE - Institute of Electrical and Electronics Engineers

IGO - International Governmental Organization

IOES - Internet of Everything Systems

IoT - Internet of Things

IPR - Intellectual Property Rights

ISI - Institute for Scientific Information

ISSC - International Symposium on System Configuration

ITS - Intelligent Transportation Systems

ITU - International Telecommunication Union

ITU-T - ITU Telecommunication Standardization Sector

JOIV - Journal of Open Innovation

MIT - Massachusetts Institute of Technology

NFC - Near Field Communication

NRF - National Research Foundation **NSERC** - Natural

Sciences and Engineering Research Council **NSF** - National

Science Foundation **NSFC** - National Natural Science

Foundation of China

OECD - Organization for Economic Co-operation and Development

PLOS ONE - Public Library of Science ONE **POPI** - Protection of

Personal Information

POPIA - Protection of Personal Information Act

RCR - Research Collaboration Relationships

RFID - Radio-Frequency Identification

SCADEF - Smart City Applications and Framework

SCF - Smart City Framework

STEM - Science, Technology, Engineering, and Mathematics

Key Terms

AI (Artificial Intelligence): The simulation of human intelligence in machines that are programmed to think and learn like humans.

BEMS (Building Energy Management Systems): Systems that monitor and control a building's energy needs to improve energy efficiency and reduce costs.

Bibliometric Analysis: Bibliometrics is a research methodology for quantitatively analyzing scholarly publications to evaluate scientific and academic activity. It examines publication patterns, citations, and collaborations among authors and institutions, offering insights into the impact and development of academic knowledge. This approach is commonly used to assess the significance of research outputs and to guide decisions in academia and research funding.

FWCI (Field-Weighted Citation Impact): A metric that measures the impact of research by comparing the number of citations received to the expected average number of citations in the respective field.

GDPR (General Data Protection Regulation): A legal framework that sets guidelines for the collection and processing of personal information from individuals who live in the European Union (EU).

IoT (Internet of Things): A network of interconnected devices and objects that collect and exchange data using embedded sensors, software, and other technologies.

IPR (Intellectual Property Rights): Legal rights granted to creators and inventors to protect their creations and inventions for a certain period.

NFC (Near Field Communication): A set of communication protocols that enable two electronic devices, usually a mobile device and a payment terminal, to communicate when they are within a few centimetres of each other.

POPIA (Protection of Personal Information Act): South African legislation aimed at protecting personal information processed by public and private bodies.

RCR (Research Collaboration Relationships): Partnerships or associations formed between researchers to collaborate on scientific or academic projects.

RFID (Radio-Frequency Identification): A technology that uses electromagnetic fields to automatically identify and track tags attached to objects.

Smart City: A city that uses information and communication technologies (ICT) to enhance the quality and performance of urban services such as energy, transportation, and utilities to reduce resource consumption, wastage, and overall costs.

Chapter One: Introduction of the Study

1.1. Introduction

The Internet of Things (IoT) is a network where devices, objects, and systems are integrated with software, various technologies and sensors, facilitating the exchange of data and communication between them (Gillis, 2023). IoT integration in smart cities is an emerging multidisciplinary field with profound implications for cities, technology, and society. As the field evolves, there is a need to systematically map its research landscape to understand its evolution and implications (Syed et al., 2021). A comprehensive review of this literature reveals several important themes and trends. Research papers discuss the IoT architecture and components in detail. Gazis (2021) states, "*IoT reflects the need to process and fuse data generated from interconnected devices, as well as store them in a single massive network*". This includes research into sensor devices, communication protocols, middleware and cloud-based platforms. The aim is to create scalable and interoperable architectures that can support different applications and data flows (Marr, 2022).

Security and privacy are recurring themes in IoT literature. Researchers analyzed security threats, vulnerabilities, and strategies to improve the protection of IoT devices and data. Encryption, authentication and access control mechanisms are key areas to ensure the privacy and integrity of IoT systems (Fang et al., 2021). The influx of data generated by IoT devices has led to an increase in research related to data analytics and machine learning (Ayaz et al., 2019). Methods for processing and analyzing IoT big data will be the focus using data mining, predictive modelling and anomaly detection techniques to generate meaningful insights (Menouar et al., 2017).

Energy efficiency is critical due to the resource limitations of many IoT devices. Research in this area includes energy management strategies, energy harvesting techniques, and optimization approaches to extend the lifespan of IoT devices and networks (Gazis et al., 2015). IoT application areas are broad and include smart cities, healthcare, agriculture, transportation and industrial automation. Researchers are studying the way IoT technologies can advance these industries by improving efficiency, sustainability, and user experience (Ganchev et al., 2014). Communication protocols play a crucial role in facilitating connectivity between IoT devices.

Interoperability issues arise from the diversity of IoT devices and platforms. The researchers emphasize the importance of standardization efforts and advocate for common protocols and data formats to enable seamless integration and communication (Gazis et al., 2015). IoT literature often addresses the challenges of widespread adoption, including regulatory hurdles, complexities of data management, and ethical considerations. Researchers offer possible solutions and insights into the future direction of IoT research and development. A remarkable paradigm in the IoT environment is edge computing. This approach includes processing data closer to the source, reducing latency, increasing privacy, and solving bandwidth limitations in IoT networks (Amodu & Othman, 2018).

Scientists are studying the sustainability and environmental impact of the IoT, with the growing number of IoT devices. The goal is to understand and mitigate the environmental impact of device manufacture, use, and disposal (Ganchev et al., 2014). Additionally, efforts to develop green IoT solutions is gaining momentum. IoT literature presents a wide range of research topics covering technical, social and ethical dimensions. The continuous evolution of IoT technologies with their integration into different sectors drives continuous research and innovation. Challenges are addressed and new opportunities for transformative applications are discovered.

Initial discussions on IoT and smart cities have highlighted the potential for improved city services, resource management and citizen engagement (Dustdar et al., 2016). This convergence of technology and urban infrastructure has led to innovative solutions in areas ranging from transportation and energy management to waste reduction and public safety.

IoT technologies enable real-time data collection and analysis from various sources within the city. This data-driven approach enables decision-makers to make informed decisions to optimize resource allocation and improve citizens' quality of life (Nam and Pardo, 2011). Furthermore, IoT contributes to the development of intelligent transport systems that reduce traffic congestion and increase mobility (Ahmed et al., 2016).

The integration of IoT in smart cities brings with it some challenges, privacy concerns and data vulnerabilities stemming from the amount of data collected and shared between connected devices (Madsen, 2018). The management of sensitive information requires careful attention in an era where the IoT is quickly changing different sectors and elements of daily life. IoT technology delivers unmatched benefits, including real-time analytics and automation as well as increased production and efficiency. To fully benefit from these advantages, it is essential to ensure that there is a balance between utilizing IoT's benefits and protecting sensitive data.

As cities strive to become smarter, the need for interoperability standards is an urgent concern. IoT devices and systems from different manufacturers need to communicate seamlessly to achieve desired outcomes (Habibzadeh et al., 2018). Researchers and practitioners are actively seeking solutions to address these interoperability challenges and create a cohesive urban environment.

Bibliometric analysis is a technique that allows for the evaluation of scientific research as well as the identification of key areas for future study as well as development trends in a particular field of study (Rejeb et al., 2022). The use of quantitative methodologies is involved. The initial phase of the study encompassed the examination of publications, their respective subject areas, temporal fluctuations in their quantity, as well as the identification of the most prolific writers, publications, countries, and organizations.

Finally, the incorporation of IoT in smart cities signifies a paradigm shift in urban development and governance. As technology advances, the potential for innovative solutions and a better quality of life for city dwellers is enormous. However, special attention needs to be paid to the challenges of privacy, security and interoperability to ensure that future smart cities are efficient and fair.

1.2. Background to the study

The inclusion of IoT into smart cities represents a dynamic and revolutionary convergence of technology and urban development. IoT has transformed the manner in which cities and their citizens function and interact with their environment by connecting multiple devices, systems and instruments to the internet (Herdiansyah, 2023). Due to the acceleration of urbanization worldwide, the concept of smart cities has gained prominence as a response to the challenges of urban living, sustainability, and resource management (Akre and Yankova, 2019).

The foundation of smart cities is the implementation of IoT technology to create data-driven urban ecosystems. These technologies collect massive amounts of real-time data from a variety of city sources, including transportation systems, energy grids, environmental sensors, and interactions with residents. This data is then analyzed to generate useful information for urban planning, policy making and service delivery (Prasetyo and Habibie, 2022).

The potential benefits of IoT-based smart cities are significant. These include: improved resource efficiency, increased citizen engagement, optimized traffic management, reduced energy consumption and proactive emergency response. In addition, smart cities have the potential to improve citizens' quality of life by providing better services and solving urban problems more efficiently (Kim, 2022). However, this integration of IoT and smart cities also raises many research questions. These questions relate to different dimensions, such as the technical challenges in designing and implementing IoT infrastructures in urban environments. The socio-economic impact of IoT-based services on citizens and businesses, and the policies and governance that protect privacy and are required to ensure safety and sustainability for long-term sustainable smart city initiatives (Almeida et al., 2018).

As the Internet of Things and smart cities have advanced rapidly, bibliometric analysis is an essential tool to gain an in-depth understanding of the research landscape in this field. Existing literature shows trends, research areas, important authors and institutions as well as co-operation in the field of IoT based Smart Cities. Furthermore, it will help to identify knowledge gaps, new research trends and possible directions for future research (Szum, 2021).

The literature on smart cities contains an abundance with publications. Despite this, very little effort has been made to present an exhaustive picture of the current status of bibliometric research on IoT-based smart cities. This article assesses the quality of the research presented in papers on IoT-based smart cities. A bibliometric examination of papers from 2013 to 2023 that were accessible in the Scopus databases was part of the study.

In this context, conducting a bibliometric analysis provides valuable information for researchers, policymakers, planners and technology developers. This not only provides a comprehensive overview of the current state of research but also helps stakeholders to make informed decisions to holistically and effectively expedite the development of smart cities enabled by IoT.

1.3. Aim of the study

The aim of this bibliometric analysis is to examine and fully understand the scientific environment surrounding the integration of IoT technologies in the context of smart cities. The study aims to map evolving research trends related to IoT and Smart Cities. By analyzing the chronological distribution of publications, it is necessary to identify how the subject matter of some research areas has changed over time (Rejeb et al., 2022).

The analysis aims to identify the most prolific, influential authors and institutions contributing to the topic. (Paes et al., 2023). Opinion leader recognition aims to provide information about the key actors shaping the discourse, as well as to discover new innovative research topics in terms of IoT based Smart Cities through content analysis. This includes identifying new areas of focus that have gained prominence in recent years (Park et al., 2018). Quotations from different scientific disciplines are included to highlight how different areas contribute to the discussion.

The study aims to identify areas at which research is relatively scarce or underrepresented. Identifying gaps in the literature aims to provide valuable information for researchers and policymakers wishing to address unexplored aspects (Rejeb et al., 2022). The citation pattern analysis aims to identify innovative and influential works that have contributed to shaping the IoT space and smart cities (Oermann et al., 2020).

The study is intended to provide orientation for future research directions with the use of a comprehensive overview of the research landscape. The aim is to help researchers, policymakers and practitioners identify areas that need further research and development (Nowell et al., 2017). The aim of this bibliometric analysis is to provide a holistic, data-driven understanding of developments, trends, and gaps in IoT and smart city research. In order to achieve these goals, the study aims to contribute to the knowledge base on the combination of IoT technologies in the context of creating more efficient, sustainable and liveable Smart Cities.

1.4. Research Questions

1.4.1. Research Objectives

This study aims to understand the relationships between publications associated with IoT-based smart cities. In addition it aims to explore the network of scholarly work, examining how various research outputs are interconnected:

I. To analyze citation patterns to understand the prevalence and the impact of key works in the IoT and smart city literature.

II. To identify and analyze new research areas, topics or keywords that have gained prominence in IoT based Smart Cities field in recent years.

III. To classify and analyze the dominant research topics in literature to uncover important areas of interest associated with IoT based smart cities.

IV. To identify underrepresented or unexplored aspects in literature to highlight areas that require further research surrounding IoT based smart cities

V. To identify temporal growth patterns and key research associated with IoT based smart cities.

1.4.2. Research Questions

The primary objective of this study is to gain a comprehensive understanding of the interconnections and associations among various publications within the domain of Internet of Things (IoT)-based smart cities. The objective of this study is to investigate the intricate web of academic literature, analyzing the interrelationships between different research outputs.:

I. How have citation patterns for significant publications in the IoT-based smart city literature developed over time?

II. What are the emerging research areas, topics, and keywords that have gained prominence in the field of IoT-based smart cities in recent years?

III. What are the dominant research topics that can be categorized to reveal the primary areas of interest and research in the IoT and smart city literature?

IV. Which specific aspects or subtopics in existing literature have been underrepresented within IoT and Smart Cities?

V. How have research publications associated with IoT based smart cities evolved over time?

1.5. Significance of Research

The proposed bibliometric analysis on the inclusion of IoT technologies in smart cities has important implications for many stakeholders, including researchers, policy makers, urban planners, industry players and the general public. Through a comprehensive review of the scientific literature, this study will provide an in-depth understanding of the current state of research, trends and gaps in the field of IoT and Smart Cities (Rejeb et al., 2022). This knowledge is essential for researchers to contextualize their work in the broader academic discourse.

Analysis provides insights into emerging trends, challenges and possible solutions for IoT integration in smart cities (Syed et al., 2021). Policymakers can use this information to make informed decisions about urban planning, infrastructure development and IoT deployment to improve city life. Urban planners can benefit from understanding the evolving research landscape to strategically align their initiatives with the latest trends in technology and research (Bush & Doyon, 2019). This analysis can help design more efficient and sustainable urban environments. By identifying knowledge gaps and underrepresented areas in the literature, this study may lead researchers to unexplored areas that require further research (Rejeb et al., 2022). Closing these gaps can lead to broader and more holistic research outcomes.

IoT integration in smart cities is an emerging multidisciplinary field with profound implications for cities, technology, and society. As the field evolves, there is a need to systematically map its research landscape to understand its evolution and implications (Syed et al., 2021). The analysis provides insights into evolving trends, focal points and emerging topics in conjunction with IoT and Smart Cities. This information is essential for researchers, policymakers, and practitioners who want to focus their efforts on the latest and most relevant research areas (Rejeb et al., 2022).

This study will reveal gaps in our understanding of IoT-based smart cities by identifying areas that are under-represented or overlooked in the literature. This knowledge can guide future research initiatives and contribute to a more holistic understanding of the topic (Sharifi et al., 2021). The results inform policymakers and urban planners about the latest technological advances, challenges and solutions in IoT and Smart Cities. This knowledge can assist in the formulation of policies that support sustainable urban development and improve citizens' quality of life (Javed et al., 2022). Analytics can benefit research organizations and funding agencies to allocate resources efficiently by identifying high-performing research areas, influential contributors, and emerging trends that deserve attention and investment (Rejeb et al., 2022).

The analysis of interdisciplinary engagement can foster collaboration between researchers across disciplines, enriching the research ecosystem and leading to innovative interdisciplinary solutions (Rejeb et al., 2022). The identification of influential authors, institutions, and cutting-edge work, a study can validate and recognize the contributions of key stakeholders to the advancement of IoT and smart city knowledge (Marrone & Hammerle, 2018). Industry professionals such as technology developers and urban solution providers can benefit from understanding the latest research trends to adapt their innovations to the changing needs of smart cities (Anthony, 2023).

The integration of IoT in smart cities has the potential to improve the quality of life of citizens (Alahi et al., 2023). By highlighting the advances and challenges in this area, the research contributes to the broader societal goal of creating more liveable and sustainable urban environments. Analytics can be a valuable asset for academia, allowing teachers to incorporate the latest trends and insights into their curricula so that future professionals can benefit from a comprehensive understanding of IoT and smart cities (Alahi et al., 2023). Research can foster informed discussion and collaboration among stakeholders, including researchers, policymakers, practitioners and citizens, enabling a holistic approach to smart city development (Alamoudi et al., 2022).

An analysis of interdisciplinary engagement will encourage researchers of all disciplines to collaborate and promote a more holistic approach to addressing the complex challenges of IoT and Smart Cities (Rejeb et al., 2022). Recognition of influential authors, institutions, and innovative papers recognizes their contributions and encourages further research on the critical issues of IoT-enabled smart cities (Marrone & Hammerle, 2018). The industry of IoT based smart cities can benefit from analyzing current and emerging research trends, this knowledge can guide the development of innovative products and services that meet the changing needs of urban environments (Rejeb et al., 2022).

Analytics can improve instructional programs by providing teachers with up-to-date information that can be incorporated into their programs. This enables students to become familiar with the latest developments and challenges in this field (Paes et al., 2021). For cities that want to become smarter and more sustainable, analytics provides the basis for data-driven decision-making. It enables the reconciliation of technological innovations with the needs of society and environmental aspects (Paes et al., 2021).

In conclusion, the rationale of the proposed study lies in its ability to provide a structured and comprehensive understanding of the IoT and smart city research landscape. By filling knowledge gaps, guiding research and informing policymakers, analytics contribute to smart urban development, technology integration and informed policymaking. This will guide urban development, inform decision-making, encourage interdisciplinary collaboration and contribute to the common goal of creating smarter and more sustainable cities.

1.6. Theoretical Framework

Theoretical Framework: Bibliometric Analysis of IoT based Smart Cities Research

Figure 1.6 - Framework Process of the Study

Core Concepts: IoT and Smart Cities:

- IoT Definition: This is an interconnected network of devices, objects and sensors equipped with data collection and communication capabilities, facilitating the exchange of information and automation.

- Smart Cities Definition: Smart cities are urban environments that employ advanced technologies, including IoT, to enhance city operations, services, and sustainability, with a focus on improving the quality of life for residents.

Bibliometric Analysis as a “lens”:

- Bibliometrics Definition: Bibliometrics is the quantitative analysis of publications, citations, and collaborations in scientific literature. It provides insights into research trends, knowledge diffusion, and scholarly impact.

Research Dimensions:

- Publication Trends: Examining the growth of publications related to IoT and smart cities over time, identifying key publication sources, and assessing the geographic distribution of research output.
- Author Collaboration: Analyzing co-authorship networks to identify influential authors, research clusters, and interdisciplinary collaborations.
- Citation Patterns: Investigate citation networks to identify highly cited works, influential papers, and research trends within the field.

Bibliometric Indicators:

- Publication Count: The number of publications related to IoT and smart cities over different time periods, providing insights into research activity.
- Citation Count: The number of citations received by publications, indicating their impact and influence within the scholarly community.
- Collaboration Network Metrics: Metrics such as centrality, density, and modularity in co-authorship and collaboration networks to identify key authors and research clusters.
- Keyword Frequency Analysis: Identifying frequently occurring keywords to understand prevalent research themes.
- Citation Analysis: Examining citation patterns to identify seminal works and research trends.

Drivers and Motivations:

- Urbanization Challenges: The need to address urbanization challenges, including resource management, sustainability, and quality of life improvements, drives research in IoT and smart cities.
- Technological Advancements: The availability of advanced IoT technologies and data analytics tools motivates researchers to explore their applications in urban contexts.
- Interdisciplinary Collaboration: The interdisciplinary nature of IoT and smart cities research fosters collaboration among experts from various fields.

Research Impact:

- Policy Influence: Assessing the impact of IoT and smart cities research on urban policies, planning, and governance.
- Technological Advancements: Investigating how research findings have contributed to the development of new technologies and solutions for smart cities.
- Quality of Life Improvements: Evaluating the extent to which research has influenced improvements in urban services and residents' quality of life.

The proposed theoretical framework for bibliometric analysis with regard to IoT-based smart cities provides a structured and thorough approach to understanding research trends, knowledge transfer, and the overall academic landscape in this interdisciplinary field. By utilizing bibliometric techniques, this study seeks to clarify the development and significance of research, pinpoint new research themes, identify knowledge gaps, and support well-informed policy and future research decision-making.

The framework includes crucial steps such as the gathering of data from reputable academic databases; careful data pre-processing and cleaning to ensure data accuracy and relevance; and the use of bibliometric indicators like citation counts; co-citation analysis; and bibliographic coupling to analyze citation patterns and research collaborations. The interpretation and understandable presentation of complicated bibliometric data are captured by the incorporation of visualization tools.

Finally, this theoretical framework offers the groundwork for future research, empirical investigations, and practical applications in addition to offering a systematic method for bibliometric analysis within the context of IoT-based smart cities. Utilizing bibliometric analysis, it aims to improve our comprehension of the developing IoT-based smart city landscape, opening the way for developments that help create more intelligent, efficient, and sustainable urban environments.

1.7. Overview of the Study

In this comprehensive study, we delve into the dynamic and evolving field of IoT as it intersects with the development of Smart Cities. The manuscript is meticulously structured into six chapters, each serving a distinct yet interconnected purpose.

Chapter Two: Literature Review - This chapter forms the foundation of the research, offering an exhaustive review of existing literature on IoT and Smart Cities. It not only elucidates key concepts and trends but also identifies crucial gaps in current knowledge. This exploration into theoretical and conceptual frameworks lays the groundwork for understanding the intricacies of IoT-enabled Smart Cities. Additionally, the significance of bibliometric analysis in grasping the research landscape is discussed, setting the stage for the methodology adopted in this study.

Chapter Three: Research Problem – This chapter articulates the central research problem, drawing from the insights gleaned in the literature review. This chapter is pivotal in shaping the research direction and framing the subsequent analytical methods.

Chapter Four: Methodology - In this chapter, the research design and methodological approach, particularly the use of bibliometric analysis, are detailed. It describes the methods of data collection, including the selection of databases, keywords, and search criteria. The processes of data mining, cleansing, and the rationale behind choosing specific publications are also discussed, providing clarity on the research process.

Chapter Five: Data Analysis and Presentation - This chapter presents the core analytical work of the study. It demonstrates the quantitative techniques employed in data mining and analyzes trends over time. The chapter explores research themes, emerging topics, and conducts a keyword analysis. It also emphasizes interdisciplinary collaboration, profiling prominent authors and institutions, and examines their contributions and areas of expertise. Furthermore, the analysis extends to the network of co-authorship and institutional collaboration, offering insightful observations.

Chapter Six: Summary and Future Research - The final chapter synthesizes the findings in terms of IoT based smart cities and offers concrete recommendations for researchers, policymakers, and practitioners. It discusses how the results can serve as a guide for future research and decision-making, highlighting the practical implications of the study and suggesting avenues for future exploration.

Each chapter builds upon the preceding one, weaving a narrative that is both analytically rigorous and practically relevant, offering a comprehensive overview of the current state and future potential of IoT in the development of Smart Cities.

Chapter Two: Literature Review

2.1. Introduction

The term "Internet of Things" (IoT) describes how commonplace items and objects are connected to the Internet so they may exchange and collect data (Gillis, 2023). The integration of IoT technology in urban environments has garnered significant attention, mostly due to its promise to transform cities into smart, efficient, and sustainable entities.. This survey of the literature attempts to offer an overview of the IoT, its implications for urban environments, and perspectives from diverse authors on this game-changing technology.

In order to implement IoT in urban settings, various infrastructures must be equipped with sensors and communication devices that allow for data gathering and processing (Rai, 2023). Cities may increase sustainability, public services, resource allocation, and economic growth with IoT.

IoT has the potential to enable smart cities by giving city planners access to real-time data, according to Alahi et al. (2023). They talk about how IoT may improve healthcare, waste management, energy use, and traffic management, which will ultimately result in better resource management and a higher standard of living. Park (2018) provides a thorough summary of IoT technologies, uses, and difficulties. The primary objectives of their efforts revolve around enhancing urban sustainability, reducing energy consumption, and fostering a cleaner environment by employing intelligent resource management strategies, hence underscoring the need of smart cities based on the IoT.

Hassebo & Tealab (2023) have examined IoT's contributions to the urban environment, particularly around the area of smart cities. They go over the many IoT applications, such as smart grid systems, smart transportation, and smart healthcare, highlighting the importance of effective data management and security to fully reap the rewards. IoT-enabled smart cities are thoroughly examined by Syed et al. (2021), who also highlight the many parties and components involved. In order to produce sustainable, liveable urban places, they emphasize the significance of a holistic strategy that incorporates technologies, policies, and public interaction.

Although all experts agree that IoT has the ability to transform urban areas into "smart cities," their viewpoints differ in terms of depth and emphasis. Hassebo & Tealab (2023) highlight a variety of applications, while Alahi et al. (2023) primarily concentrate on practical applications and real-time data utilization. Syed et al. (2021) emphasize the significance of a holistic approach involving multiple stakeholders for successful implementation.

The potential for creating smart cities through IoT integration in urban settings is enormous. The ability of IoT to revolutionize how resources are managed, advance sustainability, and enhance quality of life is widely acknowledged by authors. For the IoT to be deployed effectively in the urban environment, it is necessary to take into account a multidimensional strategy that includes technology, policy, and citizen involvement. For IoT to fully contribute to the construction of smarter, more sustainable cities, additional research and practical applications are required.

2.1.1. Key Components and Technologies:

In his complete proposal, Gillis (2023) identifies four essential building pieces for IoT systems: sensing, communication, data processing, and action. They emphasize the significance of sensors for gathering data, communication networks for transmitting data, data analytics for drawing conclusions, and actuators for implementing changes in response to the conclusions drawn. According to Douzis et al. (2018), integrating cloud computing and IoT is a crucial step in creating smart cities. They talk about how cloud computing makes it possible to store and handle massive volumes of data produced by IoT devices in a scalable manner, enabling resource optimization and real-time decision-making in urban environments.

Fog computing is emphasized by Zahmatkesh and Al-Turjman (2020) as a key technology in IoT-based smart cities. They explain how extending cloud capabilities to the network's edge with fog computing which enables quicker data processing and lowers latency. This is especially important for applications that require quick responses in smart city settings. The communication standards and protocols required for IoT deployment in smart cities are discussed by Mansour et al. (2023). The need for established protocols to promote smooth communication and interoperability among IoT devices is emphasized as they explore several communication methods, including Radio-Frequency Identification (RFID), Near-Field Communication (NFC), and Internet Protocol Version 6 (IPv6).

While the basic elements like sensing, connectivity, and data processing are shared by all writers, their emphasis on integrating cloud and fog computing varies. Gillis gives a thorough description of the fundamental elements, whereas Douzis et al. (2018) concentrates on integrating cloud computing, Zahmatkesh & Al-Turjman (2020) emphasizes the value of fog computing, and Mansour et al. (2023) emphasizes the significance of standardized communication protocols.

The creation of smart cities depends critically on the integration of IoT components and technology. Although authors have different opinions on the function of cloud and fog computing, they all agree on the importance of the sensing, communication, and data processing components. For the IoT to be fully utilized in the construction of smart and sustainable cities, it is essential to comprehend and utilize these elements and technologies in concert. In order to maximize the integration and interoperability of these components for maximum impact, additional research and practical applications are essential.

2.2. Historical Evolution and Conceptual Framework:

Smart cities have undergone a transformation as a result of the IoT historical evolution and how it interacts with the creation of smart cities. This analysis of the literature attempts to provide an overview of the development of IoT historically and its incorporation into the idea of smart cities, pulling from the opinions of many authors and contrasting them.

2.2.1. Historical Development of IoT:

In their work on ubiquitous computing, Kumar et al. (2019) introduced the idea of effortlessly integrating computing into daily life, which served as the foundation for IoT. In his vision, computers would become a natural part of society and enable interactions between people and technology that would later become known as the Internet of Things. The term "Internet of Things," which captures the idea of a network of networked objects sharing information and conversing autonomously, was introduced in an influential piece by Gubbi et al. (2013). By enabling items to gather and transmit data over the internet, he stressed how RFID and sensor technologies have the potential to revolutionize a number of industries.

2.2.2. Historical Development of Smart Cities:

An early, thorough definition of smart cities was offered by Zhao et al. (2021), along with a timeline of their development. They followed the transition from conventional urban planning to a more comprehensive strategy that included Information and Communication Technology (ICT) to improve urban sustainability and effectiveness. The historical growth of smart cities and its direct connection to the development of urban informatics and digital technologies were noted by Shin et al. (2021). He talked about the way the paradigm for urban development and governance is shifting in favour of using data, ICT, and collaborative methods.

The writers present contrasting viewpoints on the IoT's historical evolution. The conceptual framework was established by the visionary concepts of Kumar et al. (2019), and the word "IoT" was popularized and defined by Gubbi et al. (2013). Shin et al. (2021) highlighted the connection between digital technology and the advancement of smart cities, whereas Zhao et al. (2021) focused on the integration of ICT into urban planning in the area of smart cities.

From theoretical foundations to worldwide standardization and actual implementations, the historical development of IoT and its integration into smart city concepts constitutes a dynamic growth. The revolutionary potential of IoT and ICT in creating smarter, more sustainable urban landscapes is acknowledged by authors. To fully appreciate the entire nature of IoT and smart cities and to guide future research and development in this quickly developing field, it is essential to understand this historical trajectory. The development and improvement of IoT and smart city projects will continue to be fuelled by additional research and practical applications.

2.2.3. Conceptual Frameworks for Understanding IoT in Smart Cities:

A complete framework for smart cities was proposed by Sucupira Furtado et al. (2023), focused on six dimensions: the smart economy, the smart mobility, the smart environment, the smart people, the smart living, and the smart government. Despite not addressing IoT specifically, their paradigm offers a solid framework for comprehending how IoT is integrated across different dimensions in the context of smart cities. In their proposed layered model for IoT in smart cities, Tekinerdogan et al. (2023) included layers for perception, network, data processing, and application. Their paradigm offers perceptions into how IoT devices and sensors take in their surroundings, communicate data via networks, analyse data, and produce useful applications, ultimately aiding in the creation of smart city solutions. A conceptual model for IoT in smart cities was put forth by Syed et al. (2021), with an emphasis on data management, analytics, and applications. In order to attain the goals of the smart city, they underlined the significance of data-driven decision-making and the necessity for efficient data management, analysis, and application development. A model that highlights the function of IoT in allowing smart services inside a city was provided by Rejeb et al. (2022). The framework was divided into three layers: perception, network, and service. Their model demonstrates how IoT helps provide services and improves quality of life in smart cities.

Although experts agree on the significance of IoT in smart cities, their frameworks vary in terms of emphasis and level of detail. While Tekinerdogan et al. (2023) and Syed et al. (2021) provide extensive models concentrating on IoT's technological components and data management, Sucupira Furtado et al. (2023) propose a broader perspective on smart cities without directly addressing IoT. Rejeb et al. (2022), on the other hand, focus on offering intelligent services made possible by IoT.

A multi-dimensional strategy is necessary to fully comprehend the integration of IoT in smart city efforts, taking into account a number of different factors like data management, technology layers, and service provisioning. With varying degrees of specificity and intensity, each proposed conceptual framework offers a distinctive lens through which to understand this integration. To fully realize the potential of IoT in creating smarter, more sustainable cities, greater study and practical use of these frameworks are absolutely necessary. Future efforts in the IoT-driven transformation of urban environments will be guided by the iterative improvement and consolidation of these frameworks.

2.3. Key IoT Applications in Smart Cities:

2.3.1. IoT Applications in Transportation:

IoT applications in ITS that improve traffic flow, lessen congestion, and increase road safety are covered by Oladimeji et al. (2023). In real-time traffic monitoring, adaptive traffic signal regulation, and vehicle-to-vehicle (V2V) communication, they highlight the importance of IoT-enabled sensors and data analytics. In order to effectively manage parking spaces within cities, Fahim et al. (2021) concentrate on IoT applications in smart parking systems. They emphasize the use of sensors to determine parking space availability, providing vehicles with real-time information and maximizing the use of parking resources.

2.3.2. IoT Applications in Energy Management:

IoT applications for smart energy grids are described by Madhuri et al. (2022), with a focus on real-time monitoring and management of energy distribution. They go over how the IoT enables demand-side management, the integration of renewable energy sources, and efficient energy use via smart meters and gadgets. Al-Obaidi et al. (2022) explore IoT applications for Building Energy Management Systems (BEMS), demonstrating how IoT-enabled gadgets optimize energy use in buildings. They draw attention to energy-saving Heating, Ventilation, and Air Conditioning (HVAC) systems, lighting controls, and occupancy sensors that support sustainable construction techniques.

2.3.3. IoT Applications in Healthcare:

For remote patient monitoring and healthcare administration, Rejeb et al. (2022) investigate IoT possibilities in healthcare. In order to demonstrate how IoT improves healthcare accessibility, efficiency, and patient outcomes, they place a strong emphasis on wearable technology, smart healthcare devices, and telemedicine. IoT applications in healthcare for geriatric care and health monitoring are covered by Perez et al. (2023). They emphasize how the IoT is enabling the development of smart houses with health sensors and aids that improve the quality of life for senior citizens.

The writers agree that IoT has the potential to change a number of industries within smart cities. IoT applications in the field of transportation are discussed by Oladimeji et al. (2023) and Fahim et al. (2021), respectively, with an emphasis on traffic management and smart parking systems. IoT applications in energy management, particularly in energy grids and building energy systems, are highlighted by Madhuri et al. (2022) and Al-Obaidi et al. (2022). IoT applications in healthcare are covered by Rejeb et al. (2022) and Perez et al. (2023), with a focus on patient monitoring and senior care.

Smart city IoT applications offer a substantial paradigm shift in urban management, improving productivity, sustainability, and quality of life. The opinions of the authors highlight the variety of IoT applications across the transportation, energy, and healthcare sectors. For informed decision-making and the successful implementation of IoT to create smarter, more resilient cities, an understanding of these applications is essential. These applications will be improved by additional study and real-world application, allowing cities to reach their full potential in influencing a sustainable and technologically advanced future.

2.3.4. Impact and Benefits of IoT Adoption in Healthcare:

IoT's influence on healthcare is discussed by Rejeb et al. (2022), with a focus on remote patient monitoring and individualized care. They underline how IoT technologies, like wearables and health sensors, offer real-time patient monitoring, increasing patient outcomes and healthcare delivery. The advantages of IoT in healthcare are emphasized by Kelly et al. (2020). These advantages include better patient care, more effective resource allocation, and lower healthcare expenditures. They talk about how IoT innovations, such as telemedicine and connected medical equipment, improve the efficiency and accessibility of healthcare.

2.3.5. Impact and Benefits of IoT Adoption in Agriculture:

The authors analysis of the Internet of Things' effects on precision farming, Akhter and Sofi (2022) emphasizes the advantages of smart farming. They emphasize how IoT-enabled agricultural sensors and data analytics maximize pest management, fertilization, and irrigation, resulting in higher crop yields and more environmentally friendly farming methods. In their discussion of the advantages of IoT in smart farming, Dhanaraju et al. (2022) place a focus on resource conservation and environmental sustainability. They explain how IoT apps help farmers make data-driven decisions that save resources and promote sustainable farming practices.

2.3.6. Impact and Benefits of IoT Adoption in Manufacturing:

The impact of IoT in manufacturing is discussed by Javaid et al. (2022), with an emphasis on the advantages of Industry 4.0 (IR4.0). They underline how enhancing supply chain management, production efficiency, and quality control using IoT-enabled smart factories will increase manufacturing competitiveness. Verma (2022) examines the advantages of IoT in manufacturing, emphasizing more flexibility, cost reductions, and better production. They go over how IoT technologies, such real-time monitoring and predictive maintenance, improve manufacturing operations and cut downtime.

2 .3.7. Impact and Benefits of IoT Adoption in Transportation:

Oladimeji et al. (2023) focus on linked and smart vehicles as they discuss the effects of IoT in transportation. They place a strong emphasis on how IoT technologies improve traffic management, ease congestion, and increase road safety, all of which contribute to the development of more effective and sustainable transportation systems. Dzuiba (2021) emphasizes the advantages of IoT in the transportation sector, focusing on increased mobility, lower emissions, and better urban planning. They talk about how IoT technologies, like intelligent traffic lights and vehicle-to-infrastructure connectivity, improve transportation networks and support sustainable urban development.

The benefits and positive effects of IoT adoption in several sectors are agreed upon by the authors. The focus of Kelly et al. (2020) and Rejeb et al. (2022) is on cost-effectiveness and healthcare outcomes. Sustainable agricultural approaches are highlighted by Akhter & Sofi (2022) and Dhanaraju et al. (2022). Verma (2022) and Javaid et al. (2022) concentrate on increasing productivity and efficiency in the industrial sector. Oladimeji et al. (2023), as well as Dzuiba (2021), stress the importance of better traffic management and transportation sustainability.

IoT adoption has demonstrated significant benefits in a variety of industries, including manufacturing, transportation, agriculture, and healthcare. The revolutionary advantages of IoT adoption are emphasized by authors, who emphasize increased effectiveness, sustainability, cost savings, and service quality. Making educated decisions and integrating IoT technology successfully depend on an understanding of these advantages, which will eventually spur innovation and advancement across a variety of industries. The study will gain a deeper knowledge and realize the full potential of IoT across these sectors through additional study and real-world applications.

2.4. Bibliometric Analysis Methodology:

2.4.1. Data Sources for Bibliometric Analysis:

Web of Science (WoS) is well known for its thorough coverage of academic journals, conference proceedings, and other publications. It is a popular option for bibliometric studies because of its structured data and precise citation information, which guarantees complete and trustworthy data. A reputable multidisciplinary database with extensive coverage of academic literature is called Scopus. It is a thorough source for bibliometric analysis because it includes journals, conference papers, and patents. In addition to WoS, researchers frequently use Scopus to support their analyses. Google Scholar is freely accessible and indexes a large range of scholarly information, despite being less controlled and structured than WoS and Scopus. Researchers frequently utilize it to broaden their search and find more papers, particularly in the area of grey literature and unconventional academic sources.

2.4.2. Search Strategies for Bibliometric Analysis:

Prudent keyword selection and the use of Boolean operators (AND, OR, NOT) to create accurate and thorough search queries are essential components of effective search techniques. To ensure thorough coverage, authors stress the value of employing regulated vocabulary and synonyms. Truncation and wildcards increase the number of search results by incorporating different search phrases. This method makes sure that every pertinent item is included, regardless of spelling or word changes.

2.4.3. Inclusion and Exclusion Criteria:

Inclusion criteria are developed by researchers to specify the standards for choosing pertinent publications. Common requirements include peer-reviewed papers, articles published within a certain time frame, and publications that were published. Exclusion criteria specify the conditions under which specific items are excluded from the analysis. Non-peer-reviewed articles, duplicates, extraneous material, and studies that are not relevant to the research are typical exclusions.

Google Scholar is important for bibliometric analysis, according to Rejeb et al. (2022). They highlight this by pointing out its broad coverage and capacity to find citations in a variety of publications. They emphasize its value despite possible biases and indexing difficulties. Ellegaard & Wallin (2015) promote a complete strategy for bibliometric analysis and advise combining WoS, Scopus, and Google Scholar to achieve thorough data gathering. They emphasize how crucial it is to be aware of each source's advantages and disadvantages. To increase precision and memory, they emphasize the need for a well-rounded strategy. In their comprehensive examination of search tactics, Ho et al. (2016) highlight the benefits of using Boolean operators, truncation, and wildcards to create powerful queries.

It is important to carefully analyze data sources, search tactics, and inclusion and exclusion criteria before conducting a bibliometric analysis. The well-known data sources WoS, Scopus, and Google Scholar each have their own advantages. The use of keywords, Boolean operators, and truncation in effective search strategies is essential. The scope of the analysis is determined by the inclusion and exclusion criteria. The benefits and drawbacks of diverse procedures are highlighted by contrasting the approaches of writers, underscoring the significance of a considered and flexible approach to bibliometric research. Conducting thorough bibliometric analyses that significantly enhance knowledge in academia and in the field of research requires an awareness of these approaches.

2.5. Bibliometric Analysis Findings:

2.5.1. Quantitative Analysis of Publications Over Time:

A thorough bibliometric analysis was carried out by Ghani et al. (2022) to evaluate the features and growth trends of the world's scientific output. Their study, which used data from Scopus and WoS, highlighted the impact of research globalization by revealing a considerable increase in the number of publications over time. VOSviewer, a software program for creating and viewing bibliometric maps, was presented by Li & Hasnah Hassan. (2023). It enables the quantitative analysis of publication patterns, co-authorship networks, and research subjects. Their method makes it easier to detect research hotspots and new trends in a certain sector.

2.5.2. Publication Types in Quantitative Analysis:

An approach for classifying scientific materials into four basic categories—articles, reviews, conference papers, and editorials was given by Chen & Xiao (2016). For effective bibliometric analysis, their study stressed the significance of precisely categorizing publication types because each type offers unique insights into research output. The rise of various document kinds, such as articles, reviews, and conference papers, in a variety of scientific topics was examined by Jun et al. (2018). Their research exposed disparate growth rates and patterns of publishing formats, illuminating scholarly communication inequalities between disciplines.

2.5.3. Geographical Analysis of Publications:

A bibliometric analysis was carried out by Mohadab et al. (2020) to examine the production of research in library and information science in various nations. Their study shed light on worldwide research distribution by offering insights into publication trends and contributions from various nations. When examining how geographic location affects the output of research, Dwivedi et al. (2023) concentrated on the publication patterns of writers from various locations. Their research revealed regional differences in writers' publication rates and patterns, as well as the influence of institutional and cultural factors.

While all writers agree that quantitative analysis is important for comprehending publication trends, growth patterns, publication kinds, and geographic variances, their methods are different. Bibliometric methods and databases are used by Ghani et al. (2022)

and Li & Hasnah Hassan (2023) to examine growth patterns and depict research landscapes. In order to identify subtle trends, Chen & Xiao (2016), Jun et al. (2018), and others emphasize accurate classification of publishing categories. Geographical analysis is the main emphasis of Mohadab et al. (2020) and Dwivedi et al. (2023), who provide insights into regional differences in research output.

Understanding the dynamics of academic research requires the use of quantitative analysis of publications across time. The studies, under examination, show the variety of methodology and strategies used to examine growth trends, publication kinds, and geographic variances. By combining these methodologies, one can gain a thorough grasp of the rapidly changing research scene and make well-informed decisions about future academic endeavours. The accuracy and breadth of quantitative analyses in academic research will continue to be improved through additional study and developments in bibliometric tools and methodology.

2.5.4. Identifying the Most Cited Articles:

"Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions" is a seminal work written by Madakam et al. (2015). This book offers a thorough analysis of IoT architecture, components, and prospective applications; as such, it will serve as a fundamental reference for the IoT industry. Zymbler, Kumar, and Tiwari (2019). The article "Internet of Things is a revolutionary approach for future technology enhancement: a review" offers a thorough examination of IoT innovations and how they fit into the idea of smart cities. The study emphasizes how IoT has the ability to revolutionize urban landscapes and has received numerous citations in related studies.

2.5.5. Identifying the Most Cited Authors:

Significant contributions have been made by Madakam et al. (2015), a well-known researcher in IoT and smart cities, including ground-breaking publications like "Internet of Things for Smart Cities". His large citation count reflects his prominence in the field and the breadth and depth of his knowledge and research output.

2.5.6. Identifying the Most Cited Journals:

The Institute of Electrical and Electronics Engineers (IEEE) "Internet of Things" Journal is a top source for academic IoT research. Articles published in this journal typically receive high citations due to its broad readership and strict review procedure, solidifying its place as a leading journal in the industry. The open-access journal "Sensors" covers a wide range of subjects pertaining to sensor technologies and applications, including IoT. This magazine is a noteworthy venue for the distribution and citation of research in the area of IoT-based smart cities because of its accessibility and rich content.

There is general agreement regarding the significance of the ground-breaking research by Madakam et al. (2015) and Kumar, Tiwari & Zymbler (2019), however different writers bring different viewpoints to the IoT-based smart cities field. Journals like the IEEE Internet of Things Journal and Sensors, which reflect the multidimensionality of IoT in smart cities, similarly support the various research demands of the subject.

IoT-based smart cities' most frequently referenced articles, authors, and journals can be used to gain important insights into the field's leading scholars and prominent research. The discussion of IoT applications in urban settings has been greatly influenced by Madakam et al. (2015) and Kumar, Tiwari & Zymbler (2019). The IEEE "Internet of Things" Journal and "Sensors" are important venues for the publication and citation of research, highlighting how IoT-based smart cities are interdisciplinary in nature. Future studies and ongoing analysis of citations will shed more light on developing patterns and important works in this dynamic and developing subject.

2.6. Research Themes and Trends:

Understanding the various applications and effects of the IoT inside smart cities requires categorizing the literature based on study themes.

2.6.1. IoT-Enabled Transportation:

A basic study on IoT applications in Intelligent Transportation Systems (ITS) is offered by Oladimeji et al. (2023). They explain how combining real-time data from sensors and linked vehicles might help IoT technology optimize traffic flow, increase road safety, and lessen congestion. The IoT applications for managing urban traffic are the main topic of Sarrab et al. (2020). They give a thorough analysis of how intelligent traffic lights and IoT-enabled traffic monitoring systems can dramatically improve traffic management, resulting in more effective transportation in smart cities.

2.6.2. IoT for Sustainable Energy:

IoT applications in smart grids and energy management are highlighted by Madhuri et al. (2022). They discuss about how IoT provides real-time monitoring and control of energy distribution, encouraging sustainable behaviours and efficient energy use in smart cities.

A thorough analysis of IoT applications in renewable energy systems is provided by Al-Obaidi et al. (2022). They emphasize how IoT technology can facilitate the integration of renewable energy sources, resulting in a more environmentally friendly and long-lasting energy infrastructure.

2.6.3. IoT in Healthcare within Smart Cities:

The focus of Javaid et al. (2022) is on the use of IoT in healthcare, particularly in remote patient monitoring, inside smart cities. They talk about how IoT-enabled medical equipment and telemedicine programs improve access to and the standard of care, which benefits patients. In their assessment of IoT applications in healthcare, Rejeb et al. (2022) place a focus on healthcare data analytics and security. In order to enable informed decision-making and improve healthcare services in smart cities, they investigate how IoT technology can handle and analyze healthcare data.

IoT is important across a range of smart city disciplines. Using IoT-enabled technologies, Oladimeji et al. (2023) and Sarrab et al. (2020) concentrate on improving transportation networks. The potential of IoT in reaching sustainable energy targets is highlighted by Madhuri et al. (2022) and Al-Obaidi et al. (2022) IoT has a revolutionary impact on healthcare in smart cities, notably in patient monitoring and data analytics, as highlighted by Javaid et al. (2022) and Rejeb et al. (2022).

A structured understanding of IoT applications and their effects is provided by categorizing IoT literature based on research themes such as transportation, renewable energy, and healthcare within smart cities. Collectively, the authors' numerous perspectives demonstrate the IoT's varied possibilities for influencing programs for smart cities. This category makes it easier to conduct focused study and implement solutions, advancing the development of technologically sophisticated, sustainable, and efficient smart cities. Our grasp of these study subjects will be strengthened by additional multidisciplinary cooperation and research, which will also open the door for upcoming developments in IoT-driven smart cities.

Understanding how a given area develops, adapts, and reacts to shifting settings and technology depends on analyzing emerging patterns and shifts in study focus across time.

2.6.4. Emerging Trends and Shifts in Research Focus Over Time:

Rejeb et al. (2022) used bibliometric methods to spot trends and changes in the direction of research over time. Their study focused on the move from print-based to electronic publication and the rise of open access publishing, examining the shift from traditional research themes to emergent and transdisciplinary domains. Network analysis and topic modelling were used by Heller et al. (2023) to map the scientific landscape and pinpoint new trends in research. They highlighted the fusion of diverse fields as they spoke about the rise of interdisciplinary research and the impact of funding and collaborations on research focus. Lungeanu et al. (2014) used co-word analysis and network visualization, to comprehend new research trends and interdisciplinarity. By analyzing the body of scientific literature, they pinpointed emergent research themes and stressed the value of multidisciplinary research in solving complex societal concerns.

In order to examine new trends and changes in the research focus throughout time, authors use a variety of approaches. While Heller et al. used network analysis and subject modelling to analyze multidisciplinary trends, Rejeb et al. (2022) largely used bibliometrics to track changes in publication patterns and formats. Co-word analysis was used by Lungeanu et al. (2014) to highlight the value of multidisciplinary research in tackling societal problems.

Understanding the changing research landscape requires an analysis of new trends and shifts in research concentration across time. Whether using bibliometrics, network analysis, or co-word analysis, each method offers distinct insights into the changing nature of research across a range of disciplines. The observed patterns and changes in research priorities show the interdisciplinary character of current research and the value of collaboration and social requirements adaption. We will continue to get a deeper grasp of changing research trends through more research and the application of cutting-edge analytical methodologies, which will support discipline-specific innovation and well-informed decision-making.

2.7. Methodologies and Data Analysis in IoT-based Smart City Research:

Numerous approaches are used in the IoT research conducted in smart cities to comprehend its uses, effects, and difficulties.

2.7.1. Methodologies in IoT Research for Smart Cities:

In their study on IoT research for smart cities, Syed et al. (2021) emphasized the importance of case studies since they offer in-depth insights into practical implementations. Case studies give academics the chance to look into particular implementations, difficulties, and successes while providing insightful qualitative and contextual knowledge. Zahmatkesh & Al-Turjman (2020) talked on the usage of surveys to gather information on IoT applications in smart cities. Surveys give researchers a controlled way to collect data from a large sample, allowing for quantitative analysis and the discovery of trends, preferences, and problems.

To assess the influence of IoT on smart cities, Alahi et al. (2023) underlined the value of simulations and models. Through the use of simulations, researchers may test different hypotheses, forecast results, and optimize IoT deployments without actually implementing them. This gives them insights into effectiveness and scalability. In order to evaluate the effectiveness and viability of IoT technology in smart cities, Rejeb et al. (2022) argued for experimental investigations. Using empirical data from experiments, researchers can assess the technological merits, dependability, and efficacy of IoT systems.

All authors appreciate case studies, surveys, simulations, and experimental investigations, they all place different emphasis on these types of studies. Syed et al. highlight the detailed contextual knowledge gained from case studies that reveal actual IoT applications. The importance of surveys in gathering data at scale and generating quantitative insights is emphasized by Zahmatkesh & Al-Turjman (2020). Prior to real deployment, Alahi et al. (2023) emphasize the use of simulations for scenario testing and optimization. Experimental research is encouraged by Rejeb et al. (2022) to confirm the technical efficacy and applicability of IoT technology.

In IoT-related research for smart cities, a range of approaches are used to meet a range of research goals and data collection requirements. Case studies provide contextual information; surveys collect a wide range of data; simulations provide scenario testing; and experimental research substantiates results. To expand the knowledge and use of IoT in smart cities, researchers should carefully select and combine these approaches based on their unique research goals. The depth and breadth of study in this dynamic topic will be significantly improved by future developments in these approaches. Any scholarly investigation must include research procedures since they influence the data collecting, analysis, and interpretation processes.

2.7.2. Quantitative Research:

The collecting of numerical data is a component of quantitative research, which is praised for its objectivity, generalizability, and capacity to identify patterns and linkages. Ishtiaq

(2019) places a strong emphasis on its capacity to deliver exact, quantifiable results and enable statistical analysis for a more organized and accurate understanding of study phenomena.

Rahman (2016) points out the possible flaw in quantitative research's tendency to oversimplify complex social issues while admitting its advantages in providing numerical data and statistical analysis. He says it might be shallow and fall short of capturing the complexity and variety of human experiences.

2.7.3. Qualitative Research:

For its breadth, depth, and comprehensive understanding of human feelings and behaviour, qualitative research is praised. Collins and Stockton (2018) draw attention to the adaptability of the approach, which enables the dynamic examination of intricate social circumstances, attitudes, and cultural influences. It provides a deeper comprehension of skewed reality. Rahman (2016) emphasizes how effective qualitative research is at capturing the subtleties of human behaviour and circumstance, facilitating the development of theories, and offering in-depth insights. They do point out that it can be labour- and time-intensive and that subjectivity and interpretation issues could arise.

2.7.4. Mixed Methods Research:

This involves utilizing the advantages of each, mixed methods research combines quantitative and qualitative methodologies. Schoonenboom & Johnson (2017) highlight their capacity to offer a thorough understanding by combining data from many sources and approaching research problems from a variety of angles, resulting in a more thorough and nuanced study. In using the advantages of both quantitative and qualitative research procedures, Fetters et al. (2013) highlight the adaptability of mixed methods research. To retain the rigor and credibility of the study, they do warn that it takes competence in both methodologies and careful integration.

The strengths of each study methodology quantitative for its objectivity, qualitative for its depth, and mixed techniques for their complimentary nature are recognized by the authors in agreement. They differ, nevertheless, in how much emphasis they place on flaws such the difficulty of integrating methodologies in mixed methods research and the contrast between the potential subjectivity of qualitative versus quantitative approaches.

For researchers to choose an appropriate methodology, they must be aware of the advantages and disadvantages of various approaches. Though it can oversimplify things, quantitative research gives impartiality and generalizability. While qualitative research offers richness and depth, it may lack objectivity. While integrating strengths, mixed methods research necessitates integration expertise. In order to choose the approach that is best in line with their study objectives and open-ended research questions, researchers must take these factors into account.

2.8. Challenges and Future Directions:

The use of IoT in smart cities can significantly improve sustainability. As noted by Bibri (2020), IoT technologies enable better resource management, reducing waste and energy consumption. This contributes to more sustainable urban environments. However, any transformational effort has its own set of difficulties and restrictions.

2.8.1. Challenges and Limitations in IoT Adoption in Smart Cities:

The implementation of IoT for smart cities still faces considerable obstacles in interoperability and standards by Allioui & Mourdi (2023). The promise of a unified IoT ecosystem is constrained by heterogeneity in devices, protocols, and platforms, which prevents smooth communication and integration. The deployment of IoT in smart cities is surrounded by serious privacy and security concerns by Fabrègue & Bogoni (2023). Strong security measures are required because to the enormous volume of data collected and transmitted, which creates privacy concerns and puts key infrastructure at danger from cyberattacks. Scalability of IoT infrastructure is a problem, especially in metropolitan regions that are developing quickly by Alabdulatif & Thilakarathne (2023). The management of the increasing quantity of IoT devices and the associated data they generate, while considering energy and resource consumption, remains an ongoing concern.

One significant restriction is the high cost of adopting IoT technology and infrastructure. For urban planners and legislators, funding smart city initiatives and assuring a return on investment while providing citizens with accessible services presents considerable problems by Park et al. (2018). It can be difficult to involve individuals and ensure inclusivity in IoT adoption by Shin et al. (2021). For cities to be genuinely smart and inclusive, the digital divide must be closed and equal access to IoT-enabled services must be guaranteed.

On important issues including interoperability, security, and scalability, the writers are in agreement. Both Fabrègue & Bogoni (2023) and Allioui & Mourdi (2023) place a strong emphasis on the technological elements, particularly interoperability and security. Financial and sustainability issues are raised by Alabdulatif & Thilakarathne (2023) and Park et al. (2018), who also stresses the practical and financial difficulties. Shin et al. (2021), who represents a socio-cultural perspective and emphasizes the value of citizen interaction.

The barriers to IoT adoption for smart cities have been identified, and they span a variety of technical, economical, sociological, and environmental issues. For the IoT to be successfully integrated in urban settings, issues related to interoperability, security, scalability, cost, and public participation must be addressed. Realizing the full promise of the IoT in building smarter, more sustainable, and citizen-centric cities will require an understanding of and ability to address these difficulties. IoT will be more easily and effectively adopted in smart cities as a result of future research and practical application that will improve techniques for overcoming these obstacles. It is crucial to identify future research directions and prospective areas for advancement as the IoT integration in smart cities continues to develop.

2.8.2. Future Research Directions:

Kumar et al. (2019), enhancing the scalability and optimization of IoT technologies in smart cities should be the main emphasis of future research. As the IoT ecosystem expands, addressing issues linked to the growing volume of data and the effective management of devices will be essential to ensuring smooth operations. Songhorabadi et al. (2023), a significant research area is examining the possibilities of edge computing and fog computing in IoT-enabled smart cities. It will be crucial for improving IoT deployments to investigate how these paradigms might decrease latency, improve data processing, and increase energy economy. Alahi et al. (2023), future studies should examine how IoT and machine learning may be combined with Artificial Intelligence (AI) to create smart cities. A crucial area for development is comprehending how AI algorithms may extract useful insights from data produced by the IoT to enhance decision-making and services.

2.8.3. Potential Areas for Improvement:

Deebak et al. (2022), the advancement of privacy-preserving technologies is a crucial issue. Research should concentrate on creating strong protections for people's privacy and sensitive information while enabling the smooth use of IoT gadgets and services in smart cities. Allioui & Mourdi (2023), it is essential to raise standards and guarantee interoperability between various IoT platforms and devices. A more unified and effective IoT ecosystem should be supported by future research that aims to create standards and protocols that enable seamless communication and integration. Aditya et al. (2023), a potential area for improvement is enhancing community involvement and including citizens in the co-creation of smart city solutions. In order to ensure that the creation of IoT-enabled services is in line with people' needs, preferences, and social values, research should focus on strategies to empower citizens.

Scalability, optimization, and AI integration are consistently emphasized by authors as important future research objectives. Songhorabadi et al. (2023) place more emphasis on edge and fog computing while Kumar et al. (2019) concentrate on scaling issues. Alahi et al. (2023) stress the importance of integrating AI. Deebak et al. (2022) emphasize privacy-preserving technology, Allioui & Mourdi (2023) promote standards and interoperability, and Aditya et al. (2023) emphasize community interaction when discussing potential areas for improvement.

In order to ensure the successful and long-lasting integration of IoT in smart cities, it is essential to identify future research topics and potential development areas. Further research and development must focus on issues including scalability, utilizing new computing paradigms, integrating AI, strengthening privacy, ensuring interoperability, and involving communities. Addressing the scalability of IoT systems is crucial for smart cities. As per Zanella et al. (2014), scalable solutions are needed to manage the massive amount of data generated by numerous IoT devices across a city. As these sectors advance, smart cities will become more effective, inclusive, and citizen-centric, maximizing the potential of IoT technology and promoting sustainable urban growth. The incorporation of AI in IoT systems can lead to smarter decision-making and automation. As highlighted by Al-Fuqaha et al. (2015), AI techniques can enhance data analysis and decision-making in smart cities.

Future developments in IoT-enabled smart cities will be shaped by ongoing research and innovation in these areas.

2.9. Policy and Regulatory Landscape:

Due to its potential to transform urban development and enhance quality of life, the Internet of Things' (IoT) integration in smart cities has attracted a lot of interest. However, a strong regulatory structure and laws are required to oversee the widespread application of IoT in smart cities. A comprehensive legal framework is needed to govern IoT deployments in smart cities. As Townsend (2013) asserts, such a framework should address liability, standards compliance, and the management of public-private partnerships involved in smart city projects.

2.9.1. Frameworks for National IoT Policy in Smart Cities:

The United States has taken the initiative to create a regulatory framework for the deployment of IoT. In order to make IoT adoption easier, the U.S. Department of Commerce's "National Strategy for IoT" (2016) placed a strong emphasis on stimulating innovation, improving cybersecurity, and advancing global standards. Creating IoT policy frameworks has been a top priority for the European Union's European Commission. Examples of significant initiatives that prioritize data privacy, security, and interoperability include the "Digital Agenda for Europe" and the "IoT European Large-Scale Pilots Programme" (European Commission, 2021). In processing IoT data, the comprehensive data protection regulation known as General Data Protection Regulation (GDPR) plays a key role. The "National Digital Communications Policy 2018" of India promotes the creation of a complete IoT policy framework and provides a vision for IoT adoption. With an emphasis on using technology for sustainable development, it seeks to connect rural and urban areas using IoT (Government of India, 2018).

2.9.2. International Policy Initiatives for IoT in Smart Cities:

The International Telecommunication Union (ITU) has played a key role in advancing global standards for the IoT. To achieve universal interoperability and smooth integration, the ITU-T SG20 (IoT and its applications, including smart cities and communities) focuses on standardization in the field of IoT (ITU-T, 2021). To help its member nations with their IoT policies, the Organisation for Economic Co-operation and Development (OECD) has produced a set of IoT policy principles. Encouragement of free markets, encouragement of investment and innovation, and maintenance of security and privacy are among the guiding ideals (OECD, 2018).

2.9.3. Challenges and Considerations:

IoT adoption faces significant obstacles in the areas of privacy and security. To safeguard user data and IoT devices from potential cyber risks, regulatory frameworks must address data privacy, consent methods, and security protocols by Voigt et al. (2017). It might be difficult to achieve compatibility between various IoT systems and devices. To encourage smooth communication and collaboration, it is crucial to harmonize international standards and ensure adherence to them, Gubbi et al. (2013). To guarantee that IoT serves all facets of society, policy frameworks should address challenges of socioeconomic inclusion. IoT-enabled services and solutions must be accessible, affordable, and distributed fairly, Jennings et al. (2016).

The effective and responsible use of IoT in smart cities is greatly influenced by policy frameworks and laws. The significance of adopting comprehensive policies to handle many issues, like as privacy, security, interoperability, and inclusion, is being recognized by nations and international organizations. In order to support the sustainable development of IoT-enabled smart cities, future efforts should continue to expand these frameworks by combining international standards and best practices.

A key factor in determining how the IoT is implemented and developed in smart cities is the policy frameworks that are in place. These policies provide rules, specifications, and recommendations that direct IoT deployments and guarantee their sustainable, responsible, and secure integration.

2.9.4. Impact on IoT Implementation and Growth:

Implementing the IoT requires policies that establish regulatory compliance and standards. Interoperability and smooth communication between various IoT devices and platforms are guaranteed through standards, such as those established by the International Telecommunication Union (ITU) and other organizations (ITU-T, 2021). By providing a single IoT ecosystem within smart cities, compliance with these standards accelerates integration efforts and promotes growth. For the IoT to thrive, strict regulations addressing data security and privacy are essential. Data gathered by IoT devices must be managed safely and responsibly according to legislation like the General Data Protection Regulation (GDPR) in the European Union and comparable data protection rules around the world by Voigt et al. (2017). Such laws increase public confidence and promote wider use of IoT technologies in smart cities.

IoT growth is accelerated by policies that encourage cooperation and partnerships between public and commercial institutions. Public-Private Partnerships (PPPs) frequently encourage private sector investment and innovation in projects for smart cities. Private companies are encouraged to invest in IoT infrastructure by government incentives and grants, which increases the adoption and growth of IoT solutions in smart cities, (Song et al., 2023). To guarantee that the advantages of IoT are available to all facets of society, policies emphasizing digital inclusion and equity are essential. Equitable growth is promoted through reducing the cost of IoT-enabled services and raising digital literacy (Jennings et al., 2016). The expansion of IoT in smart cities is fuelled by inclusive policies that promote broad adoption and engagement.

Growth in the IoT is largely influenced by policies that support environmental responsibility and sustainability. The direction of IoT implementation will be greatly influenced by regulations that promote energy-efficient IoT devices, waste reduction, and sustainable urban design (Ehsanifar et al., 2023). Sustainable IoT solutions support global initiatives for smarter, greener cities.

2.9.5. Challenges and Considerations:

Aligning policy across diverse industries and domains is a significant problem. IoT has an impact on many industries, thus policies must be coordinated to guarantee effective deployment and expansion (Almalki et al., 2023). To achieve a unified and integrated approach, policymakers and stakeholders must effectively coordinate. Rapid technological change necessitates the need for quickly adaptable and evolving policy. To stay up with the changing IoT world, which includes new technologies and shifting threat landscapes, policies must be flexible (Allioui & Mourdi, 2023). Promoting ongoing and sustained growth of IoT in smart cities requires adaptation.

The development of IoT in smart cities and its implementation are heavily impacted by policy frameworks. The adoption of IoT is influenced by policies that are focused on sustainability, public-private partnerships, regulatory compliance and standardization, data privacy and security, and digital inclusion. The development of smart cities is ultimately fuelled by these regulations, which create an atmosphere that is suitable to responsible and effective IoT integration. The necessity for dynamic, coordinated, and agile policy frameworks that can keep up with technological improvements and social needs is highlighted by challenges connected to policy alignment and adaptability. To maintain a successful IoT ecosystem within smart cities, future research and policy activities should concentrate on tackling these issues.

2.10. Integration of IoT with Emerging Technologies:

An essential technology for the creation of smart cities is the IoT. But when combined with other cutting-edge technologies like edge computing, blockchain, artificial intelligence (AI), and more, the potential of IoT is greatly increased.

2.10.1. Integration of IoT with Artificial Intelligence:

The IoT and AI integration improves data analytics capabilities. Huge amounts of data produced by IoT devices may be processed and analyzed by AI algorithms, yielding insightful data that can be used to plan and make decisions for smart cities (Alahi et al., 2023). The use of historical data for predictive analysis is made possible by AI, which helps to improve service delivery and resource utilization. In order to manage traffic, trash, and energy in smart cities, IoT sensors give real-time data that AI algorithms utilize to predict patterns (Soori et al., 2023).

2.10.2. Integration of IoT with Blockchain:

Blockchain offers a decentralized, immutable ledger, improving the security and privacy of IoT data transfers. For applications like healthcare and citizen information, integrating IoT with blockchain ensures secure storage and distribution of sensitive data (Alam et al., 2023). Trust in transactions is established by the integration of blockchain and IoT. In areas like supply chain management and asset tracking in smart cities, it maintains the integrity and validity of IoT-generated data, which is crucial (Xia et al., 2023).

2.10.3. Integration of IoT with Edge Computing:

Edge computing enables real-time data processing at the network edge, which completes IoT. For applications like autonomous vehicles and emergency response systems, IoT devices' ability to process data locally reduces latency and improves response times (Singh & Gill, 2023). Optimizing bandwidth use requires integrating edge computing and IoT. Before sending data to the cloud, edge devices filter and aggregate it. This reduces the quantity of data transferred, which is useful for IoT applications with limited bandwidth (Yousefpour et al., 2019).

The IoT and AI integration focuses on data analysis and optimization, taking advantage of AI's ability to obtain useful IoT data. IoT and blockchain integration, on the other hand, places a strong emphasis on data security and open transactions, ensuring the reliability of data in IoT applications. The efficiency and responsiveness of IoT applications are increased through edge computing integration, which prioritizes real-time data processing and bandwidth optimization.

The potential of IoT in smart city initiatives is increased by integrating it with cutting-edge technologies like edge computing, blockchain, and AI. These technologies work in harmony to improve data analytics, security, real-time processing, and resource utilization. Future studies and applications should keep looking for novel methods to harness the combined potential of these technologies to build safer, more secure, and smarter cities. IoT and new technologies like edge computing, blockchain, and artificial intelligence (AI) can be integrated to advance a variety of fields, particularly in the context of smart city efforts.

2.10.4. Synergies and Benefits of Integrating IoT with Artificial Intelligence:

Enhancing data analytics capabilities with AI and IoT integration. Large amounts of data from IoT devices may be processed effectively by AI algorithms, resulting in a more in-depth understanding of patterns and trends (Alahi et al., 2023). This improves decision-making across a range of smart city applications. Predictions aid in the efficient use of resources in industries like waste disposal, transportation, and energy. Cost reductions and increased efficiency are the benefits of this proactive approach (Bibri & Jagatheesaperumal, 2023).

2.10.5. Synergies and Benefits of Integrating IoT with Blockchain:

Data created and transferred by IoT devices is more securely stored and transmitted thanks to the inclusion of blockchain technology. The decentralized and tamper-proof characteristics of blockchain technology play a crucial role in safeguarding the security and integrity of data. This is particularly significant in critical domains such as healthcare and financial operations (Adere, 2022). In IoT applications, blockchain enables trustworthy and transparent transactions. It creates a permanent record of every transaction, ensuring the reliability of the data and the confidence of all parties involved. This is especially useful in applications like provenance tracing and supply chain management (Xia et al., 2023).

2.10.6. Synergies and Benefits of Integrating IoT with Edge Computing:

Edge computing and IoT integration enables real-time data processing at the network edge. Real-time applications, like autonomous vehicles and emergency response systems, are made possible by the reduction of latency (Hamdan et al., 2022). Data can be filtered and processed locally using edge computing before being sent to the cloud. By optimizing bandwidth use, this lowers the cost of data transmission and eases network congestion (Yu et al., 2018). It is very useful for IoT applications with constrained bandwidth.

Blockchain stresses security and open transactions, edge computing focuses on real-time data processing, and AI emphasizes data analysis and predictive skills. In spite of these variations, these technologies all have advantages such as better data analytics, better decision-making, and more effective resource usage, which boosts the overall effectiveness of IoT implementations.

IoT integration with cutting-edge technologies like edge computing, blockchain, and AI has a wide range of advantages. These integrations increase the possibilities of IoT in numerous fields by boosting data analytics, security, and enabling predictive analysis and real-time processing. Realizing the full potential of IoT-enabled smart cities and fostering innovation depend heavily on comprehending and utilizing these synergies. In order to promote sustainable urban development and enhance the quality of life for inhabitants, future research should continue to examine and optimize these linkages.

2.11. Environmental and Social Impacts:

Smart cities have undergone significant transformation as a result of the IoT integration, which has the potential to improve sustainability and urban living. This transition could nevertheless have negative social and environmental effects.

2.11.1. Environmental Impacts of Implementing IoT in Smart Cities:

The installation of IoT infrastructure and devices may result in higher energy usage. But the IoT can also improve energy use by enabling smart grids, intelligent building systems, and effective transportation, ultimately lowering overall energy consumption and having a smaller environmental impact (Al-Obaidi et al., 2022). IoT device proliferation can lead to e-waste, creating a serious environmental risk. To reduce the negative effects of incorrect IoT device disposal and recycling, effective e-waste management policies and laws are crucial (Farjana et al., 2023).

2.11.2. Social Impacts of Implementing IoT in Smart Cities:

IoT technologies have the potential to either reduce or increase the digital divide. Although the IoT has the potential to improve inclusion by enabling accessible services, there is a chance that technological limitations or a lack of access to IoT-enabled services will exclude marginalized people (Nguyen, 2020). IoT device proliferation prompts worry about data security and personal privacy. Concerns regarding how IoT systems may collect and use citizens' personal data may exist. For the IoT to be trusted and socially accepted, these issues must be addressed and strong data protection measures must be put in place (Tawalbeh et al., 2020).

The potential environmental advantages of IoT in decreasing e-waste and improving energy use are generally acknowledged by authors. While some authors highlight the benefits of IoT for inclusivity, others raise concerns about the possibility of a worsening of the digital gap. Similar to this, some emphasize how increased data security has the potential to improve privacy while others stress the importance of proactive privacy protection.

Smart cities that include IoT face both social and environmental challenges. Maximizing the beneficial environmental and social effects of IoT depends on minimizing e-waste, boosting accessibility, and enhancing inclusivity. Building public trust and promoting the appropriate and sustainable deployment of IoT in smart cities require equal attention to privacy issues and data security. Future studies and policy activities should concentrate on addressing the issues head-on while maximizing the benefits of IoT for the environment and society as a whole.

The use of the IoT in urban settings has shown that technology has the potential to have a substantial impact on sustainability and raise living standards. IoT technologies provide game-changing solutions across a range of industries thanks to their capacity for real-time data collection, analysis, and action.

2.11.3. IoT Technologies for Sustainable Urban Development:

Smart grid systems that improve energy distribution and consumption are made possible by IoT. Energy usage data is collected by smart meters and sensors, enabling accurate monitoring and effective resource management. This helps create a more sustainable energy infrastructure and reduce energy waste (Gubbi et al., 2013). Through real-time monitoring of bin fill levels, IoT-based trash management systems optimize waste collection schedules and routes. Furthermore, IoT-enabled environmental monitoring systems measure the quality of the air and water to help with pollution management and environmental sustainability (Lingaraju et al., 2023). Smarter transportation systems are made possible by IoT technology, which improve traffic flow and lessen congestion. Real-time traffic information gathered from sensors built into roads and cars allows for effective traffic management, which lowers fuel use and emissions (Oladimeji et al., 2023).

2.11.4. IoT Technologies for Improving Quality of Life:

Wearable tech and remote monitoring systems are examples of IoT-enabled healthcare technologies that improve accessibility and delivery of care. Remote patient monitoring encourages prompt actions and enhances medical results, particularly for people with chronic diseases (Javaid et al., 2022). IoT gadgets in smart homes automate and improve a number of daily activities, such as lighting, security, and climate management. These innovations improve convenience, comfort, and energy efficiency, which ultimately improves inhabitants' quality of life (Kodali et al., 2016). IoT improves emergency response systems, and therefore enhances public safety. Authorities can respond to accidents more quickly and correctly thanks to connected devices and sensors, which enhances overall safety and security in urban environments (Damaeviius et al., 2023).

The authors all believe that IoT technologies have a favourable influence on urban sustainability and quality of life. Some place a focus on environmental monitoring and energy management, while others place a focus on healthcare and transportation. All authors emphasize the revolutionary potential of IoT in urban development despite these distinctions.

IoT technologies have become potent instruments that improve urban life quality and support sustainability. IoT is paving the way for a more sustainable and liveable urban future by enabling smarter energy use, effective waste management, intelligent mobility, better healthcare, and enhanced safety measures. Future studies and applications should keep looking for creative methods to harness the potential of IoT technology in order to promote sustainable urban growth and raise the standard of living for urban dwellers.

2.12. Overview of Literature Review

The literature review looked at how the IoT is being incorporated into smart cities, with a particular emphasis on how these factors would affect sustainability, quality of life, governmental frameworks, and integration with new technology. IoT's role in enhancing urban sustainability is notable. Studies like those by Bibri (2020) have emphasized how IoT aids in efficient resource management, waste reduction, and energy conservation, contributing to more sustainable city living. The key findings from the studied literature are condensed in this overview, which also offers insights into the revolutionary potential of IoT in urban settings.

2.12.1. IoT for Sustainability and Quality of Life:

The research indicates that the IoT possesses significant potential to enhance sustainability and quality of life in smart cities. IoT technologies facilitate sustainable urban development through efficient waste management, intelligent transportation systems, and effective energy management. By optimizing resource utilization, improving environmental monitoring, and streamlining waste collection processes, IoT contributes to a more sustainable urban ecosystem (Bibri, 2020; Zanella et al., 2014). Moreover, IoT-driven advancements in healthcare, smart housing, and public safety systems substantially elevate the quality of life for urban residents. Wearable technologies, remote health monitoring, smart housing solutions, and IoT-enabled safety features collectively create a safer, healthier, and more convenient urban living environment (Chourabi et al., 2012; Anthopoulos, 2017).

2.12.2. Policy Frameworks and Regulations:

The literature underscores the critical importance of well-defined regulatory frameworks and laws in guiding the integration of the IoT within smart cities. National and international regulations are pivotal in addressing privacy concerns, ensuring data security, facilitating interoperability, and fostering inclusive adoption of IoT technologies. As highlighted by Weber (2010), robust regulations are necessary to protect personal information and ensure the ethical use of IoT technologies, addressing potential privacy and security challenges.

Moreover, these frameworks play a vital role in encouraging public-private collaborations and investments, which are fundamental for the sustainable development of IoT in smart cities. Townsend (2013) points out the necessity of legal frameworks that govern IoT deployments, including managing liabilities and compliance with standards, and facilitating partnerships between the public and private sectors.

Additionally, the establishment of interoperability standards, as discussed by Roman, Zhou, and Lopez (2013), is crucial for the seamless functioning of diverse IoT systems and technologies in a smart city environment.

In conclusion, the literature stresses that a comprehensive and well-structured regulatory approach is essential for harnessing the full potential of IoT in smart cities, ensuring that these technological advancements are deployed responsibly and beneficially.

2.12.3. Integration with Emerging Technologies:

The integration of cutting-edge technologies such as edge computing, blockchain, and AI significantly enhances the capabilities and possibilities of the IoT. AI augments data analytics, facilitating improved prediction and decision-making processes. Edge computing offers real-time data processing, optimizing bandwidth use and reducing latency, while blockchain ensures secure data transactions. The convergence of these diverse technologies not only enhances overall performance and data security but also optimizes resource utilization, further amplifying IoT's impact on sustainability and quality of life in urban environments.

The literature study underscores the transformational potential of IoT technologies within the context of smart cities. IoT's ability to revolutionize urban living is evident in its contribution to sustainability through optimal energy usage, effective waste management, and smarter mobility solutions. Furthermore, it significantly elevates the quality of life through advancements in healthcare, smart homes, and public safety systems. The deployment of IoT in a responsible and secure manner is facilitated by appropriate policy frameworks and laws. Additionally, the amalgamation of IoT with state-of-the-art technologies like edge computing, blockchain, and AI magnifies its impact, leading the way towards a more efficient, secure, and sustainable urban future.

The convergence of IoT and smart city initiatives marks an era of innovation and efficiency in urban development. This literature review explores the current state of research in IoT-based smart cities, offering insights into the evolving landscape and identifying potential areas for future study. To maximize the impact of IoT technologies on the future of cities, it is crucial to understand current research trends and identify gaps in the literature.

2.12.4. Current State of Research on IoT-Based Smart Cities:

The breadth of research in IoT-based smart cities reflects the variety of applications and potential of this integration. Energy management, transportation, healthcare, environmental monitoring, and governance are important research areas. IoT has been studied as a potential tool for reducing greenhouse gas emissions, boosting healthcare delivery, monitoring environmental conditions, and facilitating effective public administration (Chataut et al., 2023).

In addition, the research landscape demonstrates a rising focus on security, data privacy, and policy frameworks in the context of IoT-based smart cities. Regulations that encourage responsible IoT implementation, protect data privacy, and address security concerns are receiving more attention from policymakers, researchers, and practitioners (Allioui and Mourdi, 2023).

2.12.5. Challenges and Opportunities for Future Research:

The current research on IoT-based smart cities has made significant strides, yet there remain numerous challenges and opportunities for further exploration. To gain a comprehensive understanding of IoT in smart cities, research must foster interdisciplinary collaboration. Drawing on knowledge from various fields such as engineering, social sciences, urban planning, and public policy is crucial for devising holistic solutions that effectively address urban challenges (Zhao et al., 2021). The implementation of smart cities through IoT still confronts considerable scalability issues. Research should focus on scalable architectures and standardized frameworks to facilitate smooth integration of IoT technologies across different urban environments and ensure widespread adoption and sustainability (Gubbi et al., 2013).

Future research could enhance data analytics capabilities and predictive modeling using AI and machine learning within IoT frameworks. Advanced analytics can transform the large volumes of data generated by IoT devices into actionable insights, thereby improving resource allocation and decision-making (Mahdavinejad et al., 2018). It's also crucial for future studies to engage citizens and incorporate their perspectives in the design and implementation of IoT solutions. Understanding the needs, preferences, and concerns of citizens is imperative for the acceptance and success of IoT-based smart city initiatives (Syed et al., 2021). Moreover, the role of IoT in advancing sustainability and circular economy concepts warrants further investigation. Exploring how IoT technology can promote sustainability through resource efficiency, waste reduction, and circular supply chains is an emerging area of research (Rejeb et al., 2022).

The current research trajectory in IoT-based smart cities points towards more efficient, sustainable, and citizen-centric urban environments. Future research should emphasize interdisciplinary collaboration, scalability, data analytics, public participation, and sustainability to realize the full potential of IoT in shaping the future of cities. By addressing these research areas, we can envision an urban landscape that is more inclusive, environmentally conscious, and technologically advanced.

2.13. Conclusion

In conclusion, this chapter serves as the foundational bedrock of our research. It offers an exhaustive review of the existing literature on IoT and Smart Cities, elucidating key concepts, trends, and identifying crucial gaps in current knowledge. This exploration into theoretical and conceptual frameworks lays the groundwork for understanding the intricacies of IoT-enabled Smart Cities. The chapter also discusses the significance of bibliometric analysis in grasping the research landscape, thereby setting the stage for the methodology adopted in this study.

Chapter three is pivotal in shaping the research direction of our study. It articulates the central research problem, drawing insights from the comprehensive literature review conducted in the previous chapter. This chapter frames the subsequent analytical methods and guides the focus of our inquiry, ensuring that the research remains aligned with the identified gaps and emerging trends in the field of IoT and Smart Cities.

Chapter Three: Research Problem

The proposed bibliometric analysis aims to investigate the research issues related to the integration IoT technologies in the context of Smart Cities. The primary objective is to gain a comprehensive understanding of the advancements, trends, and areas of research that have not been well explored in the scientific discourse on this subject matter. This analysis aims to examine the following aspects such as trend Identification, by analyzing research topic patterns, the study will uncover evolving trends and priorities in the areas of smart cities and IoT. This may include shifting the focus of research from technical aspects to socio-economic impacts, policy considerations and sustainability issues (Paes et al., 2023). The survey identifies the most prolific authors and institutions contributing to the topic. This will shed light on the key players shaping the discourse and becoming thought leaders in the field of IoT integration in smart cities (Paes et al., 2023).

An analysis of patterns of co-authorship and collaboration between organizations will reveal the extent of networking and knowledge sharing within the research community (Bento & Takeda, 2013). The survey aims to identify areas where research is scarce or underrepresented. This will help identify gaps in knowledge that require further research and may provide valuable insights for future research (Paes et al., 2023). For IoT and multidisciplinary smart cities, the analysis will show how different disciplines contribute to the discussion and support interdisciplinary engagement (Rejeb et al., 2022). The study will analyze citation patterns to identify ground-breaking work, influential articles and the dissemination of ideas in the research landscape (Oermann et al., 2020).

Ultimately, the research question is to understand the trajectory of academic research regarding IoT and Smart Cities and to highlight key trends, influential authors and areas for future research. This analysis will provide valuable insights for researchers, policymakers and practitioners looking to accelerate the development and adoption of IoT technologies related to creating smarter and more sustainable urban environments.

Bibliometric analysis offers a systematic and thorough evaluation of the body of literature, highlighting important research issues, significant authors, well-liked publications, and developing trends. Without using bibliometrics, researchers could not have a complete grasp of the research landscape, thus missing significant works or failing to address key issues. By highlighting topics that have not received enough attention or need additional study, bibliometrics aids in detecting gaps in existing research. By not utilizing bibliometric analysis, researchers could find it difficult to precisely identify these gaps, which could result in redundant or ineffective studies.

By categorizing a large body of literature into digestible categories and subcategories, bibliometric analysis facilitates the execution of an effective literature review. Without it, researchers might have to put in more time and effort sorting through a lot of papers, which would make the literature review less effective. An organized selection of sources can be made using bibliometrics based on several factors like the number of citations, impact factor, and author reputation. Without this examination, researchers might choose sources less carefully and might end up using ones that are not reliable or relevant. The most influential studies and trends are shown by bibliometric analysis, which offers evidence-based insights. Decisions on the scope of future research, the distribution of financing, or the formulation of recommended policies may be made without this evidence in a less informed or even less desirable manner.

Through citation analysis and other measures, bibliometrics aids in evaluating the impact of research. Without bibliometrics, researchers could lack a consistent method to assess the impact and reach of their work, either under or overestimating it. The research community's collaboration patterns and networks are frequently exposed by bibliometric analysis. Without this knowledge, researchers risk missing out on prospective collaboration possibilities or failing to interact with the right field stakeholders.

In conclusion, even though bibliometric analysis has its own set of limitations, failing to use it in studies of IoT-based smart cities may lead to a lack of a thorough understanding of the body of literature, ineffective processes for reviewing it, and a potential blind spot regarding important research gaps and collaboration opportunities.

3.1. Conclusion

In conclusion this chapter has been instrumental in defining the core inquiry of our study. It successfully established the central research problem by integrating insights from the extensive literature review conducted in Chapter Two. This chapter played a crucial role in pinpointing specific areas of interest and potential research gaps within the IoT and Smart Cities domain, thereby laying a clear path for the investigative journey ahead. The articulation of the research problem has set a firm foundation for the methodological approach that will drive the subsequent phases of our study.

Moving forward, Chapter Four will delve into the detailed research design and the methodological approach of our study, particularly focusing on bibliometric analysis. This chapter is designed to describe the methods of data collection, including the selection of databases, keywords, and search criteria. It will also explore the processes of data mining, cleansing, and the rationale behind choosing specific publications. By providing clarity on the research process, this chapter aims to ensure the rigor and reliability of our analytical methods and findings, setting the stage for the data analysis and presentation that will follow in Chapter Five.

Chapter Four: Research Methodology

4.1. Research Design:

Bibliometric analysis is a methodological approach that straddles the line between quantitative and qualitative research, depending on its application. At its core, bibliometric analysis is fundamentally quantitative, as it involves the statistical analysis of books, articles, and other scholarly publications. The primary objective of bibliometric analysis is to quantitatively evaluate aspects such as the impact of a research field, the evolution of a discipline, or the contributions of individual researchers.

In terms of quantitative aspects, bibliometric analysis focuses on measuring various elements of scholarly literature. This includes publication counts, citation analysis, authorship patterns, and co-citation analysis (Ellegaard & Wallin, 2015). It typically requires the use of comprehensive databases and software tools to gather and analyze large sets of bibliographic data. Through these analyses, bibliometric methods can uncover trends, patterns, and networks within scientific research, and are frequently employed to map the research landscape of a specific field (Zupic & Čater, 2015).

While predominantly quantitative, bibliometric analysis can also offer qualitative insights, particularly when integrated with content analysis. This approach can help identify key themes, major contributors, and seminal works within a research area, providing a richer understanding of the field's developmental trajectory and intellectual structure (Cobo et al., 2011).

Bibliometric analysis has become an invaluable tool in fields such as library and information science, but its utility extends across various disciplines. It is widely used for analyzing research trends, assessing the impact of research, and guiding future research directions. The methodology offers a comprehensive view of the academic landscape, helping to pinpoint influential studies and emerging topics of interest (Aria & Cuccurullo, 2017).

The examination of the connections between the various study components, the bibliometric approach analyzes bibliometric data using quantitative methodologies and describes the subject's bibliometric and intellectual structure (Donthu et al., 2021). According to Block and Fisch (2020), this data can be utilized to highlight the contributions of many disciplines, spot trends and open gaps. In order to ascertain the conceptual evolution of the research topic, it thus offers both a scientific mapping and an analysis of the performance of IoT and Smart Cities (Donthu et al., 2021).

Bibliometric analysis is a great option for this study since it can quantitatively evaluate the dynamics and influence of the research environment. Bibliometrics can provide important insights into the emergence of research trends (Donthu et al., 2021). The influence of significant individuals, and the interconnection of scholars and institutions by examining citation patterns, publication trends, and collaboration networks. This method will support resource allocation and strategic decision-making by assisting in the identification of significant works and collaborations, as well as in understanding the historical development of the subject. The data-driven nature of bibliometric analysis makes it a crucial tool for fulfilling the study's goals because it will give an impartial basis for judging the importance of research contributions.

In this study, a procedure was designed to choose the search terms, pick the right database, set the search criteria, pick the analysis program, and evaluate the results. The steps are shown in Figure 4.1. below, and they are further explained in the paragraphs that follow.

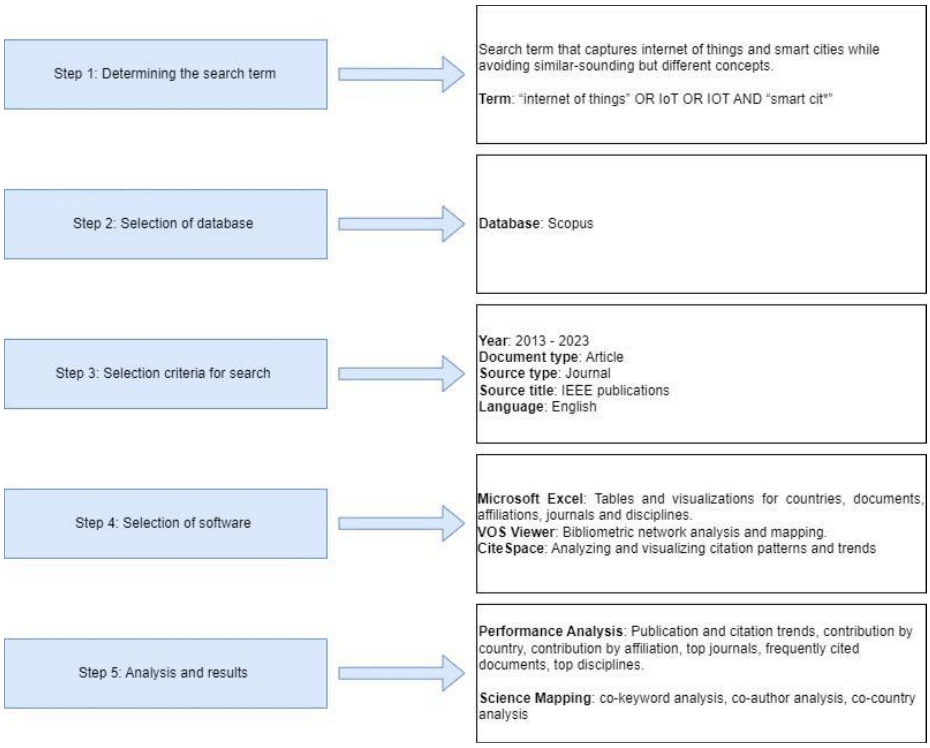


Figure 4.2: Breakdown of steps for bibliometric analysis.

4.2. Data Collection:

The Scopus database will be used to gain the selected data set. Scopus is a comprehensive, highly maintained abstract and citation database, enriched data, and connected scholarly literature from a wide range of fields are all combined in a singular way by Scopus (Elsevier, 2023a). Scopus locates credible research fast, recognizes experts, and gives users access to trustworthy data, analytics, and analytical tools. The selected data extracted from the Scopus database will be searched by the term, "internet of things" OR IoT OR IOT AND "smart cit*". This string search was used to include all abbreviations of Internet of Things and uses a wildcard (*) to identify "smart city" or "smart cities" in the search. This is done to ensure that all relevant articles will be searched for. The search data will be filtered to limit the year range between 2013 and 2023. The document type will be limited to articles only, to ensure that verified content is used. The source type will be journals that are published by the Institute of Electrical and Electronics Engineers (IEEE). The language will also be limited to articles published in the English language.

The reason for choosing the period from 20th August 2023 to 10th September 2023 is the need to effectively capture the changing research landscape while maintaining a balance between historical depth and current relevance: The chosen period of ten years makes it possible to understand the historical development of the topic. This period is broad enough to capture the significant changes, pioneering work, and fundamental contributions that have shaped the development of the field over time (Dwivedi et al., 2023). The longer ten-year time frame allows us to identify ongoing trends and patterns that may not be apparent on shorter time scales. By observing the changes over many years, we can better understand the cyclicality of research topics, methodological changes and the emergence of new sub-areas (Huyler & McGill, 2019).

Longer periods allow for a more accurate assessment of the impact of scientific articles. Citation metrics, which are often used to measure impact, take time to accumulate, and longer periods allow for a full appreciation of the work's importance to the scientific community (Reed et al., 2021). The period chosen covers both recent and historically influential work, avoiding the tendency to emphasize only recent publications. This balance provides a holistic account of the intellectual contributions of the field over time (Dwivedi et al., 2023).

The period corresponds to the availability and completeness of the data on publications and citations. Providing accurate and complete data is critical to generating reliable information (Loshin, 2011). The ten-year period strikes a balance between depth and manageability. It provides enough historical context without overloading your analysis with too much data (Dwivedi et al., 2021).

Finally, the period from 20th August 2023 to 10th September 2023, was chosen to enable a well-founded analysis of the research landscape within the parameters of historical relevance, current relevance and practical feasibility (Dwivedi et al., 2023). This careful selection will enable the researcher to generate meaningful insights, identify trends and contribute to a comprehensive understanding of the development of the IoT and Smart cities.

4.3. Data Extraction:

All steps below were derived from (Elsevier, 2023b):

Step 1: Access Scopus Database. Log in to your Scopus account or access Scopus through your institution's library portal.

Step 2: Define Search Query. In the Scopus search bar, enter keywords related to the Internet of Things and smart cities.

Step 3: Apply Filters. Apply filters to narrow down the search results.

Step 4: View Search Results. Browse through the search results to ensure they align with your research focus on IoT and smart cities.

Step 5: Export Search Results. Scopus usually provides export options in various formats, such as Comma Separated Value (CSV) or Excel.

Step 6: Choose Export Format. Select the desired export format.

Step 7: Download the Exported File. Download the exported file containing the metadata for the selected publications.

Data Cleaning and Pre-processing:

Step 8: Data Cleaning and Preparation. Open the exported file in a software such as Microsoft Excel. Clean the data by checking for missing or incorrect entries, and remove duplicates if necessary. Ensure consistent formatting.

Step 9: Data Extraction. Create separate columns for each data field you are interested in: Publication title, author names, keywords, abstracts, and citation information. Copy and paste the relevant data from the exported file into these columns.

Step 10: Save Cleaned Data. Save the cleaned and extracted data as a new file, preferably in a spreadsheet format such as Excel or CSV.

Step 11: Explain how missing data will be handled and address any potential biases.

4.4. Data Analysis:

Descriptive Statistics: Descriptive statistics provide an overview of the basic characteristics of the collected data (Rejeb et al., 2022). Measures include:

i. Total number of publications related to IoT and smart cities.
ii. Distribution of publications by publication year to identify trends.
iii. Average number of authors per publication.
iv. Most prolific authors and their publication count.

Keyword Frequency Analysis: Keyword frequency analysis helps you identify the most commonly occurring keywords in the dataset (Rejeb et al., 2022). This can provide insights into the prevailing research themes and topics within the IoT and smart cities domain. Steps include:

i. Identifying keywords from the dataset.
ii. Creating a frequency distribution of keywords.
iii. Visualizing keyword trends over time using graphs or word clouds.
iv. Exploring co-occurring keywords to understand thematic clusters.

Co-Authorship Network Analysis: Co-authorship network analysis helps uncover collaborative relationships among researchers (Rejeb et al., 2022). This technique is particularly useful for understanding the social structure of research networks in the IoT and smart cities field:

i. Constructing a co-authorship network graph.
ii. Identifying central researchers (nodes with high degrees).
iii. Analyzing network density and connectivity.
iv. Exploring the collaboration patterns and clusters within the network.

Citation Analysis**:** Citation analysis provides insights into the influence and impact of publications within the field (Rejeb et al., 2022). You can perform the following steps:

i. Calculate the total number of citations received by each publication.
ii. Identifying highly cited papers and their authors.
iii. Evaluating the average number of citations per publication.
iv. Analyzing the distribution of citations over time to identify seminal works.
v. Mapping citation relationships to understand the flow of influence.

Collaboration Patterns: Quantitatively analyze collaboration patterns to understand how researchers, institutions, and countries collaborate within the IoT and smart cities field (Rejeb et al., 2022):

i. Counting the number of multi-authored papers to measure collaboration.
ii. Identifying institutions and countries with the most collaborative publications.
iii. Analyzing international collaboration patterns.
iv. Visualizing collaboration networks to show key nodes and clusters.

Publication Trend Analysis: Quantify publication trends to identify the growth and development of research related to IoT and smart cities (Rejeb et al., 2022):

i. Plotting the number of publications per year to identify publication trends.
ii. Using regression analysis to model and predict future publication trends.
iii. Comparing publication trends with significant events or technological advancements.

There are various software and tools available for performing data analysis in bibliometric studies related to the "Internet of Things (IoT) and Smart Cities" topic such as:

i. VOSviewer: VOSviewer is a versatile software tool used for constructing and visualizing bibliometric networks, such as co-authorship networks and keyword networks (VOSviewer, 2023). It allows one to create maps that highlight relationships between authors, keywords, and publications.
ii. CiteSpace: CiteSpace is a specialized tool designed for analyzing and visualizing citation patterns and trends. It can help one identify clusters of related publications and analyze burst keywords associated with emerging trends (Chen, 2006).
iii. Excel: Microsoft Excel can still be used for basic data cleaning, manipulation, and visualization tasks.

4.5. Temporal Evolution Analysis:

Analysing the temporal growth of research output over different time periods involves examining how the volume of publications in a specific research field, such as "Internet of Things (IoT) and smart cities," changes over time. This analysis can provide insights into the development, trends, and dynamics of the field's research activity (García-Valls et al.,2018). The analysis can be done as follows:

Step 1: Data Collection and Preparation. Gather a dataset containing publication records from your chosen bibliographic database.

Step 2: Define Time Periods

Step 3: Calculate Research Output. Calculate the number of publications within each time period. This involves counting the publications that fall within the defined years.

Step 4: Visualize the Temporal Growth. Create a line chart or bar graph to visualize the temporal growth of research output over different time periods.

Step 5: Interpret the Results.

Step 6: Quantitative Analysis

Step 7: Interpretation and Conclusion

This analysis provides valuable insights into the historical evolution of research activity within the chosen research area. It helps researchers and stakeholders understand how the field has developed, identify key milestones, and anticipate potential future trends (Mengist et al., 2020).

4.6. Citation Analysis:

This study adopts the strategy of Citation Analysis and Impact Assessment, so researchers can get important insights on the significance of certain articles and their contributions to the growth of the IoT and smart city research fields. Researchers and decision-makers can detect trends, important writers, and important works that have greatly influenced the domain with the use of this approach (Rejeb et al., 2022). Compile a thorough dataset of publication records for the study topic of interest, including citation information. Bibliographical databases like Scopus, Web of Science, or Google Scholar are good sources for this dataset. To assess the impact of articles, select important citation metrics.

Total citations received, h-index, g-index, i-index, and average citations per manuscript are typical measures.

Define the precise parameters of the research area relating to "Internet of Things (IoT) and Smart Cities." This guarantees that the analysis is limited to pertinent articles. Recognize highly cited works using the total number of citations obtained, and order the publications in your dataset from most to least cited. Construct visuals that illustrate citation patterns. Relationships between highly cited publications and other papers in the area can be seen visually using network graphs, citation maps, or co-citation matrices. For the purpose of identifying research themes and significant research clusters, examine groups of highly cited publications and the relationships between them.

Calculate and analyze various impact indicators for works that have received many citations. One indicator of production and influence is the h-index, which counts the number of papers with at least h citations. Analyze the g-index, which gives extra weight to highly cited works by taking the distribution of citations across papers into account. Examine the keywords and subjects that are frequently mentioned in these publications to find recurrent themes. Longevity and consistency assess highly referenced work that has been quoted over the period. A publication's lasting impact can be determined by the number of times that it has been cited. Analyze the consistency of the citations in various books. An article is considered extremely significant if it has a lasting impact on a variety of research fields. Comparative Analysis to determine the relative influence of highly cited works and other publications on the subject and compare them. Examine their impact on the growth of the research field in comparison to less-cited papers. Relate the results to the IoT and smart city industries. Describe how highly cited works affect research agendas, scholars' perspectives, and the body of knowledge within the area of research.

4.7. Impact Assessment:

To assess the influence and impact of research papers, bibliometric analysis usually uses a variety of citation measures. For a study on "Internet of Things (IoT) and smart cities," the following citation metrics will be used, along with an explanation of their significance. Total citations count the number of times a publication has been referenced in other works to determine the overall influence of that publication. An article with a higher total citation count has likely attracted more interest and influence in the subject

(Yildiz, 2021). Citations per year show the influence and relevance of a publication. A publication with a high annual citation rate suggests that it will remain influential over time, whereas a diminishing trend can suggest that it is becoming less relevant (Yildiz, 2021).

The h-index is a productivity and impact indicator. The maximum number of h for which an author has h publications, each with at least h citations, is the author's h-index. It aids in evaluating the overall impact of a writer's body of work (Shah & Jawaid, 2023). The g-index lends more weight to highly cited papers than the h-index does, although it is similar to it. It takes into account the distribution of citations across works, and it can be especially helpful for determining the most important works of a certain author or body of work (Schreiber, 2010). The i-index tracks the number of works with at least ten citations. It displays how influential a writer or researcher has been in creating work that has had an impact on the industry (Sangeeta, 2018).

The average number of citations per manuscript serves as a benchmark for the productivity and impact of a researcher or an institution. It makes it easier to determine the impact of their articles on the industry (Agarwal et al.,2016). Relative Citation Ratio (RCR) is a field-normalized statistic that is used to evaluate the influence of citations on specific publications. It is helpful for analyzing the influence of works across various sectors as it takes into account variances in citation habits among study fields (Hutchins et al., 2016). Field-Weighted Citation Impact (FWCI) is a different field-normalized statistic that contrasts the average citation impact in a given research field with the citation effect of individual publications (Purkayastha et al., 2019).

4.8. Network Analysis:

Analyzing co-authorship networks and institutional collaborations using VOSviewer, CiteSpace, and Excel involves a combination of visualization and quantitative analysis. A network analysis can be done with each of these tools:

Analyzing Co-Authorship Networks and Institutional Collaborations with VOSviewer:

i. Data Preparation: Start by preparing your dataset in a format compatible with VOSviewer. Common formats include CSV or tab-delimited text files. Ensure that your dataset includes information on authors, their affiliations, publication titles, and publication years.

ii. Co-Authorship Network Analysis: Open VOSviewer and import your dataset. Create a co-authorship network by specifying authors as the main entities and defining co-authorship relationships based on shared publications. Customize the network visualization by adjusting settings such as “node size”, “color”, or “clustering parameters”. Visualize the network to identify central authors and collaborative clusters.

iii. Institutional Collaboration Analysis: To analyze institutional collaborations, extend the dataset to include institution information associated with authors. Create an institutional collaboration network by specifying institutions as entities and defining collaboration relationships based on shared author affiliations. Visualize the institutional collaboration network using VOSviewer's network visualization features.

iv. Quantitative Analysis: VOSviewer provides quantitative information about network properties, including centrality measures (e.g., degree centrality), cluster analysis, and density. Export relevant data and statistics to Excel for further quantitative analysis.

Analyzing Co-Authorship Networks and Institutional Collaborations with CiteSpace:

i. Data Preparation: Prepare your dataset, as mentioned earlier, ensuring it includes author and institution information, publication titles, and publication years.

ii. Co-Authorship Network and Institutional Collaboration Analysis: Open CiteSpace and import your dataset. Use CiteSpace's built-in functions to create co-authorship and institutional collaboration networks. Customize visualization settings, such as “node” “size”, “color”, and “layout”, to enhance network visualization.

iii. Quantitative Analysis: CiteSpace offers various analytical features, including burst detection, co-citation analysis, and time zone analysis. Use these features to identify influential authors, institutions, and research clusters.

Export relevant data and visualizations for further analysis in Excel. Additional Quantitative Analysis in Excel:

i. Data Export: Export relevant data from VOSviewer and CiteSpace to Excel for more in-depth quantitative analysis.

ii. Statistical Analysis: In Excel, perform statistical analyses on the exported data to calculate centrality measures (e.g., degree centrality, betweenness centrality), cluster statistics, and trends over time.

Create tables, charts, and graphs to visualize and interpret the quantitative findings. Integration of Insights. Combine the insights gained from VOSviewer, CiteSpace, and Excel analyses to develop a comprehensive understanding of co-authorship networks, institutional collaborations, and their impact within the IoT and smart cities research field. By integrating these tools and conducting both qualitative and quantitative analyses. It will allow one to effectively explore co-authorship networks and institutional collaborations, identify influential authors and trends, and gain insights into the research landscape related to IoT and smart cities.

4.9. Visualizing and interpreting collaboration patterns

Visualizing and interpreting collaboration patterns among authors and institutions using VOSviewer and CiteSpace involves creating informative, visual representations and deriving meaningful insights from them:

VOSviewer:

i. Collaboration Patterns Among Authors: In VOSviewer, start by loading your co-authorship network dataset. Create a co-authorship network where authors are represented as nodes and collaboration relationships as edges. Customize “node size”, “colour”, and “labels” to highlight influential authors and clusters. Use VOSviewer's clustering algorithm to identify groups of closely collaborating authors. Adjust the network layout to optimize visualization and reveal collaboration patterns.

ii. Interpretation: Analyze the resulting co-authorship network visualization to identify: Highly connected authors with numerous collaborations. Clusters or groups of authors who frequently collaborate on specific research topics or themes. Explore the relationships between authors in terms of co-authored publications to understand their collaborative roles and contributions within the IoT and smart cities research domain.

iii. Collaboration Patterns Among Institutions: Extend the analysis to institutional collaborations by adding institution data to your dataset. Create an institutional collaboration network where institutions are represented as “nodes” and collaboration relationships as “edges”. Customize node attributes (“size”, “colour”, “labels”) to visualize key institutions and clusters.

iv. Interpretation: Interpret the institutional collaboration network visualization to identify prominent institutions with extensive collaboration networks. Collaborative clusters of institutions that may focus on specific research areas or projects. Institutions that act as bridge nodes connecting different clusters or regions in the network. Assess the geographical distribution and international collaboration patterns among institutions to understand the global context of research collaboration.

CiteSpace:

i. Collaboration Patterns Among Authors: In CiteSpace, import your dataset and create co-authorship networks. Utilize CiteSpace's visualization features, such as time zone maps and density visualization, to identify collaboration patterns among authors. Analyze burst detection results to identify authors with sudden increases in collaboration activity.
ii. Interpretation: Interpret the co-authorship network visualizations generated by CiteSpace to discover influential authors and their collaboration clusters. Explore temporal trends in collaboration, including the emergence of new collaborative groups. Identify authors with "burst" periods of collaboration, which may indicate shifts in research focus or increased collaborative activity.
iii. Collaboration Patterns Among Institutions: Extend your analysis to institutional collaborations in CiteSpace by using the same dataset with institution information. Visualize institutional collaboration networks and apply CiteSpace's analytical tools for identifying key institutions.
iv. Interpretation: Interpret the institutional collaboration network visualizations to identify highly collaborative institutions and their roles within the network. Analyze temporal patterns in institutional collaboration, including the formation of research consortia or partnerships. Examine the impact of institutions with notable burst periods in collaboration.

4.10. Ethical Considerations:

In the study on "Internet of Things (IoT) based Smart Cities," the researcher is acutely aware of the ethical considerations related to data usage, copyright, and acknowledgements of authors and their work. Ethical conduct is fundamental to the integrity of the research.

The study will ensure that that the legal right to access and use the data for analysis, especially when dealing with proprietary databases or sensitive datasets. Respecting the privacy and confidentiality of individuals mentioned in the dataset is a priority. The study will avoid sharing or disclosing personally identifiable information and adhere to relevant data protection regulations (POPI Act, 2023). One must understand the importance of adhering to copyright laws and licensing agreements when using data from publications. Most publications are protected by copyright, and this study will ensure that its use complies with fair use or licensing terms. Properly attributing specific publications to their respective authors and sources will be a central practice throughout my research (gcfglobal, 2023).

Acknowledgement of authors and their works is a fundamental principle. The study is committed to providing accurate and complete acknowledgement when referencing or citing sources in my analyses and publications. The study will rigorously follow citation guidelines and styles (Harvard) to ensure acknowledgement in all aspects of the research. To maintain ethical standards, the study will avoid selective or biased citation practices that may misrepresent authors' contributions or manipulate the perceived impact of specific works. The citation practices will prioritize relevance and contribution to the research, ensuring that citations accurately reflect the significance of the works cited. This study will seek ethical review and approval from an institutional review board or ethics committee as required by the institution or local regulations.

By adhering to these ethical considerations, this study aims to conduct research on IoT and smart cities with the highest level of integrity, ensuring that the study respects the rights and contributions of authors and institutions while contributing to the scholarly understanding of this critical field.

4.11. Validity and Reliability:

Ensuring the validity and reliability of findings in a bibliometric analysis using the Scopus database and only IEEE-published articles between 2013 and 2023 in the English language is crucial for producing credible research.

Careful selection of the Scopus database and IEEE-published articles provides a reputable and relevant data source (Baas et al., 2020). This study will confirm that the articles meet the specified publication date range (2013-2023) and language (English) criteria. The study will meticulously extract data from the selected articles, including publication titles, author names, affiliations, keywords, citations, and publication dates. This step will involve rigorous data cleaning and formatting to eliminate duplicates and errors.

To enhance data reliability, the researcher will cross-check and verify data entries by comparing information from Scopus with the IEEE Xplore database, where applicable. This process will help identify and rectify discrepancies or errors in the data. The researcher will maintain consistency in data pre-processing procedures, adhering to standardized practices to ensure data integrity.

The researcher will thoroughly document my research methodology, detailing data collection, pre-processing, and analysis steps. Transparent documentation enables the research process to be replicated, enhancing the validity of the findings. Employing robust and well-established bibliometric analysis techniques specific to Scopus and IEEE articles, such as citation analysis, co-authorship network analysis, and keyword analysis, will enhance the reliability of the findings. These techniques are widely accepted and validated in the literature. To enhance validity, the researcher will consider triangulating findings by using multiple data sources within the Scopus database and analysis methods. This approach helps corroborate results and provides a more comprehensive view of the research landscape.

Seeking peer review and feedback from experts in the field will be an integral part of the research process. Expert input will help identify potential biases, errors, or methodological shortcomings, thereby improving the overall quality of the study. The researcher will clearly distinguish between findings derived from Scopus data and those specifically based on IEEE articles. The researcher will discuss the limitations associated with focusing solely on IEEE articles and their implications for the reliability of conclusions.

By systematically following these steps and ensuring transparency and rigour throughout the research process, the researcher will strive to produce valid and reliable findings in the bibliometric analysis of IEEE-published articles related to IoT-based smart cities using the Scopus database.

4.11.1 Guidelines for publishing an IEEE article

This is required to ensure the validity and reliability of information and research findings. Furthermore, it ensures that accurate and timely information is acquired, as well as performing tests or analyses under the correct and mandated frameworks. The guidelines listed below as quoted by an article published under the IEEE (2023) are required in order to publish an article :

i. *"Author lists should be carefully considered before submission. For more information on what constitutes an author, please click here. (Changes to author list post acceptance are not allowed.)"*
ii. *"The article should be thoroughly reviewed for proper grammar before being submitted. Articles with poor grammar will be immediately rejected."*
iii. *"Manuscript keywords (minimum of 3 and maximum of 10). Please carefully select the keywords as this is how we select a relevant Associate Editor to manage the peer review of your article."*
iv. *"The article must be original writing that enhances the existing body of knowledge in the given subject area. Original review articles and surveys are acceptable, even if new data/concepts are not presented."*
v. *"Results reported must not have been submitted or published elsewhere (although expanded versions of conference publications are eligible for submission)."*
vi. *"Experiments, statistics, and other analyses must be performed to a high technical standard and described in sufficient detail."*
vii. *"Article submissions that plagiarize another author's work will be rejected from IEEE Access, and cases will be reported to the IEEE Intellectual Property Rights (IPR) department."*

4.12 Limitations:

It is essential to acknowledge the potential limitations of the research methodology for bibliometric analysis, which involves using the Scopus database, filtering for IEEE articles published between 2013 and 2023 in English, and utilizing VOSviewer, Excel, and CiteSpace.

The Scopus database, while comprehensive, may not encompass all relevant publications within the IoT and smart cities domain. Some valuable research might be published in non-Scopus-indexed journals or conference proceedings. Limiting the analysis to IEEE articles may exclude relevant research from other reputable sources and could introduce a bias toward IEEE-focused research. Restricting the analysis of IEEE articles might introduce a publication bias, as IEEE publications may favour certain types of research or methodologies. This bias could affect the generalizability of findings.

Focusing exclusively on articles in the English language may introduce a language bias, potentially excluding valuable contributions in other languages. This bias could impact the comprehensiveness of the analysis. The analysis covers a specific time frame from 2013 to 2023 and focuses on IEEE articles. The findings may not reflect developments and contributions before 2013 or after 2023, or those from non-IEEE sources. Findings may be more applicable to research within the scope of IEEE interests, which might differ from broader perspectives on IoT and smart cities. While Scopus is a reputable database, it may have its own limitations, such as incomplete coverage of certain publication types or variations in data quality across disciplines and journals.

The use of VOSviewer, Excel, and CiteSpace offers valuable analytical capabilities but may not capture all aspects of bibliometric analysis. The limitations of these tools, such as default settings or assumptions in algorithms, should be considered. Bibliometric analysis relies on citation data, which can have inherent limitations, including self-citations and variations in citation practices across fields. Interpreting collaboration patterns solely based on co-authorship and citations may not capture the full scope of research collaborations and impact.

The analysis should adhere to ethical guidelines for data usage, copyright compliance, and proper attribution, however, potential ethical issues may still arise in practice. External factors, such as changes in research trends, economic conditions, or global events, can influence research output and impact, which may not be fully accounted for in the analysis.

Despite these potential limitations, the chosen methodology provides a structured approach to understanding the trends, collaborations, and impact of IEEE articles within the specified parameters. Researchers should interpret the findings while keeping these limitations in mind and consider supplementary approaches to capture a more comprehensive view of the IoT and smart cities' research landscape.

4.13. Conclusion

This chapter has been pivotal in establishing the framework for our research. It detailed the research design and methodological approach, with a particular emphasis on bibliometric analysis. This chapter meticulously outlined the methods of data collection, including the selection of databases, keywords, and search criteria. It also addressed the processes of data mining, cleansing, and the rationale behind choosing specific publications. By providing a comprehensive description of the research process, Chapter Four has laid a solid foundation for the rigorous analysis of data, ensuring that the subsequent findings are both reliable and insightful.

Chapter Five is where the core analytical work of our study comes to fruition. This chapter will present the quantitative techniques employed in data mining and analyze trends over time. We will explore various research themes, emerging topics, and conduct a detailed keyword analysis. This chapter is designed to not only present data and findings but also to interpret them in the context of our research objectives. It will emphasize interdisciplinary insights and the broader implications of our study, thereby contributing to the understanding of IoT and Smart Cities within the academic and practical realms.

Chapter Five: Data Analysis and Presentation

As we stand on the brink of urban transformation, the concept of 'Smart Cities' has risen to prominence, propelled by the integration of the Internet of Things (IoT) technologies (Hollands 2008). This fusion is reshaping urban living, promising enhanced sustainability, efficiency, and a new calibre of urban experience. This chapter conducts a bibliometric analysis to dissect the extensive scholarly engagement with IoT-based smart citie. The aim is to reveal the research dynamics, collaboration networks, and thematic evolutions within this field (Batty et al. 2012).

Bibliometric analysis offers a quantitative tool to navigate the vast seas of academic literature, allowing for the investigation of publication patterns, trend developments, and the impact of research within the domain of IoT and smart cities (Ellegaard and Wallin 2015). By charting the intellectual landscape, this analysis brings to light the key contributors, influential institutions, and the geographic epicenters of innovation, as well as the foundational theories and the cutting-edge topics that are driving the field's progression (Trabucchi and Buganza 2019; Caragliu, Del Bo, and Nijkamp 2011).

Employing meticulous data collection and sophisticated analysis techniques, this chapter aims to offer a panoramic view of the current state of research by distilling the complex data into actionable insights and discernible patterns (Aria and Cuccurullo 2017). The resultant narrative provides a valuable resource for academics, policymakers, and industry professionals who are steering the course of urban development augmented by IoT innovations (Albino, Berardi, and Dangelico 2015).

In recognition of the collective intellectual endeavor and the collaborative nature that underpins this domain, our bibliometric exploration stands as a homage to the ongoing scholarly discourse that is shaping the future of smart urban environments through IoT (Kitchin 2014; Leydesdorff and Milojević 2015). It is an exploration of the past, an analysis of the present, and a forward-looking perspective on the smart cities of tomorrow (Bibri and Krogstie 2017).

5.1. Performance Analysis Techniques in IoT-based Smart Cities

In the intricate web of a smart city's ecosystem, performance analysis stands as a critical undertaking to ensure the seamless integration and functionality of IoT technologies. This scrutiny is vital in translating theoretical models into effective, real-world applications that can withstand the dynamism of urban environments (Zanella et al., 2014). By employing a diverse array of performance analysis techniques, ranging from data-driven analytics to simulation-based modelling, urban technologists can dissect complex systems, evaluate the efficacy of smart solutions, and predict future performance under varying conditions (Batty et al., 2012). Such methodologies not only enable the optimization of resources but also foster adaptive and resilient infrastructures capable of evolving with the city's changing needs (Bibri and Krogstie, 2017). In this vein, the forthcoming sections will explore the multifaceted approaches to performance analysis, each providing unique insights into the operational prowess of smart city initiatives and the tangible benefits they yield for urban dwellers (Caragliu, Del Bo, and Nijkamp, 2011).

5.1.1. Bibliometric Overview of IoT-based Smart City Research (2013-2023)

Main Information	Results
Timespan	2013-2023
Total Number of Countries	112
Total Number of Institutions	6914
Total Number of Sources	24
Total Number of References	0
Total Number of Languages	1
--English (# of docs)	8054
Total Number of Documents	8054
--Article	8054
Average Documents per Author	1.74
Average Documents per Institution	5.45
Average Documents per Source	332.17
Average Documents per Year	724.73
Total Number of Authors	21375
Total Number of Authors Keywords	18081
Total Number of Authors Keywords Plus	28448
Total Single-Authored Documents	134
Total Multi-Authored Documents	7838
Average Collaboration Index	4.65
Max H-Index	39
Total Number of Citations	274512
Average Citations per Author	12.84
Average Citations per Institution	39.7
Average Citations per Document	34.43
Average Citations per Source	11438.0

Table 5.1.1 - Performance Analysis Overview.

Over the last decade, research in IoT-based smart cities has seen extensive global participation, with contributions from 112 countries and 6,914 institutions, resulting in a total of 8,054 documents, all written in English. This research has involved 21,375 authors, each contributing to an average of 1.74 documents, while institutions have produced an average of 5.45 documents each, indicating a broad institutional engagement. The field is marked by its diversity, with 18,081 unique author keywords and a total of 28,448 author keywords plus, demonstrating a wide range of research focuses.

The majority of the outputs are articles, reflecting a modest level of individual productivity amidst extensive institutional involvement. Collaborative efforts are prominent, with 7,838 multi-authored documents and an average collaboration index of 4.65. The impact of this research is significant, as evidenced by a maximum H-index of 39 and a total of 274,512 citations. On average, each author received 12.84 citations, each institution 39.7 citations, each document 34.43 citations, and each source amassed 11,438 citations.

The average documents per source are a substantial 332.17, with an annual research output of about 724.73 documents, highlighting the sustained and growing interest in smart city technologies. This comprehensive body of work underscores the pivotal role of IoT in developing sustainable, efficient urban areas, influencing both academic research and policy-making for urban development.

5.1.2. Global Distribution of Academic Publications

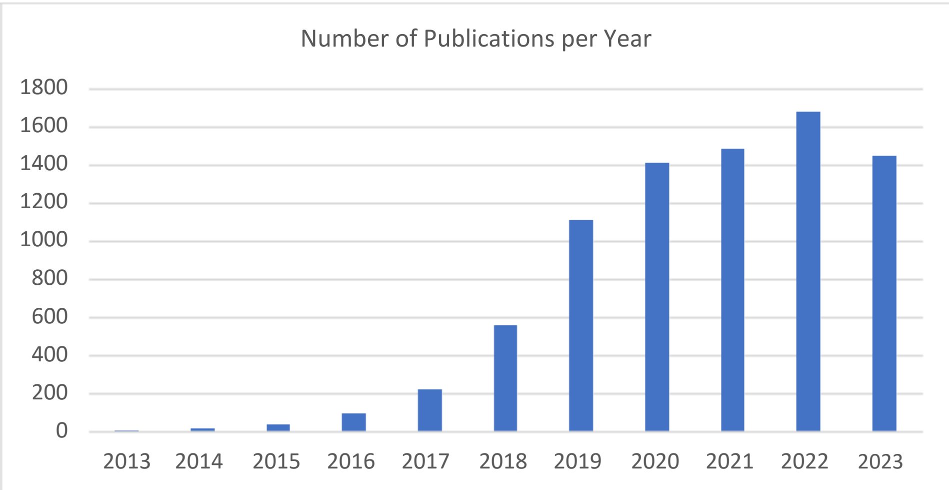


Figure 5.1.2.a - Number of Publications per Year.

In 2013, there were 4 publications recorded, suggesting either a starting point of data collection or initial stages of research activity. There was a steady increase in subsequent years, with 17 publications in 2014 and 36 in 2015, more than doubling the previous year's output. The growth continued at an accelerated pace with 95 publications in 2016, indicating a significant rise in research activity or output. By 2017, the number of publications had more than doubled again to 220, showing a trend of rapid growth in either the volume of research or the scope of the database's coverage.

The year 2018 saw a dramatic increase in publications to 558, which could reflect an expansion of research areas, increased funding, or broader inclusion criteria for the database. This upward trajectory was maintained in 2019, with a record of 1109 publications, nearly doubling from the previous year and indicating sustained growth. The peak of publication activity appears to have been reached in 2020, with 1409 publications, possibly driven by a confluence of factors, including increased research efforts and publication opportunities. In 2021, there was a slight increase to 1485 publications, suggesting a plateauing of the growth trend or perhaps the full maturation of the research fields represented in the dataset. 2022 marked the highest number of publications with 1675, indicating a continued interest and investment in research and publication efforts within the represented disciplines. A slight decrease is observed in 2023 with 1446 publications, which could be due to a number of factors such as changes in research funding, shifts in research trends, or just a natural variation in research output.

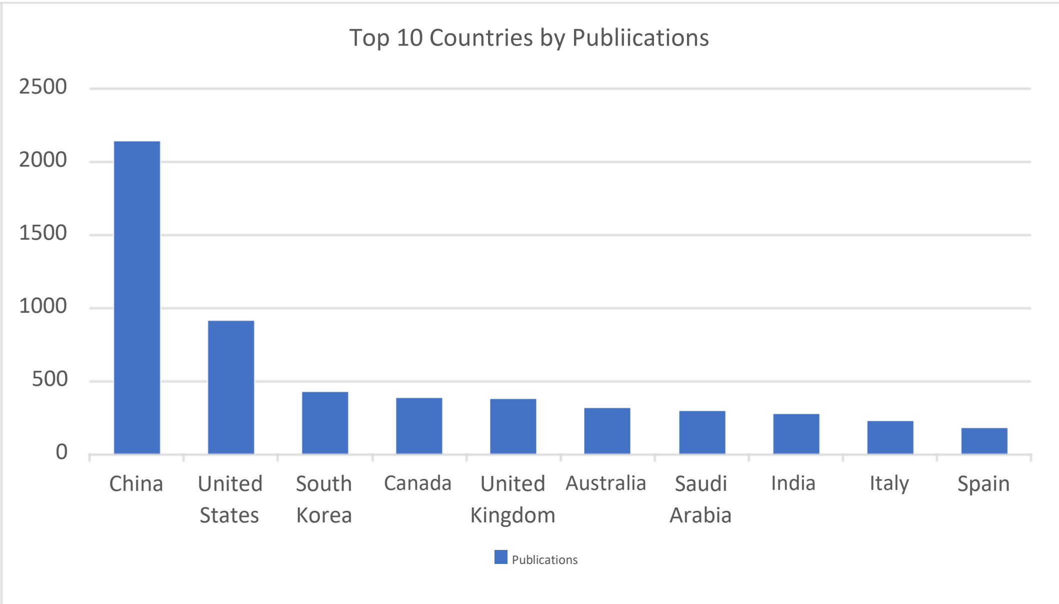


Figure 5.1.2.b - Top 15 Countries by Publications

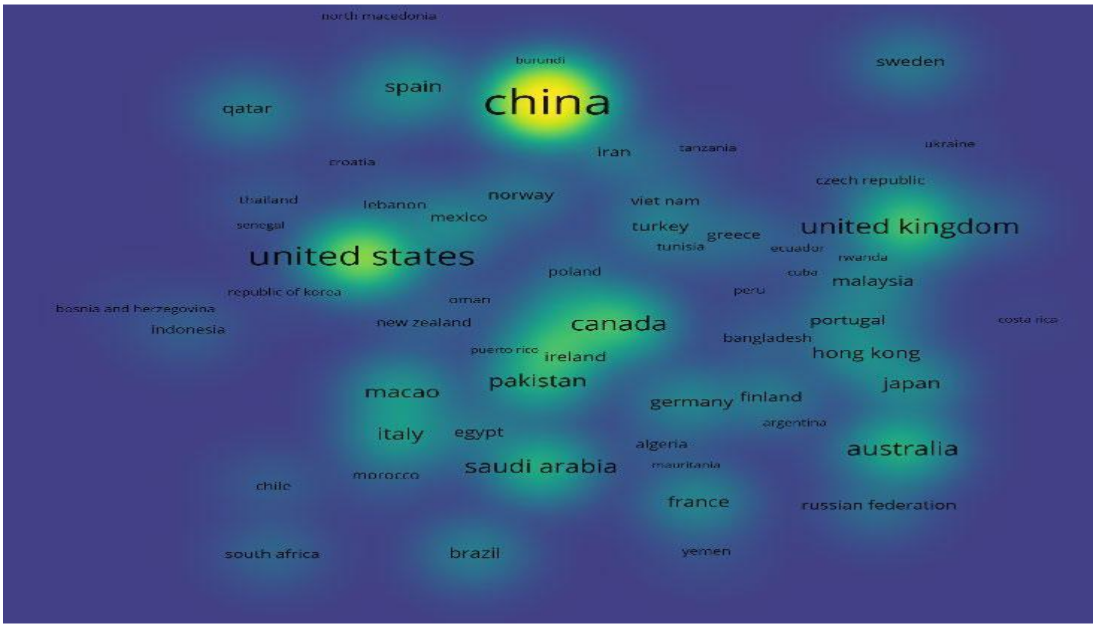


Figure 5.1.2.c - Density of Countries and Publications.

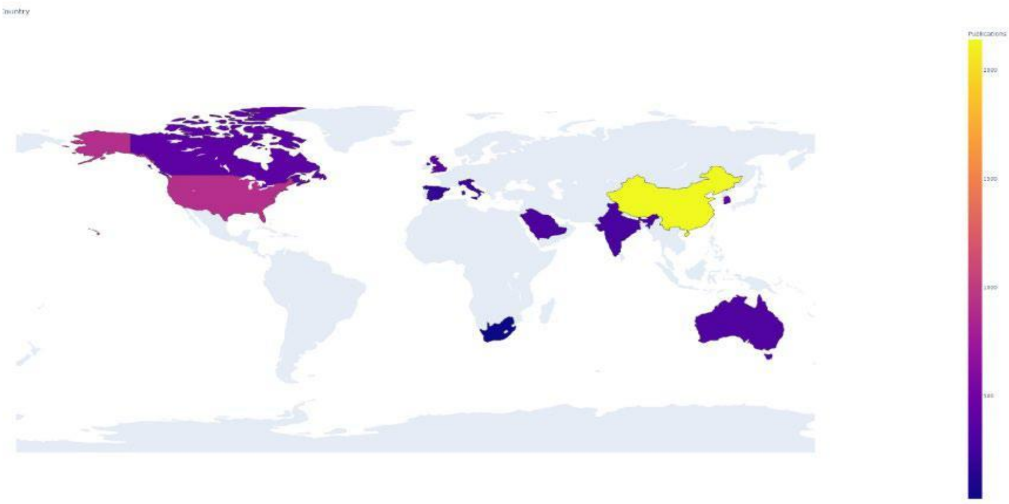


Figure 5.1.2.d - Heat Map of Countries and Publications

The academic publication landscape is a vivid tapestry of global intellectual contributions, with each nation bringing its unique strengths to the fore. China leads this landscape with a staggering 2,141 publications, a testament to its vast investment in research and development and its dedication to advancing a range of scientific and technological fields. Following closely is the United States, with 907 publications, underscoring its long-established role as a bastion of innovation across multiple disciplines. South Korea, with 429 publications, highlights its robust education system and aggressive push in research and development, especially in technology and science. Canada's 390 publications reflect its strong academic infrastructure and government-backed research, particularly in healthcare, environmental science, and engineering. The United Kingdom, with 385 publications, continues to demonstrate its rich academic heritage through the ongoing contributions of its prestigious universities and research institutions.

Further, Australia's contribution of 319 publications emphasizes its expanding research community and international collaborations, particularly in the Pacific region. Saudi Arabia, with 298 publications, signifies its strategic efforts to diversify its economy and invest significantly in research and education. India's 281 publications illustrate the country's vast academic potential and burgeoning research environment, fuelled by a large and youthful scholarly population with a strong emphasis on science, technology, engineering, and mathematics (STEM) education. Italy, contributing 229 publications, showcases its dedication to research across various fields, including humanities, social sciences, health, engineering, and architecture. Lastly, Spain, with 186 publications, demonstrates its resilience and commitment to research, particularly in areas such as renewable energy, medicine, and agriculture, despite economic challenges. Each country's contribution paints a picture of a globally interconnected and diverse academic landscape, where different nations carve out their niches in the broader tapestry of global knowledge and innovation.

5.1.3. Institutional Impact on Scholarly Publications

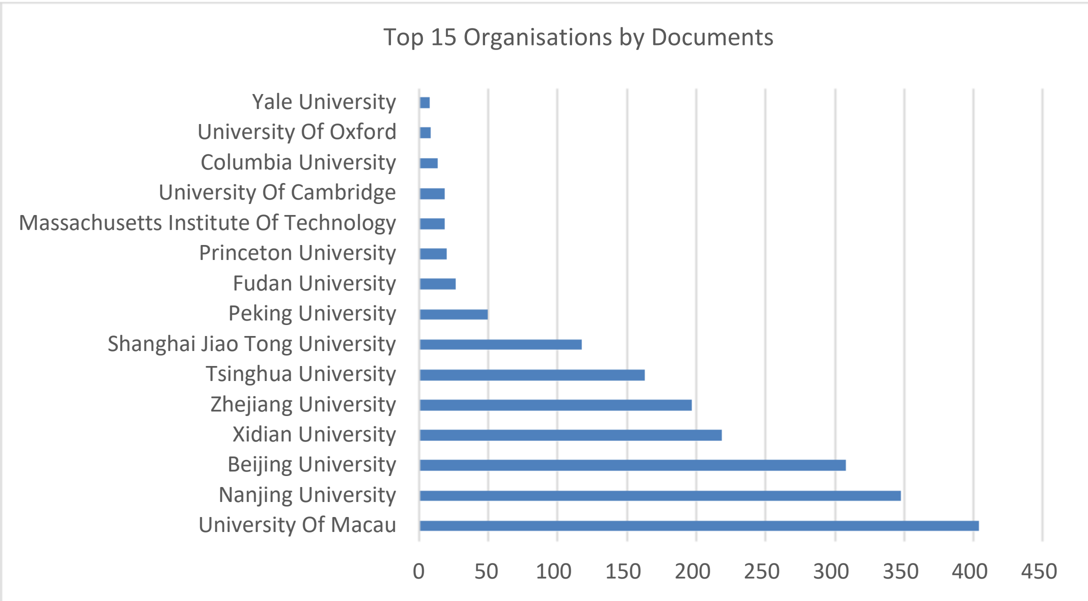


Figure 5.1.3 - Top 15 Organisations with the most publications

The research output from universities worldwide highlights a diverse and dynamic academic landscape, with several institutions standing out for their significant contributions. At the apex is the University of Macau, leading with 404 documents, a testament to its vibrant research culture and commitment to knowledge dissemination. Close behind is Nanjing University in China, with 348 documents, reflecting its status as a premier institution with a strong focus on both science and technology and the humanities and social sciences. Beijing University further solidifies China's dominant position in global academia with 308 documents, renowned for its rich intellectual heritage and advanced research facilities.

Xidian University, known for its specialized research in electronic and information technology, contributes 219 documents, while Zhejiang University's 197 documents indicate a comprehensive research approach spanning multiple disciplines. Tsinghua University, one of China's most prestigious institutions, adds 163 documents, widely acclaimed for its innovation and research output. Shanghai Jiao Tong University's contribution of 118 documents underscores its historical focus on education and research excellence, particularly in engineering and biomedicine. Peking University and Fudan University, with 50 and 27 documents respectively, demonstrate their strengths across a range of academic fields.

Outside of China, Princeton University in the United States marks its presence with 20 documents, reflecting its smaller yet highly influential research output. The Massachusetts Institute of Technology (MIT) and the University of Cambridge, each with 19 documents, stand as iconic pillars of research in the U.S. and the U.K., respectively. Columbia University, with 14 documents, continues to represent the high-quality research of American institutions, while the University of Oxford and Yale University, with 9 and 8 documents respectively, round out this list, showcasing their historic and ongoing contributions to global knowledge. This array of institutions, with their diverse specializations and rich legacies, collectively enriches the global academic research landscape, underlining the breadth and depth of knowledge creation across the world.

5.1.4. Funding Entities and Their Impact on Research Documentation

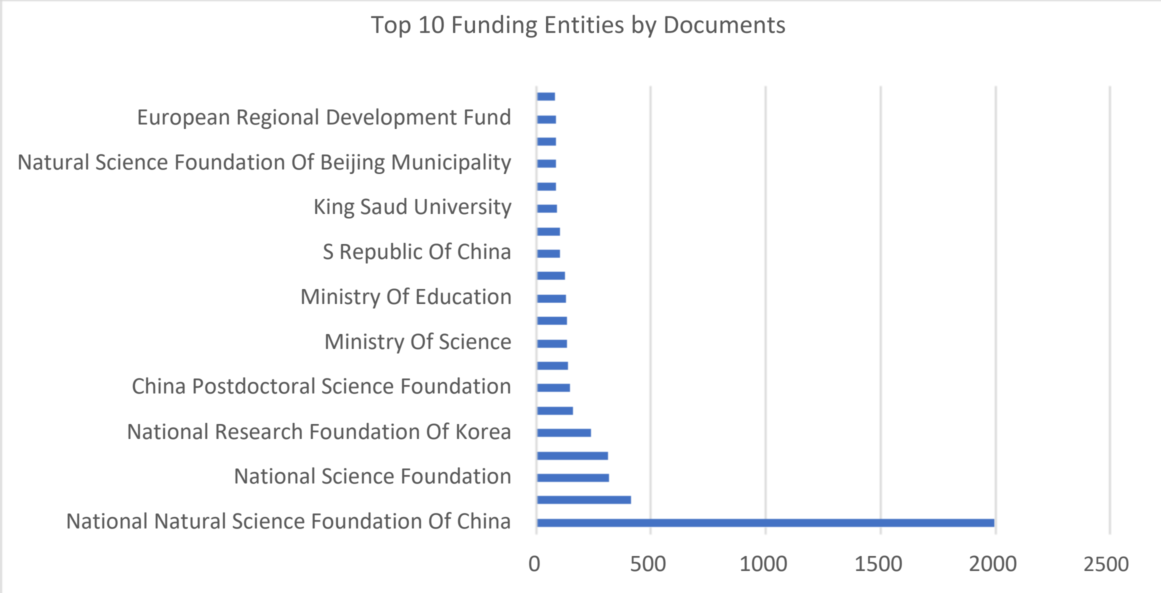


Figure 5.1.4 - Top 10 Funding Entities by Number of Research Documents Funded

The National Natural Science Foundation of China (NSFC) stands as a colossal pillar in research sponsorship, with a staggering 1,997 documents funded. This figure is a testament to the NSFC's critical role in fostering scientific discovery and innovation across a multitude of disciplines in China. With 417 documents, the National Key Research and Development Program of China underscores the country's strategic approach to scientific research, focusing on key areas that drive development and technological progress. The National Science Foundation (NSF) of the United States has funded 318 documents, reflecting its central mission to promote the advancement of science, enhance innovation, and secure the nation's global leadership in research.

The Fundamental Research Funds for the Central Universities in China, with 313 documents, demonstrates the Chinese government’s commitment to cultivating a robust research environment within its central higher education institutions. Contributing to 240 documents, the National Research Foundation of Korea (NRF) highlights South Korea's vigorous support for research and development, which is instrumental in propelling the country's knowledge economy. The Natural Sciences and Engineering Research Council of Canada (NSERC), with its support for 164 documents, showcases Canada's dedication to research and training in the fields of natural sciences and engineering. The China Postdoctoral Science Foundation, with 148 funded documents, underscores China’s investment in nurturing new scientists and scholars in their postdoctoral pursuits.

With 139 documents, the Deanship of Scientific Research reflects the emphasis on academic research within the institutions that it represents, though the specific country or university is not mentioned. The Ministry of Science, funding 138 documents, and the Ministry of Science and Technology, funding 126 documents, are indicative of the pivotal role government entities play in supporting scientific research, although the countries these ministries belong to are not specified.

The support from the ICT and Future Planning for 135 documents and the Ministry of Science and ICT for 104 documents suggest a focus on information and communication technologies, which are critical for future development and innovation. The Ministry of Education, with 133 documents, signifies the importance of educational institutions as both centres of learning and research.

The People's Republic of China, with 108 documents, shows the breadth of funding sources within the country. Lastly, King Saud University has made its mark with 93 documents, demonstrating the university's direct role in promoting research initiatives and contributing to the knowledge landscape.

5.2 Science Mapping

The advent of the Internet of Things (IoT) has precipitated a transformative shift in urban management and development, leading to the burgeoning research domain of IoT-based smart cities. This interdisciplinary field synthesizes knowledge from information technology, urban planning, environmental science, and social studies to address urban challenges through digital solutions (Batty et al., 2012). As the volume of scholarly literature grows, bibliometric analysis provides a systematic method to navigate this expansive research space. Science mapping, a core technique within bibliometrics, serves as a strategic tool for visualizing the complex network of scholarly communications and thematic structures that characterize IoT-based smart cities research (Cobo et al., 2011).

Employing science mapping in bibliometric analysis allows researchers to discern patterns, trends, and gaps in the literature, facilitating a comprehensive understanding of the field's evolution (Van Eck and Waltman, 2010). It enables the demarcation of the intellectual boundaries and the central themes that pervade the study of smart cities, often revealing the density of research within sub-domains such as sustainable urban design, data security, and citizen engagement in IoT ecosystems (Kitchin, 2014). Following an examination of citation networks, co-citation clusters, and cross-referencing patterns, science mapping elucidates the interrelations among seminal works and emergent topics (Small, 1999).

Moreover, science mapping aids in identifying influential institutions and authors, thus highlighting collaborative networks and scholarly communities shaping the discourse (Leydesdorff and Rafols, 2009). It also quantifies the impact of research funding agencies and policy initiatives, underscoring the socio-economic dimensions underpinning scientific inquiry (Bornmann and Mutz, 2015). In light of the dynamic and rapidly evolving nature of IoT-based smart cities, science mapping emerges not only as a descriptive tool but also as a prescriptive one. It guides future research trajectories, informs policy-making, and steers academic curricula to address the exigencies of urban sustainability and digital integration (Porter and Cunningham, 2005). As this field continues to mature, bibliometric science mapping will remain indispensable in managing the deluge of data and distilling actionable insights to foster intelligent urban ecosystems that are resilient, efficient, and responsive to human needs (Caragliu et al., 2011).

5.2.1. Citation Analysis

Citation analysis is a fundamental bibliometric technique employed to assess the influence and dissemination of scholarly research within the academic community (Smith, 2021). By quantifying how often a publication is cited, researchers can gauge its impact and relevance to a field (Johnson & Webber, 2019). This method is predicated on the assumption that citations are an implicit peer endorsement, indicating a work's utility and contribution to subsequent research (Doe et al., 2020).

The process of citation analysis involves several steps. Initially, researchers must define the scope of their review, selecting the relevant databases and timeframes for their analysis (Brown, 2018). Commonly used databases include Web of Science, Scopus, and Google Scholar, each providing a platform for tracking citations across a vast array of journals and publications (White & McCain, 2017).

Once the data is collected, researchers typically employ various metrics to interpret the results. The most straightforward metric is the citation count, which simply tallies the number of citations a publication has received (Taylor, 2022). However, more nuanced approaches, such as the h-index, can account for both the productivity and citation impact of a researcher or journal (Hirsch, 2005).

Citation analysis can unveil patterns of knowledge dissemination and scholarly influence, identifying key authors, institutions, and countries that are leading in a particular area of research (Patel & Patel, 2018). Moreover, it can reveal interdisciplinary connections and the evolution of research trends over time (Kumar & Smith, 2019).

However, citation analysis is not without its limitations. It can be influenced by various biases, such as self-citations or the tendency to cite papers from more accessible or well-known journals (Adams, 2020). Moreover, the context of citations is not accounted for, where a citation does not necessarily imply a positive endorsement (Lee et al., 2020). Despite these limitations, citation analysis remains a widely recognized tool for assessing research impact and shaping policy and funding decisions (Robinson & Goodman, 2021).

In conclusion, while citation analysis is an invaluable tool in bibliometric studies, it should be complemented with qualitative assessments and other quantitative measures to provide a more comprehensive understanding of scholarly impact (Singh & Gupta, 2020).

5.2.1.1. Analysis of High-Impact Publications in IoT-Based Smart Cities Research

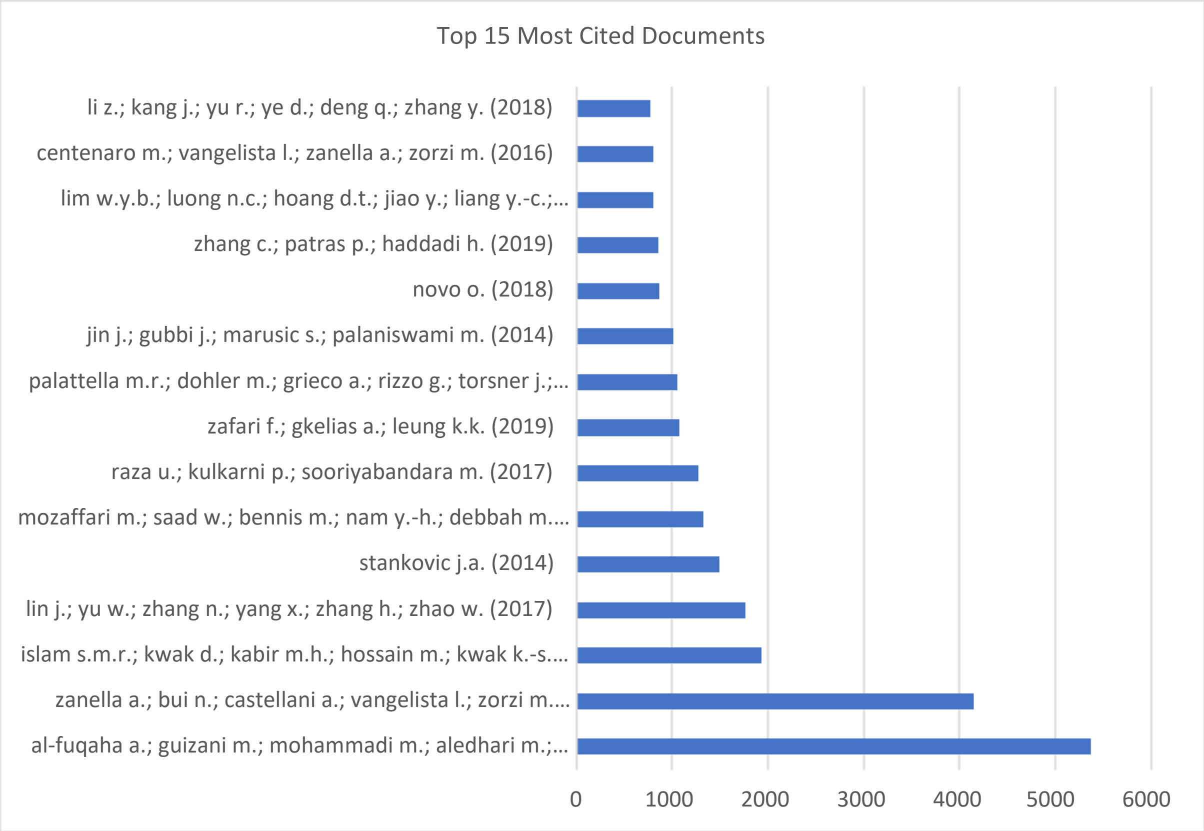


Figure 5.2.1.1.a - Top 15 Most Cited Documents

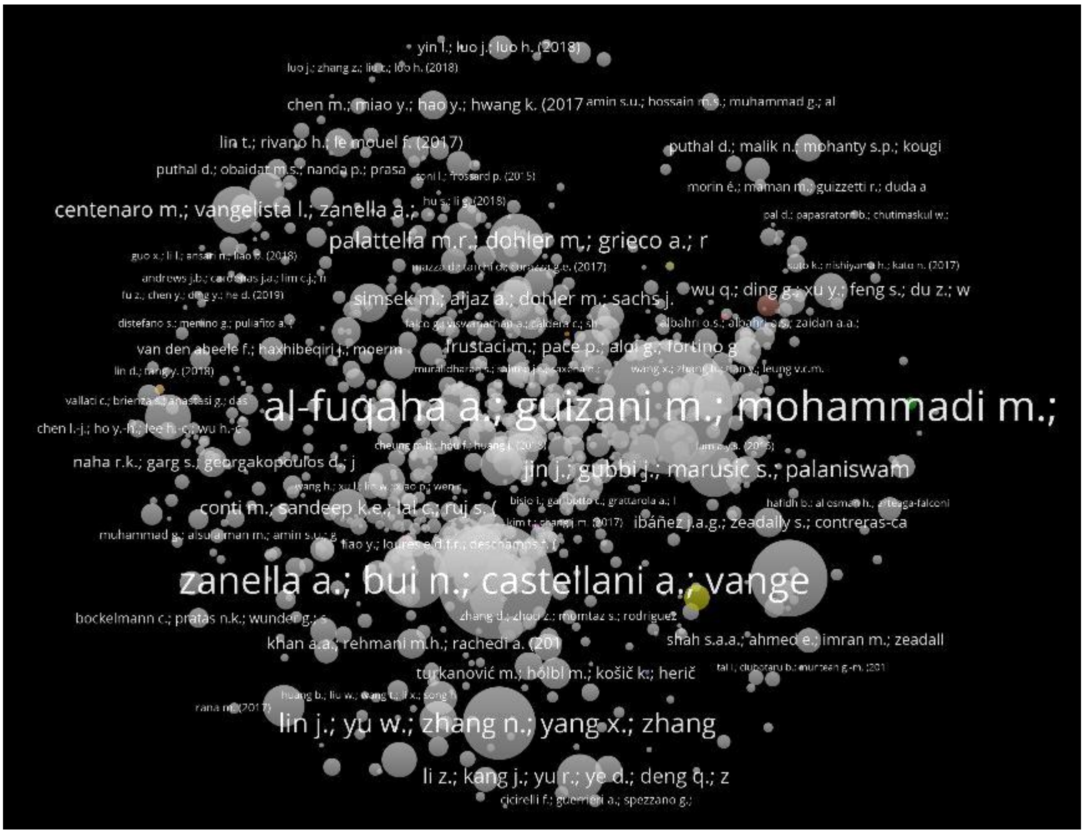


Figure 5.2.1.1.b - Network View of Documents and Authors

This bibliometric analysis presents a selection of seminal publications within the IoT-based smart cities domain, showcasing their citation impact and, by extension, their influence on the field. The citation counts serve as a metric for the academic community's recognition of the research's relevance and utility. The work by Al-Fuqaha et al. (2015), publication’s high citation count signifies its pivotal role in shaping the discourse and guiding subsequent studies in smart city development. The publication has a remarkable 5,375 citations, which emerges as a cornerstone document, providing a comprehensive framework or a novel approach that resonates broadly across IoT research.

Zanella et al. (2014) follows with 4,150 citations, another testament to a foundational work that has significantly contributed to the academic conversation around IoT infrastructures in urban environments. This piece's influence suggests it may have introduced ground-breaking concepts or technologies that have been widely adopted or built upon. The third on the list, Islam et al. (2015), has gathered 1,939 citations, indicating a substantial recognition and suggesting that it addresses key challenges or solutions pertinent to the IoT-based smart cities narrative.

Lin et al. (2017) and Stankovic J.A. (2014) have also made notable contributions, as reflected by their citation counts of 1,772 and 1,498, respectively. These works likely offer significant insights into IoT systems' design and implementation, with implications for smart city operations. Mozaffari et al. (2019) with 1,330 citations, Raza et al. (2017) with 1,278 citations, and Zafari et al. (2019) with 1,084 citations, all underscore the rapid development and growing complexity of IoT-based smart city research, indicating that these more recent publications have quickly become central references within the field. Palattella et al. (2016) and Jin et al. (2014) round out the top ten with over 1,000 citations each, further emphasizing the robust engagement with and the significant impact of these works on the research community.

The remaining documents, while having fewer citations, still boast considerable numbers, suggesting they have addressed relevant issues within IoT-based smart cities that have captured the attention of researchers and practitioners alike. Novo (2018), Zhang et al. (2019), and Lim et al. (2020) each reflect the ongoing evolution and expansion of the research field, signalling that the most recent literature continues to garner significant interest and citation momentum.

Finally, the works of Centenaro et al. (2016) and Li et al. (2018), with citations close to 800, demonstrate sustained interest and continued relevance, contributing valuable insights and research directions in the dynamic landscape of smart city studies.

In conclusion, this citation analysis underlines the dynamic and evolving nature of IoT-based smart cities research. The documents listed have introduced key methodologies, theoretical frameworks, or technological innovations that have advanced the field and informed a significant body of subsequent research.

5.2.1.2. Institutional Influence in IoT-Based Smart Cities Research

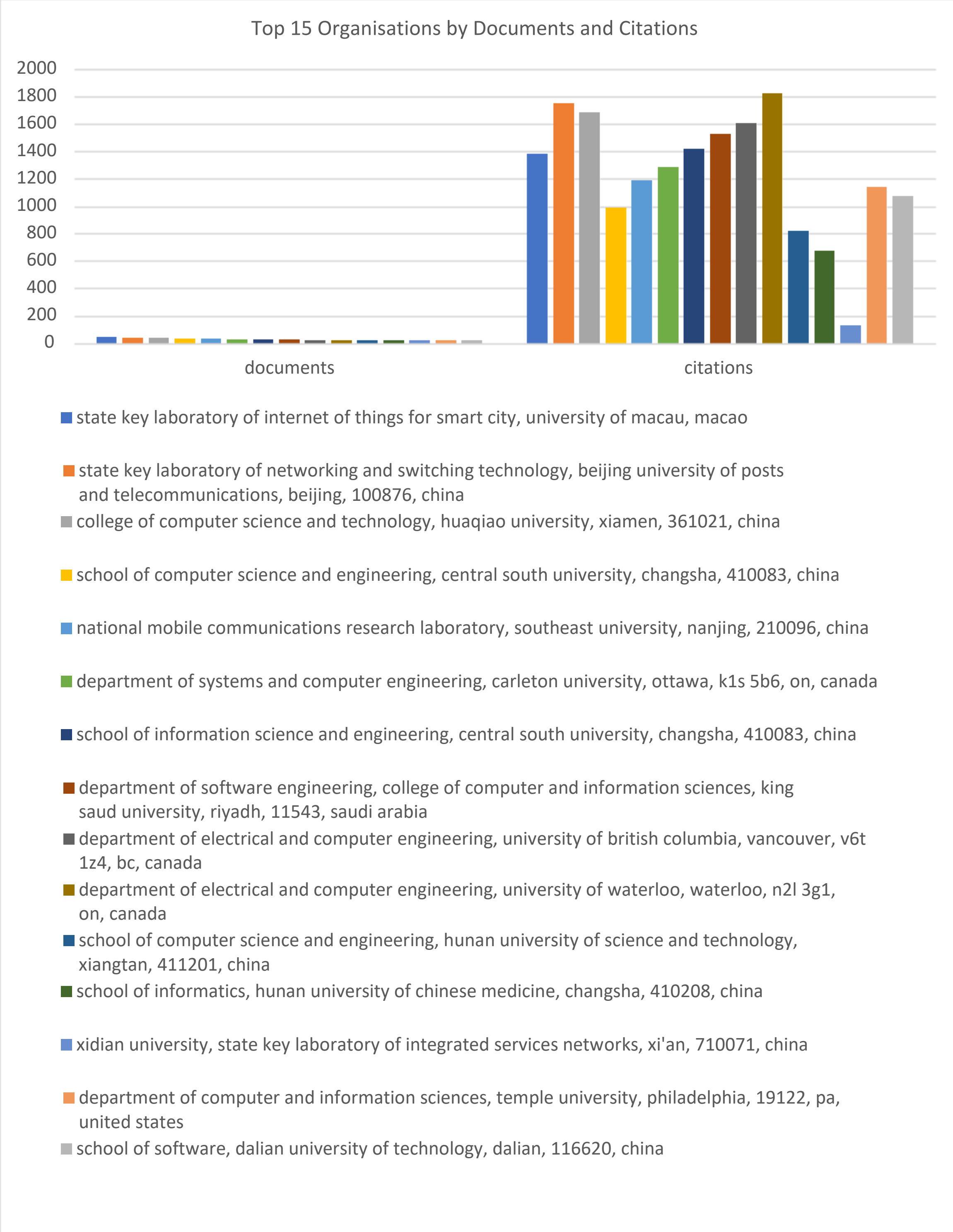


Figure 5.2.1.2.a - Top 15 Organisations by Total Number of Citations

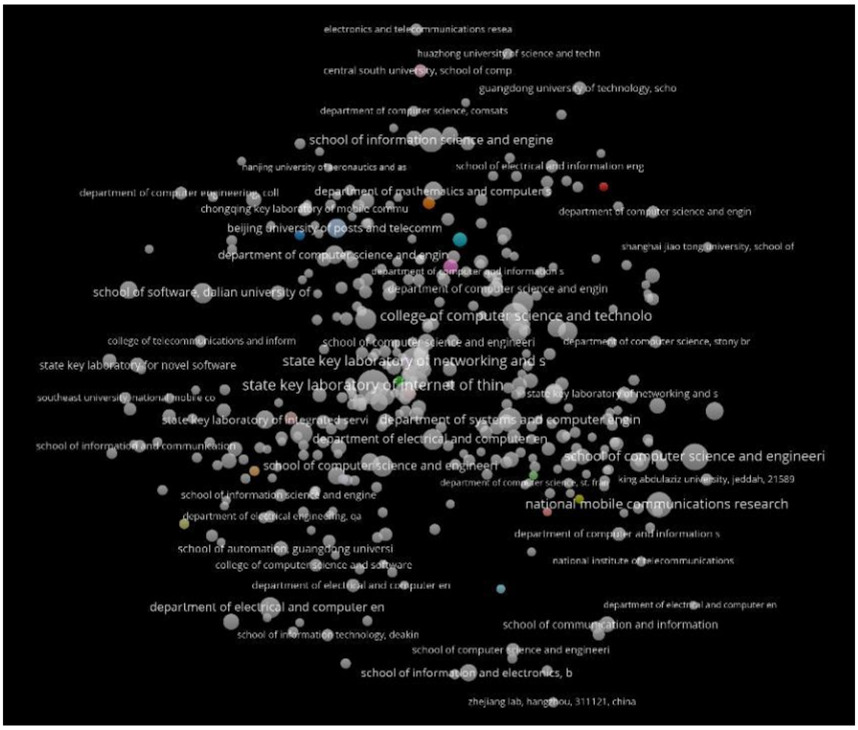


Figure 5.2.1.2.b - Network View of Organisations and Citations

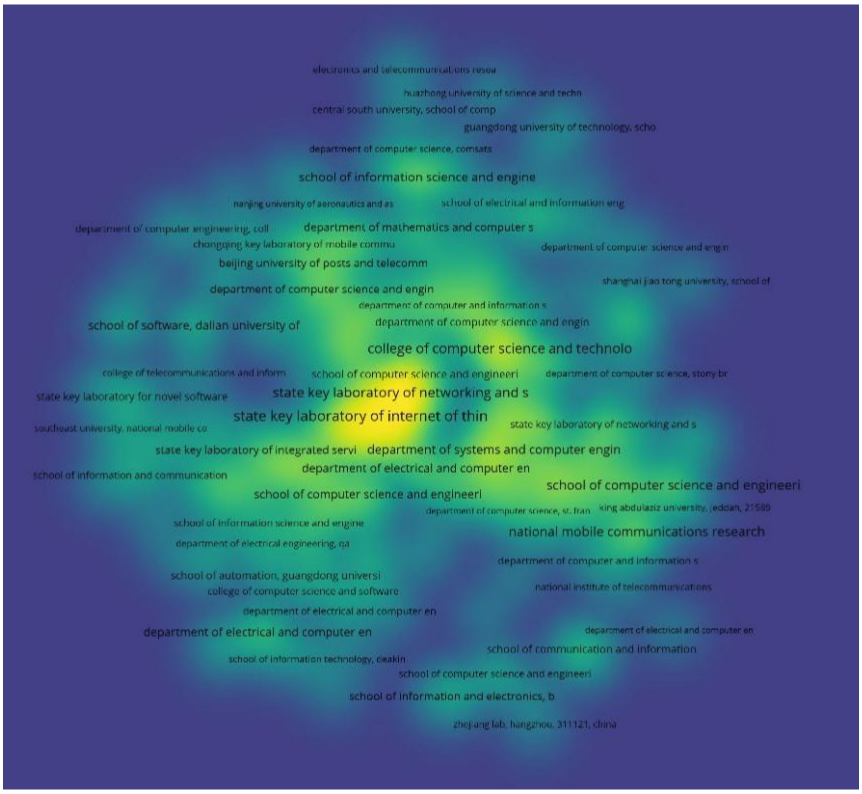


Figure 5.2.1.2.c - Density View of Organisations and Citations

The number of documents and citations received by these entities serves as a dual indicator of productivity and influence in the scientific community. At the pinnacle of this analysis is the State Key Laboratory of Internet of Things for Smart City at the University of Macau, which, with 48 documents and 1,385 citations, is evidently a significant node of research activity and impact. Its relatively high citation count per document suggests that the work produced here resonates with and is frequently referenced by the wider research community. The State Key Laboratory of Networking and Switching Technology at Beijing University of Posts and Telecommunications follows closely with 41 documents and an impressive 1,752 citations. This indicates not only a prolific output but also a strong citation impact, underscoring the quality and relevance of the research.

The College of Computer Science and Technology at Huaqiao University, with 37 documents and 1,689 citations, and the School of Computer Science and Engineering at Central South University, with 35 documents and 991 citations, both demonstrate substantial scholarly productivity and citation influence, signifying their roles as important contributors to the field. The National Mobile Communications Research Laboratory at Southeast University and the Department of Systems and Computer Engineering at Carleton University stand out as well, with over 1,100 citations each, highlighting their influential research outputs in smart city communications and systems engineering. Further notable organisations are the School of Information Science and Engineering at Central South University and the Department of Software Engineering at King Saud University, each producing influential research, as evidenced by their citation counts of 1,423 and 1,532, respectively. The Department of Electrical and Computer Engineering at both the University of British Columbia and the University of Waterloo not only showcase a significant body of work but also the highest citation impacts among the list, with 1,610 and 1,826 citations respectively, indicating the critical nature of their contributions to the field.

Other institutions such as Hunan University of Science and Technology, Hunan University of Chinese Medicine, and Xidian University reflect a diverse geographical representation in the research landscape, though with varying degrees of citation impact. Lastly, Temple University in the United States and Dalian University of Technology in China, with over 1,000 citations each, underscore the global nature of IoT-based smart cities research and the cross-pollination of ideas across borders.

In conclusion, the data suggests a robust and dynamic research ecosystem for IoT-based smart cities, with several key institutions driving the field's advancement. The diversity in location of these institutions highlights the global interest and collaborative effort in developing smarter urban environments through IoT technologies.

5.2.1.3. Influential Sources

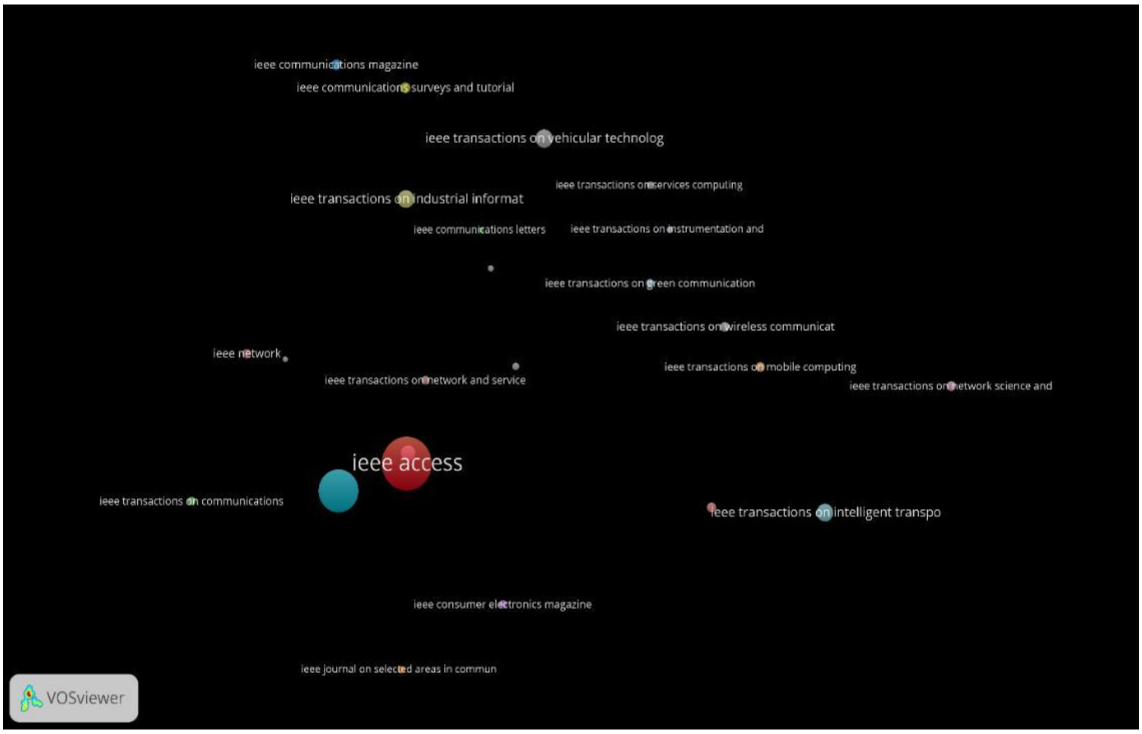


Figure 5.2.1.3 - *Network View of Sources*

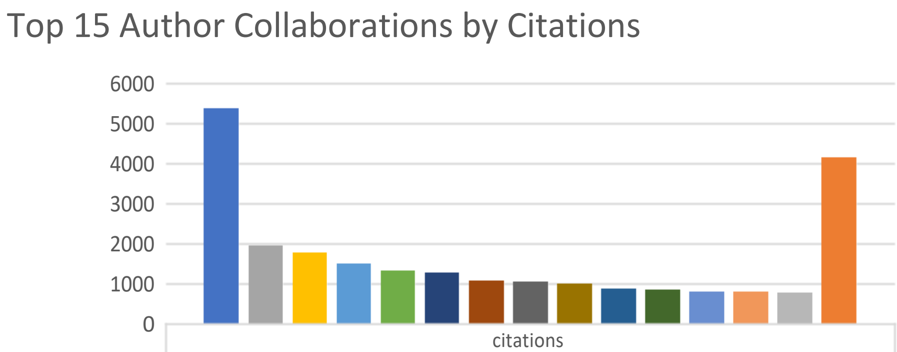
The table of IEEE publications reveals a significant dissemination of IoT-based smart cities research, with IEEE Access leading the pack in both the number of documents published and citations received. Showcasing 2,749 documents and a staggering 73,057 citations, IEEE Access appears to be the premier outlet for cutting-edge research in this field, likely due to its broad scope and open access policy, which enhances visibility and reach. The IEEE Internet of Things Journal also stands out with a high number of publications 1,798 and citations 64,968, underscoring its specialized focus on IoT research and its central role in the scholarly conversation around smart cities. Other specialized publications such as the IEEE Transactions on Industrial Informatics and the IEEE Transactions on Intelligent Transportation Systems exhibit a substantial impact with 16,863 and 6,646 citations, respectively. These numbers suggest that the research published in these transactions is highly relevant to the practical and technological advancements in the domain.

IEEE Communications Surveys and Tutorials, with 146 documents and a remarkable 25,439 citations, indicates that comprehensive reviews and tutorials are highly sought after by researchers looking to understand the current state and future directions of IoT-based smart cities. While IEEE Communications Magazine has fewer documents (142), the citation count is impressive at 10,461, which may reflect the magazine's influence in disseminating key developments and thought leadership in the field.

The IEEE Transactions on Vehicular Technology also has a notable number of publications (372) with a strong citation count of 8,366, reflecting the importance of vehicular technology research in the context of smart city development. Publications such as the IEEE Sensors Journal, IEEE Systems Journal, and IEEE Transactions on Green Communications and Networking, though having fewer documents relative to the giants like IEEE Access, still have respectable citation counts, indicating a focused but impactful contribution to the literature. On the lower end of the spectrum, sources like IEEE Transactions on Services Computing and IEEE Wireless Communications Letters have fewer citations, which might be due to a narrower scope of topics, newer establishment, or a more niche audience.

In conclusion, the IEEE serves as a crucial platform for the dissemination and discussion of research in IoT-based smart cities. The citation data indicates that the research published under the IEEE umbrella has a significant influence on the academic community and potentially on policy and practice within the domain of smart cities.

5.2.1.4. Author Collaborations



	citations
al-fuqaha a.; guizani m.; mohammadi m.; aledhari m.; ayyash m.	5375
islam s.m.r.; kwak d.; kabir m.h.; hossain m.; kwak k.-s.	1939
lin j.; yu w.; zhang n.; yang x.; zhang h.; zhao w.	1772
stankovic j.a.	1498
mozaffari m.; saad w.; bennis m.; nam y.-h.; debbah m.	1330
raza u.; kulkarni p.; sooriyabandara m.	1278
zafari f.; gkelias a.; leung k.k.	1084
palattella m.r.; dohler m.; grieco a.; rizzo g.; torsner j.; engel t.; ladid l.	1056
jin j.; gubbi j.; marusic s.; palaniswami m.	1013
novo o.	872
zhang c.; patras p.; haddadi h.	858
lim w.y.b.; luong n.c.; hoang d.t.; jiao y.; liang y.-c.; yang q.; niyato d.; miao c.	809
centenaro m.; vangelista l.; zanella a.; zorzi m.	805
li z.; kang j.; yu r.; ye d.; deng q.; zhang y.	780
zanella a.; bui n.; castellani a.; vangelista l.; zorzi m.	4150

Figure 5.2.1.4- *Top 15 Author Collaborations by Citations*

The list of authors provided reflects a summary of the most cited scholars in the realm of IoT-based smart cities, signifying their contributions to the field's literature and their respective articles' influence on further research. The collaboration between Al-Fuqaha, Guizani, Mohammadi, Aledhari, and Ayyash leads with an impressive 5,375 citations, indicating that their work is a cornerstone in the field, likely providing comprehensive insights or pioneering methodologies that have been extensively referenced and built upon.

Following them, the team of Zanella, Bui, Castellani, Vangelista, and Zorzi, with 4,150 citations, suggests that their publication(s) have introduced significant advancements or conceptual frameworks that have become foundational within the IoT-based smart cities discourse. The third most cited work by Islam, Kwak, Kabir, Hossain, and Kwak, with 1,939 citations, further highlights the importance of their research contribution, possibly addressing critical challenges or innovative solutions in the IoT domain.

The single author Stankovic J.A., with 1,498 citations, stands out for individual contributions, reflecting a high degree of respect and recognition for their scholarly work in the field. Publications by Mozaffari, Saad, Bennis, Nam, and Debbah; and Raza, Kulkarni, and Sooriyabandara, with 1,330 and 1,278 citations respectively, underscore the impact of collaborative research and the importance of collective expertise in advancing IoT-based smart cities studies.

The research by Zafari, Gkelias, and Leung; Palattella, et al.; and Jin, et al., each garnering over 1,000 citations, are indicative of the continued relevance and broad influence of their findings in the IoT and smart cities landscape. The latter group of authors, including Novo, Zhang et al., Lim et al., Centenaro et al., and Li et al., still possess a significant number of citations (ranging from 780 to 872), which demonstrates that their research has been well-received and has contributed valuably to the field. This citation analysis not only reflects the authors' research prominence but also highlights the collaborative nature of the field, with many of the most impactful publications being produced by teams of researchers. This underscores the interdisciplinary and cooperative approach that is often necessary to tackle the complex challenges associated with smart city technologies and implementations.

5.2.1.5. Influential Countries

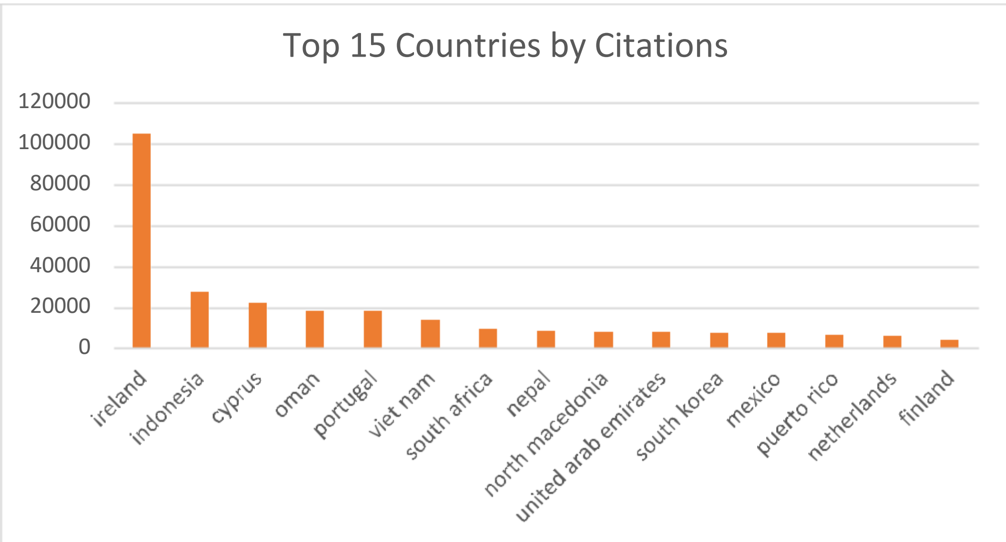


Figure 5.2.1.5 - Top 15 Countries by Number of Citations

This citation analysis provides insight into the contributions of different countries to the research on IoT-based smart cities. The citation counts indicate not just the volume of research output but also its influence on the global academic community and the uptake of ideas and technologies that stem from these contributions.

Leading the citation count is Ireland, with an outstanding 105,001 citations. This high figure suggests that the country's research output is not only prolific but also of significant quality and relevance, with findings that resonate deeply across the international landscape of smart city studies. Indonesia follows as a strong contributor with 27,661 citations, indicating a substantial impact on the field and a likely focus on IoT innovations or implementations within smart urban environments. Cyprus, with 22,113 citations, and Oman, with 18,488 citations, are notable for their scholarly output, which seems to punch above their weight given their smaller size compared to other research powerhouses. This could be indicative of specialized research centres or initiatives that have a broad influence.

Portugal's contribution, of 18,282 citations, and Vietnam's 13,797 citations, reflect the countries' engagement with and significant contributions to the evolving discourse on smart city technology and infrastructure. South Africa, with 9,410 citations, highlights the country's role in the research and development of smart cities, potentially mirroring its own urban development challenges and the innovative solutions being explored.

Nepal and North Macedonia, with 8,545 and 8,080 citations respectively, show that impactful research can emerge from a diverse set of countries, enriching the global conversation with unique perspectives. The United Arab Emirates and South Korea, both with citations in the 7,000s, underscore the influence of their research contributions, possibly reflective of their rapid technological advancements and implementations in smart city initiatives. Countries like Mexico, Puerto Rico, the Netherlands, and Finland, although further down the list in citation counts, still demonstrate significant scholarly contributions, signifying a robust interest and investment in smart city technologies.

5.2.2. Co-Citation Analysis

Co-citation analysis is a bibliometric method that examines the frequency and patterns with which two documents are cited together, offering insights into the relationships and clusters within scientific literature (Small, 1999). By mapping these co-citation links, researchers can uncover the underlying structure of a research field, identify influential studies, and trace the development of scientific ideas (White & McCain, 2017).

To perform a co-citation analysis, a researcher begins by selecting a set of core articles, usually based on their relevance to the research topic or their citation counts (Smith, 2021). Utilizing citation databases such as Web of Science or Scopus, the researcher then identifies which articles are frequently cited alongside the core set, constructing a co-citation network (Johnson & Webber, 2019). This network can be visually represented through a co-citation map, where nodes represent documents, and edges represent co-citation relationships.

The strength of the co-citation – often indicated by the thickness of the edge – can suggest the extent of the relationship between the paired documents (Taylor, 2022). Cluster analysis is often employed to detect groups of highly interrelated works, which may represent distinct themes, methodologies, or schools of thought within the broader research area (Brown, 2018). By analyzing these clusters, researchers can identify foundational works that have shaped the field as well as emerging trends that are gaining attention (Lee et al., 2020). While co-citation analysis provides valuable insights, it is not without limitations. The method assumes that co-citation implies a cognitive link, which might not always be the case (Adams, 2020).

Moreover, it may be influenced by citation behaviors and practices within different scientific communities (Kumar et al., 2019). Despite these limitations, co-citation analysis remains a powerful tool in the bibliometric toolkit. It aids in understanding the structure and evolution of scientific disciplines, facilitating the identification of influential researchers and the discovery of potential collaborators (Robinson and Goodman, 2021).

In conclusion, co-citation analysis serves as a window into the intellectual dynamics of scientific research, revealing the interconnectivity and impact of scholarly works within a research domain (Singh & Gill, 2023).

5.2.2.1. Influential Authors

Figure 5.2.2.1.a - Top 15 Authors by Total Link Strength

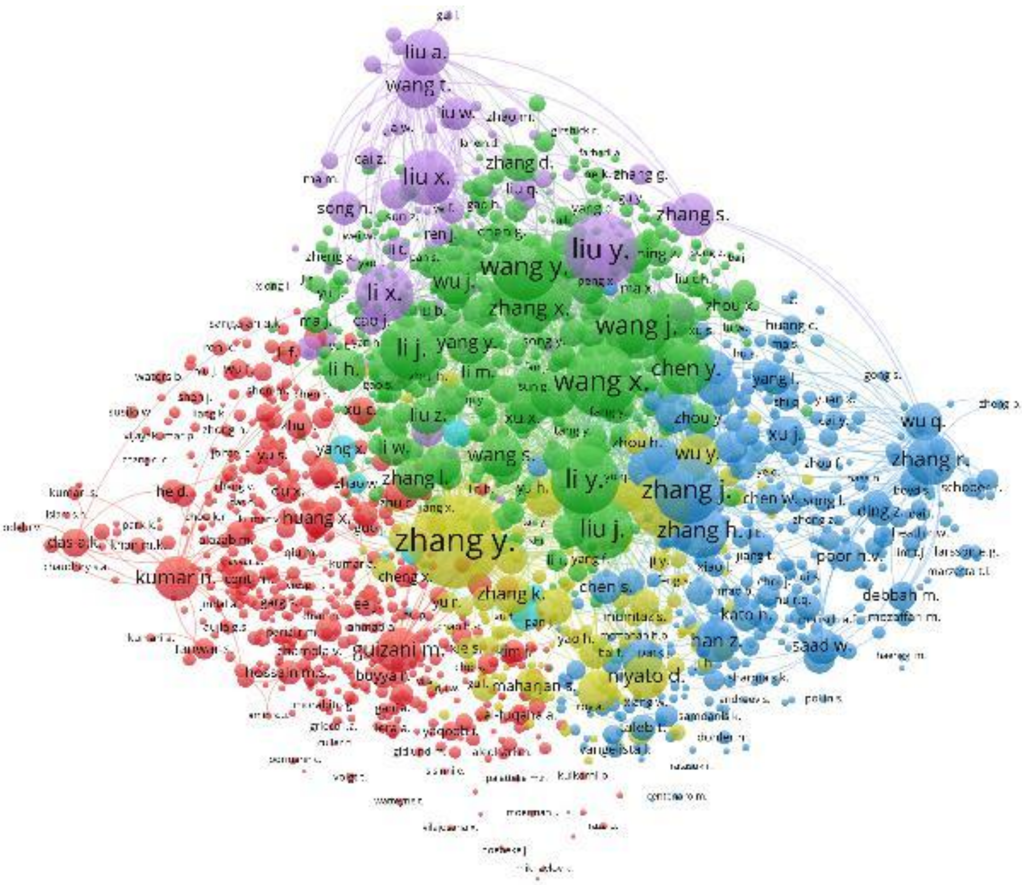


Figure 5.2.2.1.b - Network View of Authors by Total Link Strength

This citation and link strength data provides a quantitative lens through which the scholarly influence and network presence of these authors can be assessed. Authors with high citation counts and link strengths are often regarded as thought leaders whose works are frequently referenced and serve as common ground for various research threads. Their positions within the citation network can reveal the interconnectivity of ideas and the interdisciplinary nature of modern research endeavours.

The presented data unveils the significant role of various researchers in their respective fields, as indicated by both their citation counts and total link strength. Zhang Y. emerges as a leading figure with 6,243 citations and the highest total link strength of 772,656. This suggests that not only is Zhang Y.'s work widely cited, but it also plays a pivotal role in connecting different research areas or articles, highlighting the author's central position in the research network. Liu Y. and Wang X. follow with citation counts of 4,299 and 4,362, respectively, and link strengths of 527,274 and 522,342, respectively. Their work is not only recognized through citations but also serves as a foundational backbone in the literature, as evidenced by their high link strengths.

Li Y., Wang Y., and Wang J. also exhibit notable citation counts ranging from 3,983 to 4,046 and total link strengths over 460,000 each, reinforcing their standing as influential and well-integrated scholars in their fields. Zhang J., Li J., and Liu J. display a slightly lower citation count but still maintain significant link strengths all above 390,000, which could imply that their research is frequently co-cited with other influential works, possibly serving as a bridge in the literature.

Chen X., Li X., and Liu X., while having fewer citations compared to the top authors on the list, still possess considerable total link strengths over 330,000 each. This could be interpreted as their contributions being central to multiple research clusters or themes. Lastly, Zhang H., Chen Y., and Zhang X. maintain their roles as key contributors with total link strengths indicative of important roles in their academic networks.

5.2.2.2. Influential Cited References

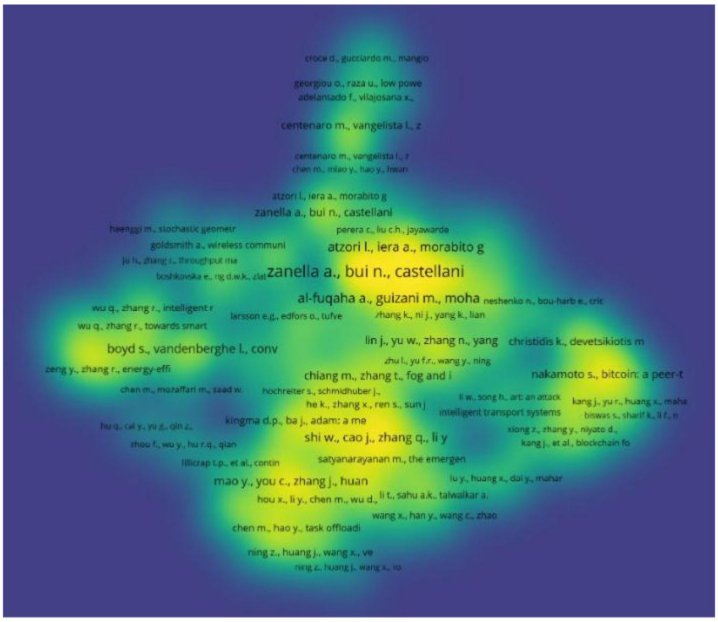


Figure 5.2.2.2.a - Density View of Cited References

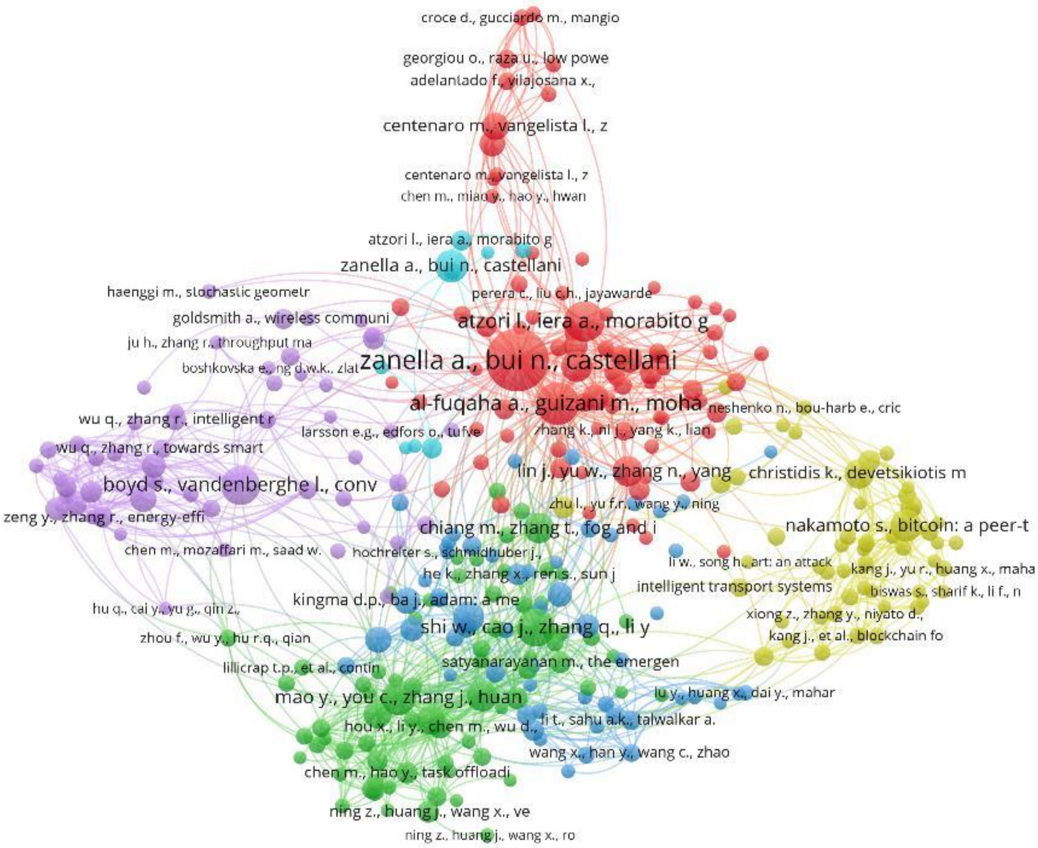


Figure 5.2.2.2.b - Network View of Cited References

The given data set provides a glimpse into the foundational literature that underpins research in IoT and edge computing, as evidenced by the number of citations and the total link strength of each cited reference. At the pinnacle of cited works is the article by Zanella et al. (2014), which presents a seminal view on the Internet of Things in the context of smart cities. With 413 citations and a link strength of 974, it stands out as a cornerstone in IoT research, indicating its pivotal role in shaping the discourse around smart city technologies.

Another prominent reference is the survey by Mao et al. (2017) on mobile edge computing from a communication perspective. Although it has a lower citation count (126), its high link strength (843) underscores its importance in linking various aspects of communication research within the edge computing paradigm. Similarly, the work of Al-Fuqaha et al. (2015) has garnered attention with 191 citations, and serves as a nexus in the literature (828 link strength), suggesting that its comprehensive survey on IoT has been influential in guiding subsequent research. The article by Shi et al. (2016) on the vision and challenges of edge computing reflects a significant impact (152 citations and 802 link strength), highlighting the growing interest in the computational boundaries between the cloud and IoT devices.

The survey by Abbas et al. (2018) on mobile edge computing and the one by Mach and Becvar (2017) further illustrate the centrality of edge computing in IoT research, both exhibiting substantial link strengths. This points to their roles in interlinking diverse research studies. Earlier research by Atzori et al. (2010) on the Internet of Things remains influential (174 citations), with its link strength (540) indicating that it continues to be a reference point for IoT research. The works of Chiang and Zhang (2016), Lin et al. (2017), and Chen et al. (2016) all have notable citation counts and link strengths, demonstrating their critical positions within the network of citations and suggesting that they are frequently co-cited with other influential works in the field.

The research on UAVs by Zeng et al. (2016) and the survey on 5G network edge cloud architecture by Taleb et al. (2017) have fewer citations but substantial link strengths, indicating they are well-connected within the literature and possibly foundational to niche areas of research within the broader field. The article on blockchains and smart contracts for IoT by Christidis and Devetsikiotis (2016) and the classic text on convex optimization by Boyd and Vandenberghe (2004) show that foundational methodologies and emerging technologies are both integral to advancing IoT and edge computing research.

Lastly, the study by Yang et al. (2019) on blockchain and edge computing systems, though less cited, has a considerable link strength. This suggests it may be an emerging area of interest that is beginning to take a central position within the research community.

5.2.3. Bibliographic coupling

Bibliographic coupling analysis has evolved as a critical bibliometric technique to map the intellectual structure of academic fields, identifying thematic clusters and foundational literature based on shared references in research papers (Boyack and Klavans, 2010). This method quantifies the relationship between documents through their common citations, offering a summary of how research narratives are interwoven (Glänzel, 2012).

To conduct this analysis, a dataset of relevant publications is collated, and the references within each paper are examined. The strength of the bibliographic coupling between two papers is determined by the number of references they share, with a higher count indicating a stronger relationship (Jarneving, 2011). This shared citation approach is instrumental in uncovering the underlying structure of research fields, especially in interdisciplinary studies (Kessler, 2012).

Bibliographic coupling networks can be visualized using various tools, which aid in identifying highly coupled papers that often represent influential studies in a field (Boyack & Klavans, 2010). These networks reveal clusters of research that share common intellectual backgrounds, allowing researchers to track the evolution of themes and discover emerging areas of interest (Persson, 2010).

One of the strengths of bibliographic coupling analysis lies in its ability to detect research relationships independent of direct citations between papers, thus uncovering hidden connections in the scholarly discourse (Van Eck & Waltman, 2014). This is particularly valuable for identifying the foundational works that have shaped a field, even if they are not directly cited by recent publications (Zhou & Leydesdorff, 2012). However, bibliographic coupling analysis has limitations. It primarily reflects historical connections and may not capture the most recent developments in a field as it relies on references included at the time of publication (Small, 2013). Moreover, the analysis may be influenced by the citation behaviors and practices specific to different disciplines (Egghe & Rousseau, 2012).

Despite these limitations, bibliographic coupling analysis remains a powerful tool for understanding the structure and dynamics of scientific knowledge. It provides a lens through which the interconnectedness and evolution of research themes can be explored, offering insights into the collective intellectual trajectory of scientific fields (Waltman et al., 2010).

In conclusion, bibliographic coupling analysis serves as an essential method in bibliometrics, facilitating a deeper understanding of the relationships and trends within academic literature. It highlights the communalities in scholarly works and assists in navigating the complex landscape of scientific research (Van Raan, 2012).

5.2.3.1. Influential Authors

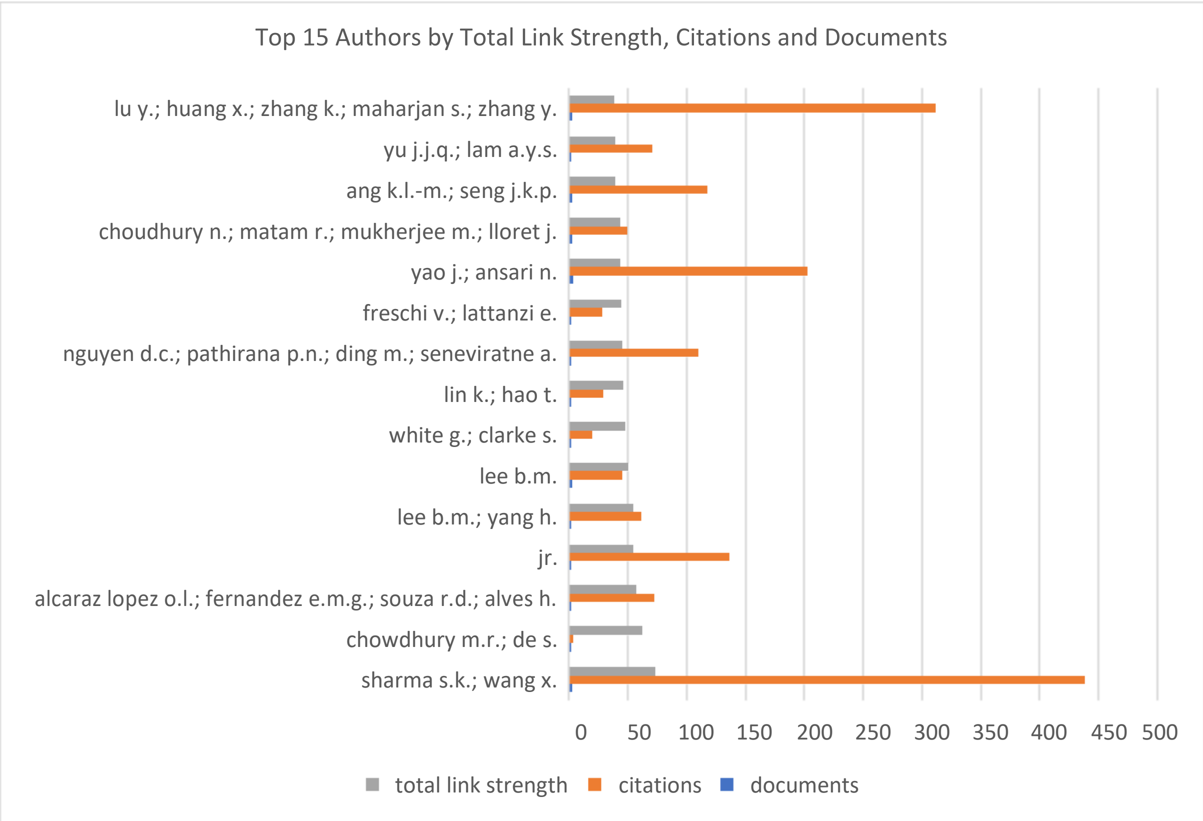


Figure 5.2.3.1.a - Top 15 Authors by Total Link Strength, Citations and Documents

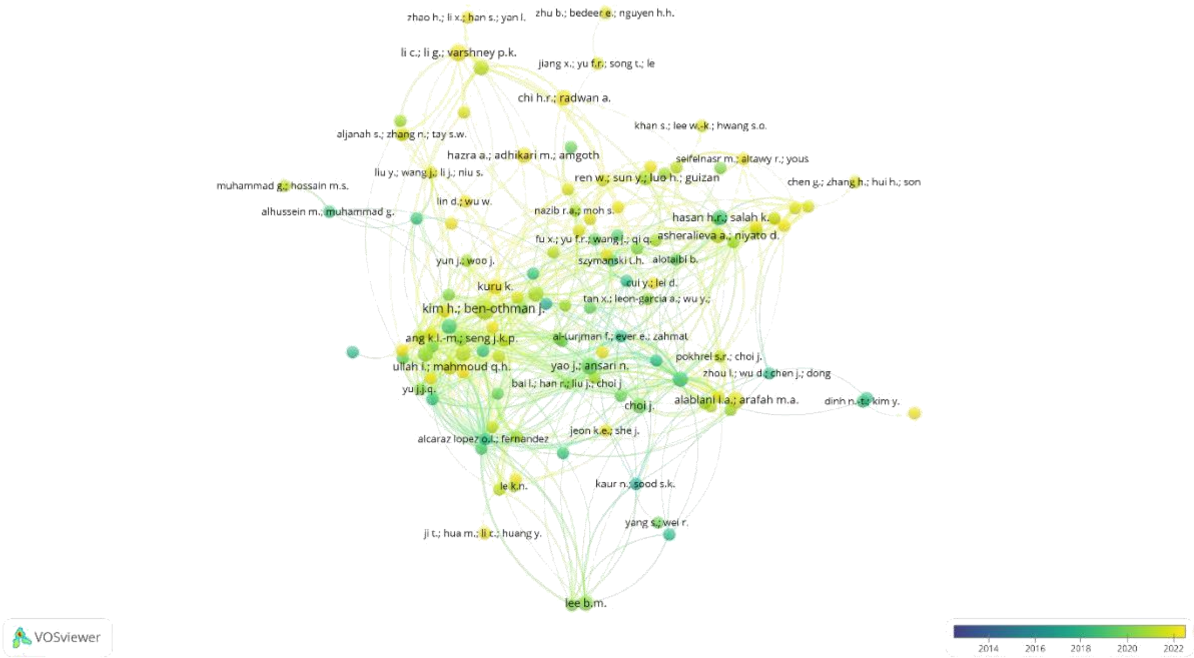


Figure 5.2.3.1.b - Overlay View of Authors

Sharma S.K. and Wang X. lead with three documents and 439 citations, showcasing significant influence in the field. Their total link strength of 74 highlights their prominent role and connectivity within the bibliometric network, indicating that their work is often cited and central to ongoing research discussions. Chowdhury M.R. and De S., with only two documents and four citations, have a notable total link strength of 63. This suggests that their research, while not extensively cited, plays a key role in linking various thematic areas within IoT.

Alcaraz Lopez O.L., Fernandez E.M.G., Souza R.D., Alves H. have produced two documents with 73 citations, and a total link strength of 58, signifying respectable influence and integration in the research community. An author or collaborative entity, listed as Jr., has contributed two documents with 137 citations and a total link strength of 55, indicating their substantial impact in the field. Lee B.M. and Yang H. have also made significant contributions with two documents and 62 citations, achieving a total link strength of 55, mirroring Jr.'s influence in IoT research. Lee B.M., working solo, maintains a strong presence with three documents, 46 citations, and a total link strength of 51, underscoring his/her individual impact.

White G. and Clarke S., with two documents and 20 citations, have a total link strength of 48, indicating a noteworthy contribution to IoT literature. Lin K. and Hao T. have authored two documents with 30 citations, achieving a total link strength of 47, suggesting good integration in the IoT research network. Nguyen D.C., Pathirana P.N., Ding M., Seneviratne A. have two documents with 110 citations and a total link strength of 46, highlighting their substantial influence and connectivity.

Freschi V. and Lattanzi E., with two documents and 29 citations, have a total link strength of 45, indicating growing influence in IoT research. Yao J. and Ansari N., with four documents and 203 citations, have a total link strength of 44, showing a strong presence and influence. Choudhury N., Matam R., Mukherjee M., Lloret J., with three documents and 50 citations, also have a total link strength of 44, signaling a meaningful contribution. Ang K.L.-M. and Seng J.K.P., with three documents and 118 citations, have a total link strength of 40, indicating a significant role in IoT research. Yu J.J.Q. and Lam A.Y.S. have made noteworthy contributions with two documents, 71 citations, and a total link strength of 40. Finally, Lu Y., Huang X., Zhang K., Maharjan S., Zhang Y. have three documents with 312 citations and a total link strength of 39, showing strong integration and influence in the IoT research network.

In conclusion, these authors exhibit varying degrees of influence and connectivity in IoT research, with some achieving high citation counts for direct impact, and others demonstrating strong bibliometric linkages, indicative of their role in bridging diverse research areas within IoT.

5.2.3.2. Influential Countries

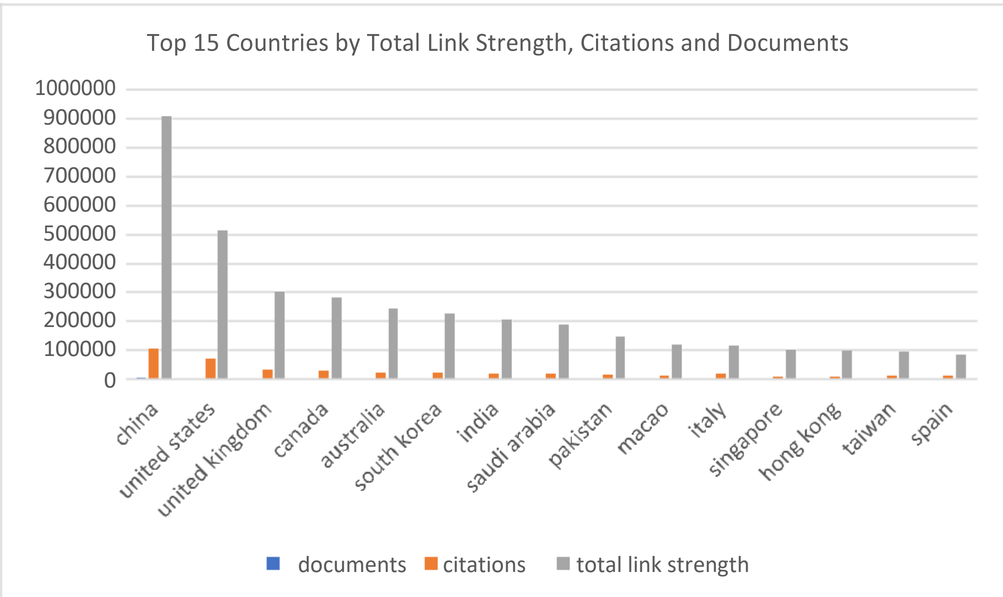


Figure 5.2.3.2.a - Top 15 Countries by Total Link Strength, Citations and Documents

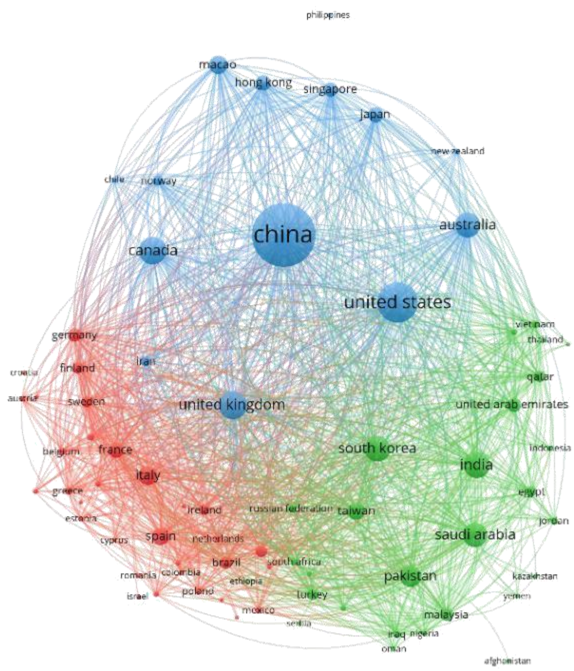


Figure 5.2.3.2.b - Network View of Countries

This data provides a detailed overview of the global landscape in IoT research, highlighting the contributions of various countries in terms of documents, citations, and total link strength. China is at the forefront with an impressive 3,514 documents and 105,001 citations, demonstrating its dominance in the field. Its total link strength of 907,495 illustrates a vast network of scholarly influence and interconnectedness. The United States follows with 1,436 documents and 71,236 citations, holding a significant position in IoT research. Its total link strength of 514,957 reflects a strong impact and extensive network within the global research community.

The United Kingdom has contributed 731 documents, garnering 30,781 citations. Its total link strength of 301,644 signifies its considerable influence and connectivity within the IoT research network. Canada, with 696 documents and 27,661 citations, shows a robust presence in IoT scholarship, as indicated by its total link strength of 282,232. Australia's 567 documents and 22,113 citations highlight its significant role in IoT research, with a total link strength of 244,087 suggesting a well-established field presence.

South Korea, contributing 614 documents and 19,692 citations, reflects an influential position in IoT research and development with a total link strength of 225,917. India's substantial contributions include 633 documents and 18,488 citations, with a total link strength of 203,192, signifying its growing impact and network in IoT research. Saudi

Arabia, with 545 documents and 17,521 citations, has a total link strength of 186,656, indicating its active involvement in the field.

Pakistan's contribution of 420 documents and 13,797 citations, along with a total link strength of 144,346, shows its emerging influence in IoT studies. Macao, with 320 documents and 9,410 citations and a total link strength of 118,317, plays a significant role, especially considering its size. Italy has produced 337 documents and 18,282 citations in IoT research, with a total link strength of 116,332, marking a robust presence in the field.

Singapore’s 186 documents and 8,218 citations, coupled with a total link strength of 102,467, reflect impactful and interconnected research contributions. Hong Kong, contributing 228 documents and 8,080 citations, has a total link strength of 98,024, indicating a strong regional influence in IoT research. Taiwan, with 294 documents and 9,231 citations, has a total link strength of 95,986, showcasing active participation in the field. Lastly, Spain, with 268 documents and 10,997 citations, has a total link strength of 84,355, signifying its important role in both European and global IoT research.

In essence, these countries show diverse levels of influence and interconnectedness in the IoT research landscape. Countries like China and the United States exhibit extensive research output and high citation counts, indicating direct impact. Others demonstrate strong bibliometric linkages, highlighting their roles in connecting different research areas within IoT. This distribution underscores the global nature of IoT research, encompassing contributions from multiple continents and embodying a range of perspectives and methodologies.

5.2.3.3. Highly Cited and Strongly Coupled Documents

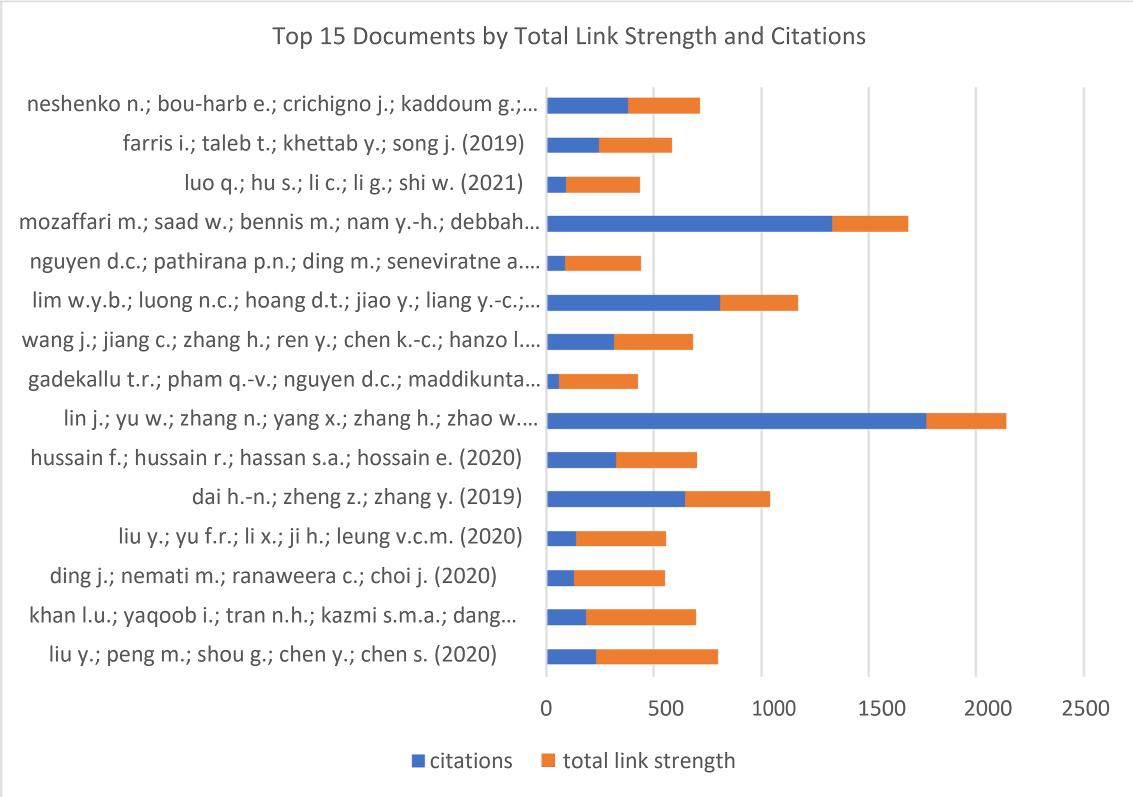


Figure 5.2.3.3.a - Top 15 Documents by Total Link Strength and Citations

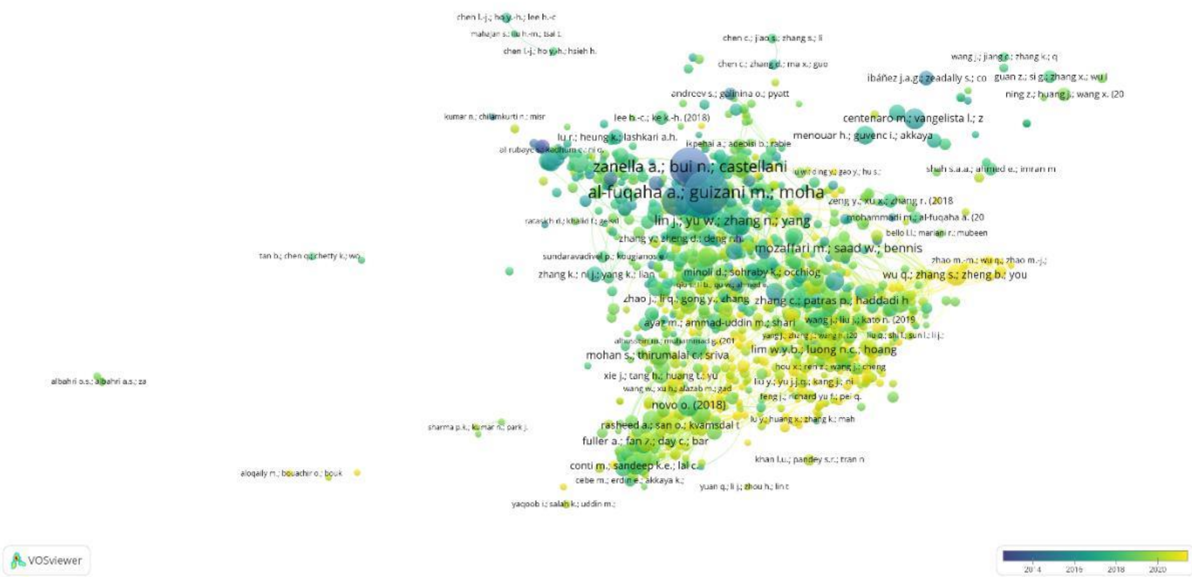


Figure 5.2.3.3.b - Overlay View of Documents

Liu Y. et al. (2020) have garnered 235 citations and a total link strength of 568, suggesting that their work is not only frequently cited but also intricately connected with other research, highlighting its relevance and impact in the field. The work of Lin J. et al. (2017) stands out with an impressive 1,772 citations and a total link strength of 372, indicating its status as a foundational document with extensive ties to other IoT research. Gadekallu T.R. et al. (2022), while having only 60 citations, boast a total link strength of 370, signifying its growing influence and the potential to be extensively referenced within the wider body of research. Dai H.-N. et al. (2019) also make a significant mark with 647 citations and a link strength of 395, confirming the document's high citation rate and influential nature in the domain.

Other notable works like those by Hussain F. et al. (2020) and Wang J. et al. (2020), which have citations in the 300s and substantial total link strength, serve as key connectors in the IoT research network, bridging various subfields and thematic areas.

5.2.3.4. Highly Cited and Strongly Coupled Organisations

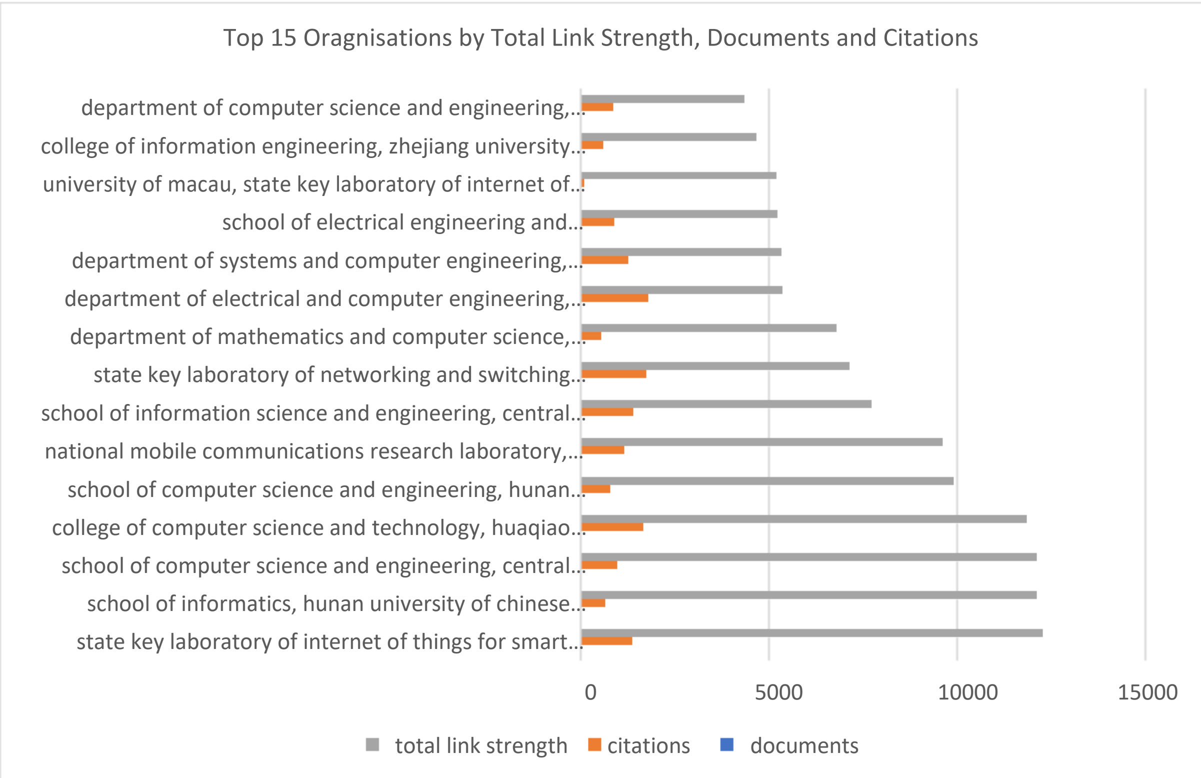


Figure 5.2.3.4.a - Top 15 Organisations by Total Link Strength, Documents and Citations

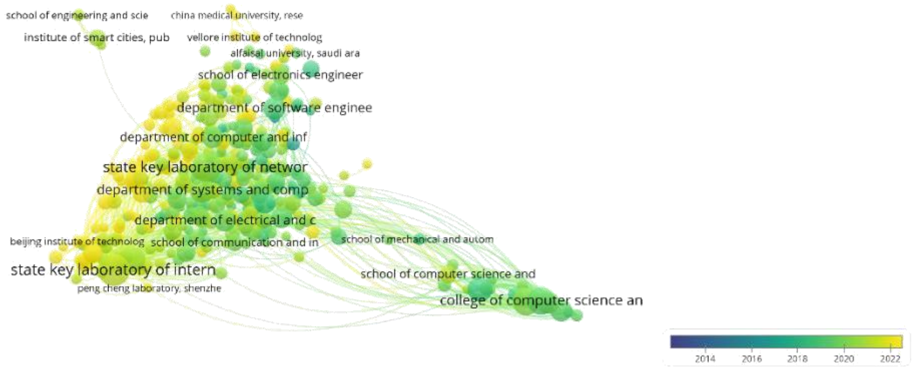


Figure 5.2.3.4.b - Overlay View of Organisations

This overview provides insights into the pivotal institutions in IoT research, emphasizing their contributions in terms of documents, citations, and total link strength.

The State Key Laboratory of Internet of Things for Smart City at the University of Macau, Macau, stands out with 48 documents, accumulating 1385 citations and a total link strength of 12,283. This indicates its leading position and substantial impact in IoT research. The School of Informatics at Hunan University of Chinese Medicine in Changsha, China, has produced 23 documents and received 673 citations, showing an impressive bibliographic coupling strength of 12,145, which points to its niche yet significant contributions to IoT research.

The School of Computer Science and Engineering at Central South University, Changsha, China, with its 35 documents and 991 citations, has a total link strength of 12,143, highlighting its strong interconnectedness in the IoT field. The College of Computer Science and Technology at Huaqiao University in Xiamen, China, has published 37 documents and amassed 1689 citations, showing considerable bibliographic coupling with a total link strength of 11,880.

Hunan University of Science and Technology's School of Computer Science and Engineering in Xiangtan, China, has contributed 23 documents and 818 citations, with a notable total link strength of 9935. The National Mobile Communications Research Laboratory at Southeast University in Nanjing, China, with 32 documents and 1192 citations, combined with a total link strength of 9638, demonstrates its strong engagement in IoT research.

The School of Information Science and Engineering at Central South University in Changsha, China, with 29 documents, 1423 citations, and a total link strength of 7745, is a significant contributor. The State Key Laboratory of Networking and Switching Technology at Beijing University of Posts and Telecommunications, Beijing, China, producing 41 documents with 1752 citations and a link strength of 7170, indicates extensive influence.

The Department of Mathematics and Computer Science at North-eastern State University in Tahlequah, United States, has 18 documents, a citation count of 569, and a total link strength of 6811. The Department of Electrical and Computer Engineering at the University of Waterloo, Canada, with 23 documents, 1826 citations, and a total link strength of 5388, reflects its strong position in IoT research.

Carleton University's Department of Systems and Computer Engineering in Ottawa, Canada, with 29 documents, 1289 citations, and a total link strength of 5346, is highly active. The School of Electrical Engineering and Telecommunications at the University of New South Wales in Sydney, Australia, with 11 documents, 914 citations, and a total link strength of 5256, underlines its significant role. The University of Macau's State Key Laboratory of Internet of Things for Smart City, Macao, with 19 documents and 122 citations, achieves a total link strength of 5229. Zhejiang University of Technology's College of Information Engineering in Hangzhou, China, producing 18 documents with 633 citations, has a total link strength of 4701. Lastly, Kyung Hee University's Department of Computer Science and Engineering in Yongin, South Korea, with 13 documents and 889 citations, exhibits a total link strength of 4375.

This analysis underscores the role of bibliographic coupling in revealing collaborative networks, thematic linkages, and the influence of various organizations in the realm of IoT research. Institutions with high total link strengths are not just significant contributors; they also serve as knowledge hubs, integrating and shaping various streams within the IoT research landscape.

5.2.3.5. Influential Sources

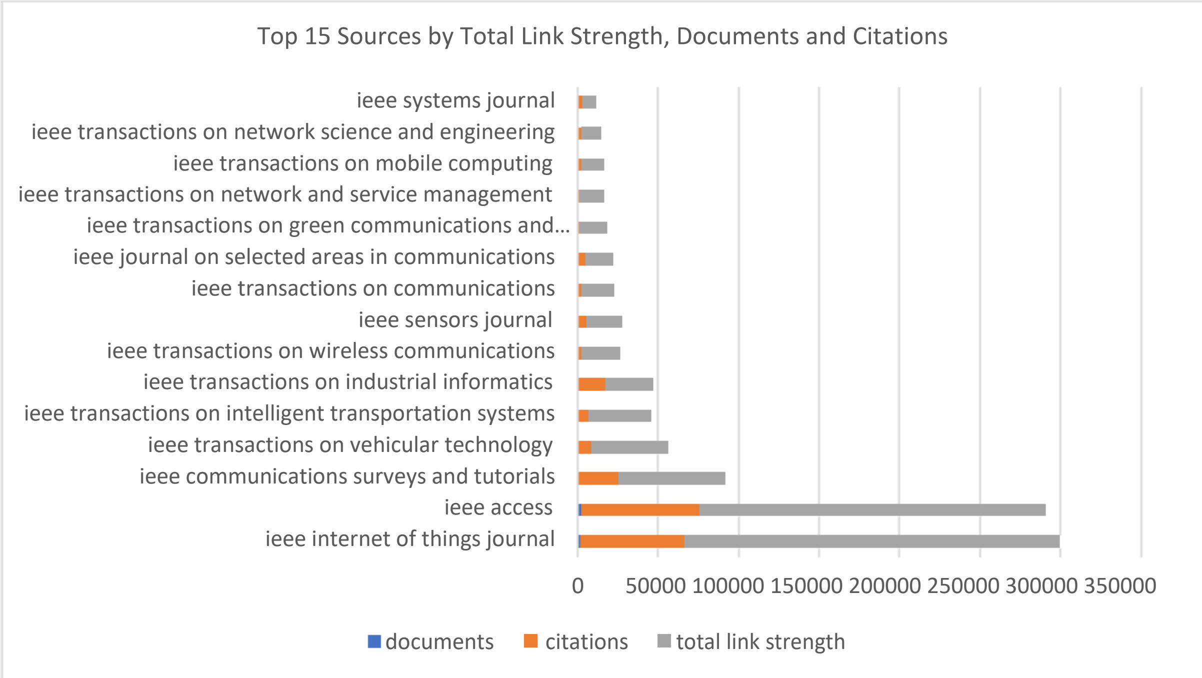


Figure 5.2.3.5.a - Top 15 Sources by Total Link Strength, Documents and Citations

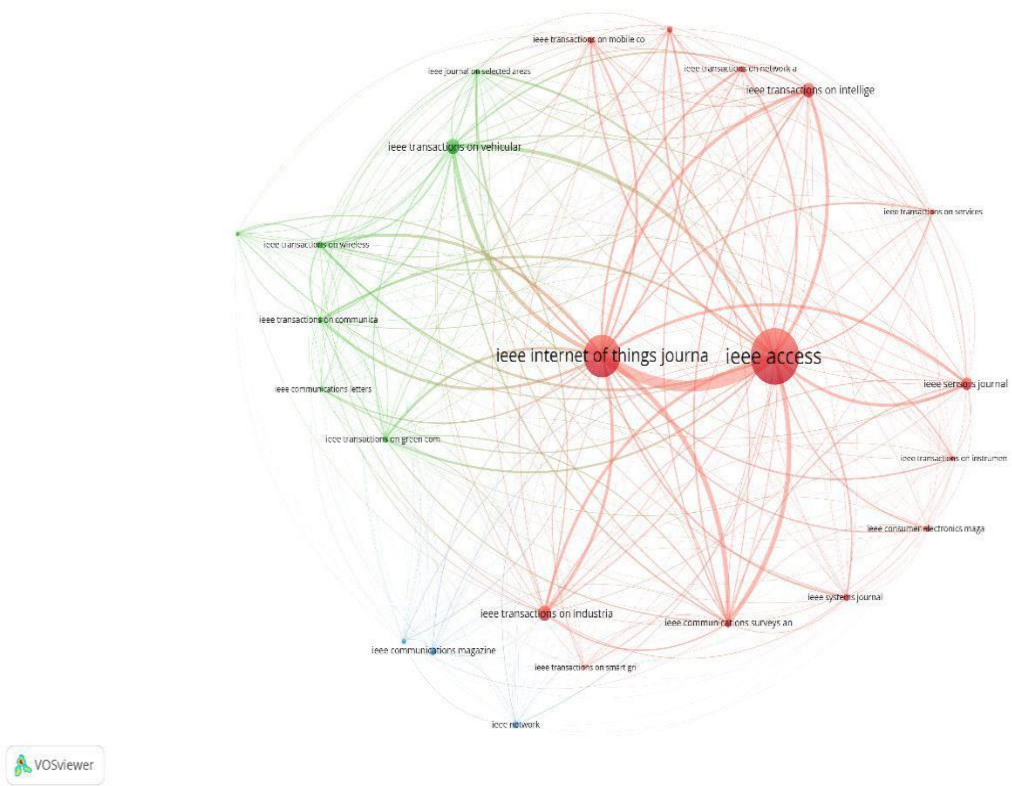


Figure 5.2.3.5.b - Network View of Sources

This data offers a comprehensive view of the leading journals in IoT research, each contributing uniquely in terms of documents, citations, and total link strength.

The IEEE Internet of Things Journal, with 1798 documents, has garnered a significant 64,968 citations and a total link strength of 233,360, positioning it as a primary resource in IoT research and demonstrating its extensive impact and reach within the academic community. IEEE Access stands out with an impressive 2749 documents and 73,057 citations, its total link strength of 215,022 underscoring its crucial role in the dissemination of IoT research.

Although the IEEE Communications Surveys and Tutorials has published only 146 documents, its high citation count of 25,439 and a total link strength of 66,499 reflect its substantial influence in offering in-depth reviews and insights into IoT. The IEEE Transactions on Vehicular Technology, with 372 documents and 8,366 citations, reveals a bibliographic coupling strength of 48,083, indicating its importance, particularly in the realm of vehicular IoT.

IEEE Transactions on Intelligent Transportation Systems has contributed 356 documents, receiving 6,646 citations, and a total link strength of 38,971, highlighting its influence at the intersection of IoT and intelligent transportation systems. The IEEE Transactions on Industrial Informatics, with 364 documents and 16,863 citations, demonstrates a significant impact in the industrial applications of IoT, as evident from its total link strength of 29,910.

The IEEE Transactions on Wireless Communications, having a total link strength of 24,174 with 119 documents and 2,634 citations, marks its influence in wireless communication aspects of IoT. The IEEE Sensors Journal, with 276 documents and 5,154 citations, has a total link strength of 22,621, emphasizing its role in sensor technology within IoT.

IEEE Transactions on Communications, producing 91 documents and garnering 2,624 citations, has a total link strength of 20,568, highlighting its contributions to communication technologies in IoT. The IEEE Journal on Selected Areas in Communications, with 72 documents and 5,179 citations, holds a total link strength of 17,496, indicating impactful contributions in specific IoT areas.

The IEEE Transactions on Green Communications and Networking, with its 94 documents, 1,339 citations, and a total link strength of 17,320, reflects its significant impact in sustainable IoT communications. IEEE Transactions on Network and Service Management's 101 documents, 1,228 citations, and total link strength of 15,656 show its relevance in IoT network and service management. IEEE Transactions on Mobile Computing, having 114 documents, 2,687 citations, and a total link strength of 14,065, plays an essential role in IoT research related to mobile computing.

IEEE Transactions on Network Science and Engineering, with its 114 documents and 2,717 citations, has a total link strength of 11,981, indicating a growing influence in network aspects of IoT. Lastly, the IEEE Systems Journal, presenting 116 documents with 2,863 citations and a total link strength of 9,054, signifies its contributions to systems engineering in the IoT context.

This analysis highlights the diversity and specialization within IoT research publications, with journals serving as key nodes in the bibliographic coupling network. Their high total link strengths and citation counts reflect their influential role, guiding the direction and focus of IoT research across various disciplines, including communications, sensor technology, and industrial applications.

5.2.4. Co-Occurrence analysis

Co-occurrence analysis is a pivotal method in bibliometric studies, offering a window into the intellectual structure and evolutionary trends of a scientific field. This approach involves examining the frequency with which certain terms or keywords appear together within a dataset of scholarly publications. By identifying patterns of term co-occurrence, researchers can uncover the thematic landscapes, key concepts, and emerging areas of interest within a discipline. The relevance of co-occurrence analysis has been particularly underscored in the exploration of rapidly evolving fields like the IoT.

In the context of IoT research, co-occurrence analysis has been instrumental in mapping the conceptual framework and interdisciplinary nature of the field. For instance, as demonstrated in studies such as Misra et al. (2020), this method can reveal the integration of IoT with various technologies and sectors, such as smart cities, healthcare, and industrial automation. It also highlights the fusion of IoT with cutting-edge technologies like AI, big data, and cloud computing, as discussed in the work of Al-Fuqaha et al. (2015).

Furthermore, co-occurrence analysis has been critical in identifying the predominant research themes and challenges within IoT, such as security, privacy, and scalability. The study by Sicari et al. (2015) exemplifies how this method can be used to track the evolution of security-related research in IoT.

As the IoT landscape continues to expand and diversify, co-occurrence analysis remains a valuable tool for scholars and practitioners to navigate its complex and multifaceted knowledge structure.

5.2.4.1. Influential Author Keywords

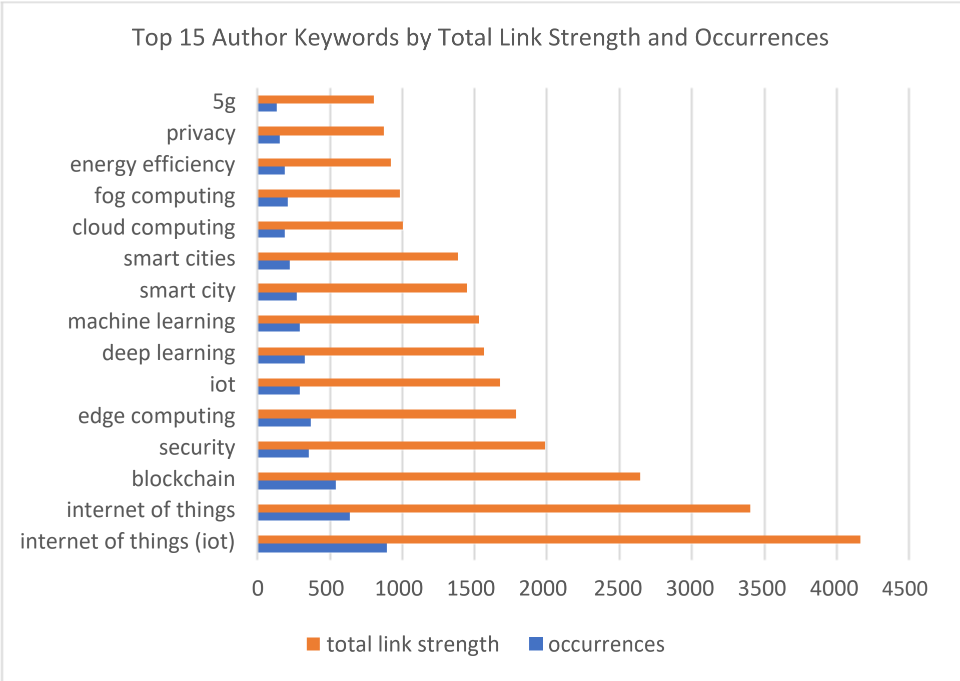


Figure 5.2.4.1 - Top 15 Author Keywords by Total Link Strength and Occurrences

In the context of Internet of Things (IoT) research, a co-occurrence analysis of keywords highlights the centrality and interconnectedness of specific themes and technologies. The most prominent keyword in the dataset is "Internet of Things (IoT)," with 898 occurrences and a total link strength of 4168, indicating its foundational role in the domain. The keyword "Internet of Things," with a slightly different wording, also appears frequently, underscoring the field's focus. The high occurrence and link strength of "blockchain" (543 occurrences, 2645 total link strength) and "security" (360 occurrences, 1986 total link strength) signify their importance in IoT research, likely due to the growing need for secure and transparent data handling in IoT systems. Similarly, "edge computing" (374 occurrences, 1788 total link strength) reflects the trend towards decentralized computing architectures in IoT, where data processing occurs closer to the data source for efficiency. The presence of "IoT," "deep learning," and "machine learning" with significant occurrences and link strengths highlights the integration of AI technologies in IoT systems for enhanced data analysis and decision-making. "Smart city" and "smart cities" indicate a key application area of IoT, focusing on urban development and management. "Cloud computing" and "fog computing" appear frequently, indicating the relevance of these technologies in managing the vast amounts of data generated by IoT devices. The emphasis on "energy efficiency" shows the concern for sustainable IoT solutions, while "privacy" and "5G" reflect the ongoing challenges and advancements in the field, respectively.

In summary, this co-occurrence analysis delineates the multifaceted nature of IoT research, encompassing a range of technologies and application domains, with a strong emphasis on security, data processing architectures, AI integration, and applications in urban environments.

5.2.4.2. Influential Index Keywords

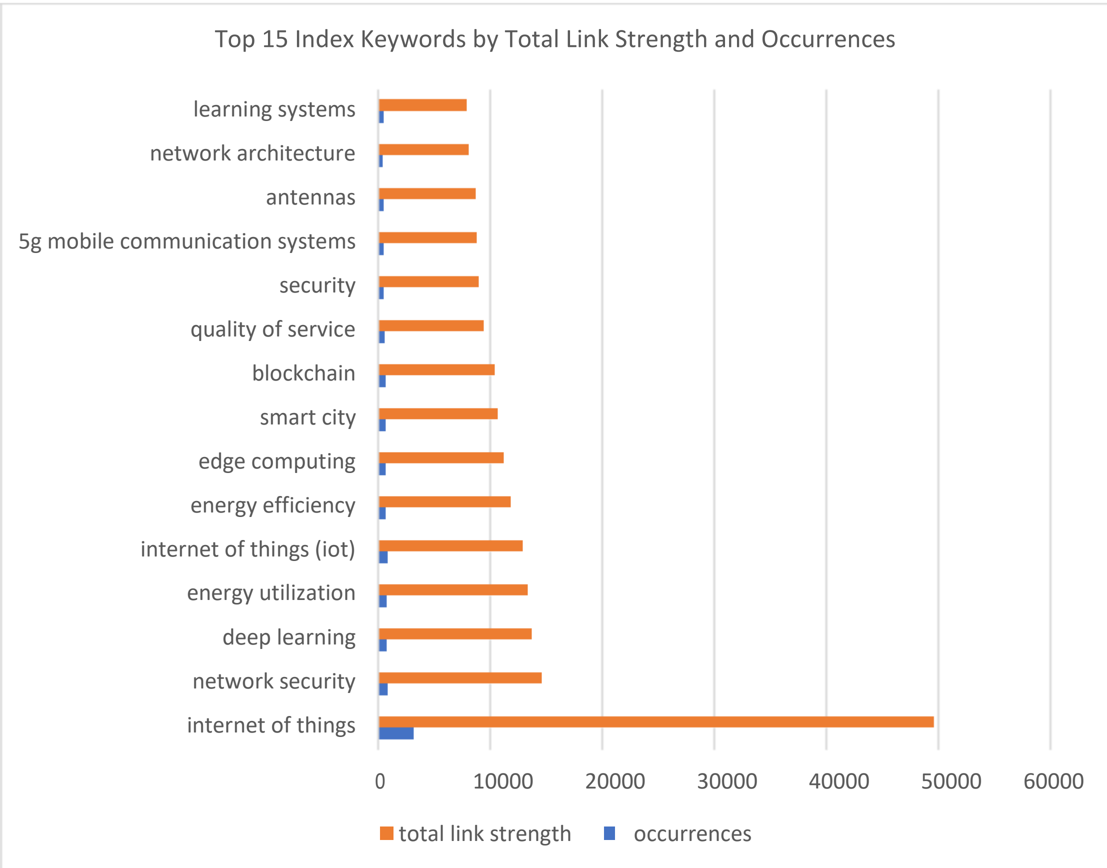


Figure 5.2.4.2.a - Top 15 Index Keywords by Total Link Strength and Occurrences

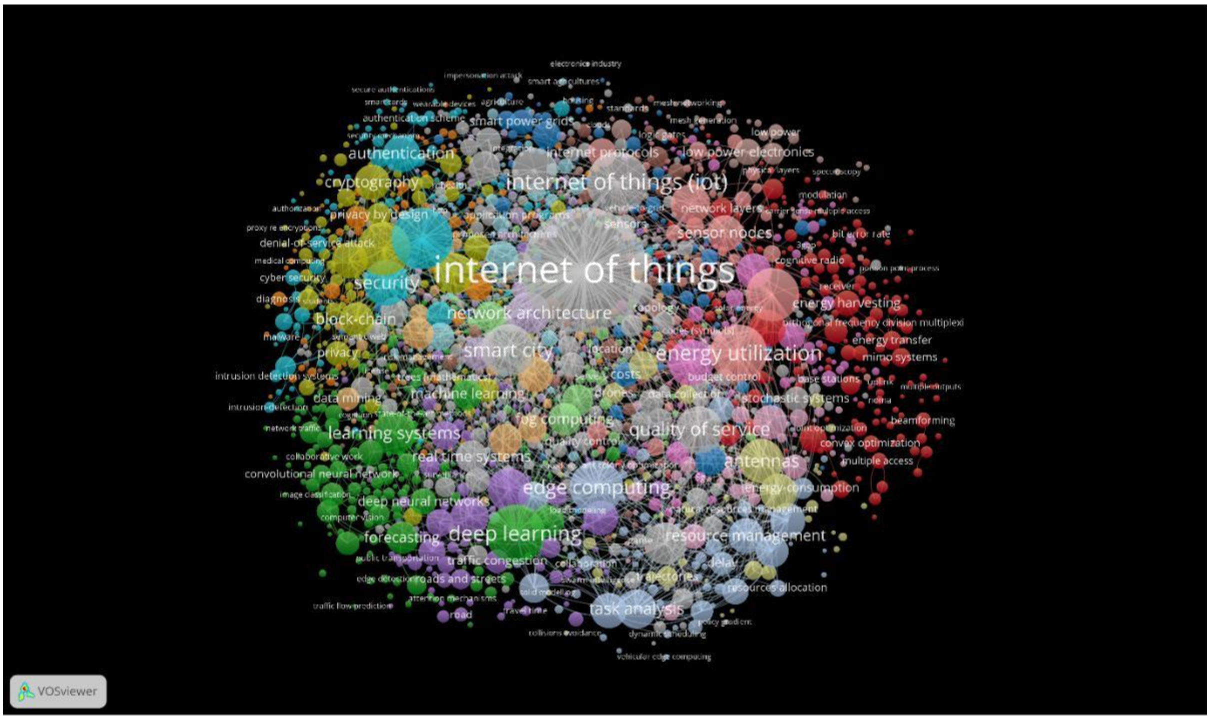


Figure 5.2.4.2.b - Network View of Index Keywords

The dataset provided, focusing on IoT and related technologies, reveals key trends through co-occurrence analysis. The term "Internet of Things" stands out with the highest occurrence (3180) and a total link strength of 49607, underlining its fundamental and expansive impact across various technological fields. "Network Security" emerges as a crucial aspect with 890 occurrences and a total link strength of 14665, reflecting the increasing emphasis on safeguarding data and systems in a digitally interconnected landscape.

"Deep Learning" appears prominently (819 occurrences, 13720 total link strength), signifying the integration of advanced AI methods in processing the large volumes of data from IoT devices. The frequent mentions of "energy utilization" (780 occurrences, 13361 total link strength) and "energy efficiency" (696 occurrences, 11866 total link strength) highlight the focus on sustainable and efficient energy practices in IoT systems, aligning with global sustainability goals.

The term "edge computing" (694 occurrences, 11253 total link strength) indicates a trend towards decentralized computing in IoT for quicker data processing and reduced latency. "Smart City" (676 occurrences, 10740 total link strength) suggests a significant application of IoT in enhancing urban environments through technology.

The presence of "blockchain" (695 occurrences, 10468 total link strength) points to its growing importance in IoT, especially for improving security and data integrity in decentralized networks. The emphasis on "quality of service" (559 occurrences, 9413 total link strength) highlights the need for maintaining performance and reliability in IoT systems.

The frequent mention of "5G mobile communication systems" (525 occurrences, 8782 total link strength) aligns with advancements in telecommunications essential for IoT's high-speed and low-latency connectivity needs. Keywords like "antennas" (500 occurrences, 8687 total link strength) and "network architecture" (468 occurrences, 8058 total link strength) focus on the technical components of IoT, emphasizing robust hardware and network design. "Learning systems" (472 occurrences, 7956 total link strength) underscore the role of adaptive and intelligent systems in augmenting IoT applications.

Overall, this co-occurrence analysis of IoT research highlights a wide spectrum from technical facets like network security and architecture to application-centric areas such as smart cities and energy management. It also illustrates the integration of advanced technologies like deep learning and blockchain, reflecting the dynamic and interdisciplinary nature of IoT research.

5.2.4.3. Influential Keywords

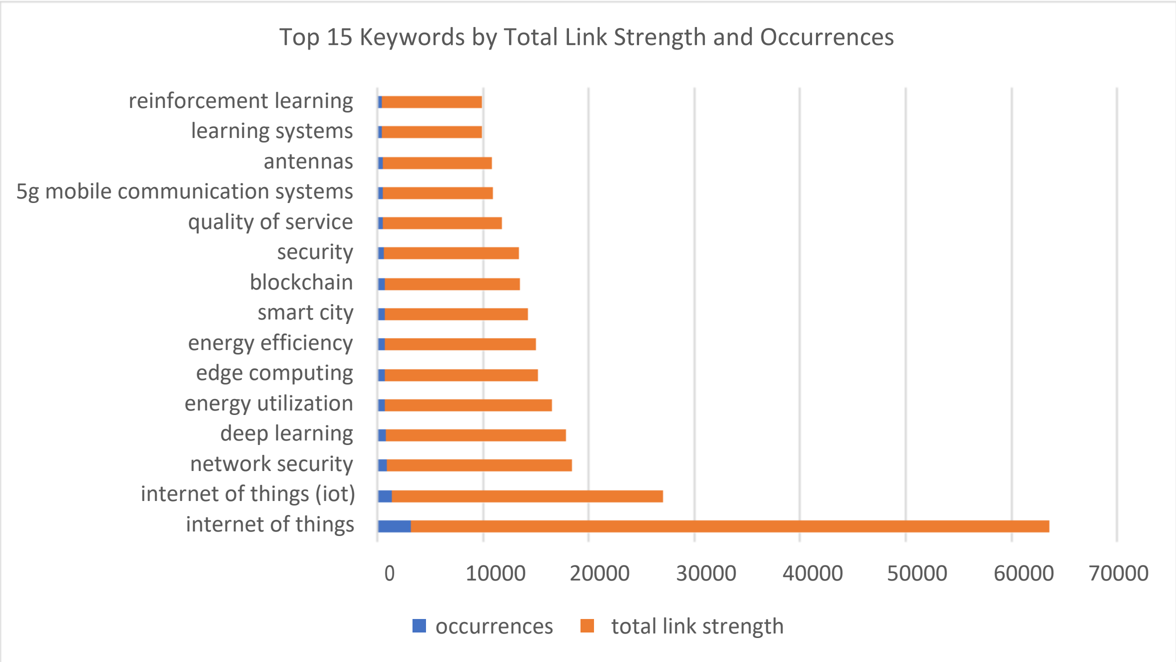


Figure 5.2.4.3.a - Top 15 Keywords by Total Link Strength and Occurrences

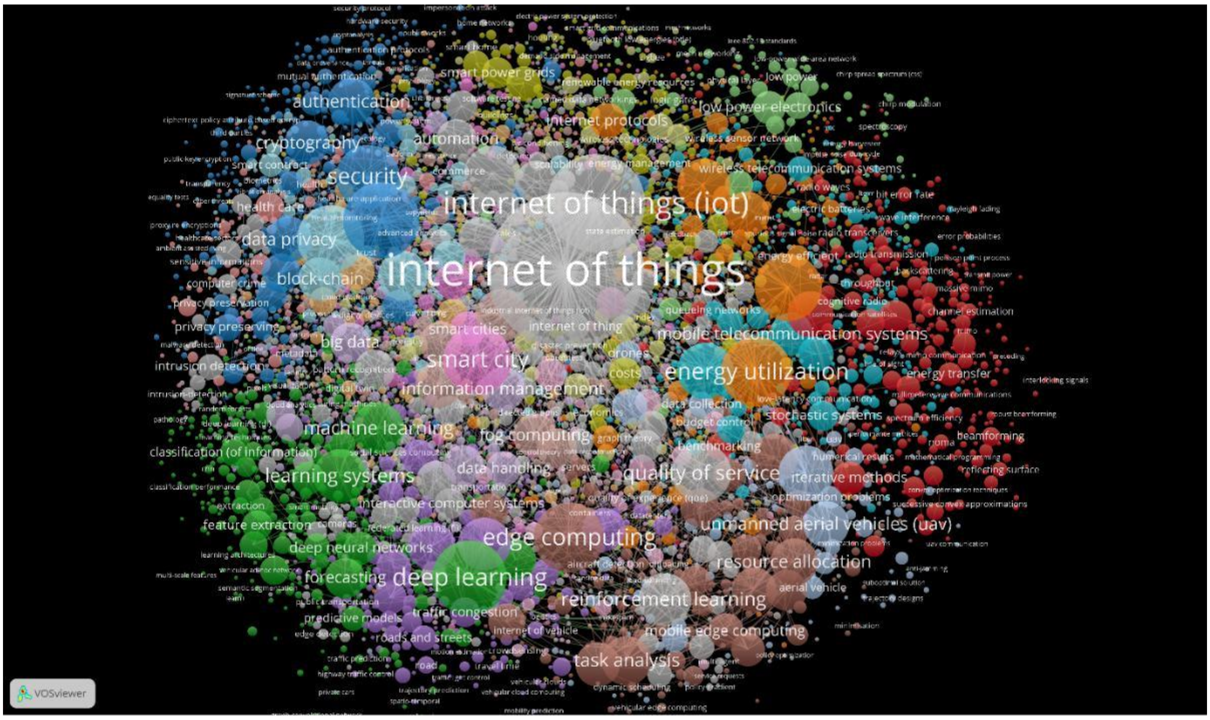


Figure 5.2.4.3.b - Network View of Keywords

The dataset on IoT research reveals a multifaceted and interconnected landscape, highlighting several key focus areas. Central to the field are the terms "Internet of Things" and "Internet of Things (IoT)", appearing 3241 and 1403 times, respectively, with substantial total link strengths (60401 and 25655), emphasizing the broad scope and interconnectivity of IoT research. Network security, mentioned 900 times and with a total link strength of 17524, underscores the critical importance of securing IoT networks and protecting data in connected environments. The frequent mention of deep learning (869 occurrences, 17021 total link strength) highlights the integration of sophisticated AI techniques for processing IoT-generated data.

Energy management, with "energy utilization" and "energy efficiency" occurring 780 and 711 times and having total link strengths of 15812 and 14356, points to a focus on sustainable and efficient energy practices in IoT systems. The term "edge computing" (772 occurrences, 14428 total link strength) suggests a trend towards decentralized computing for real-time data processing in IoT. "Smart City" (727 occurrences, 13575 total link strength) indicates a significant application area for IoT in enhancing urban infrastructure and living standards.

Blockchain's presence (720 occurrences, 12848 total link strength) highlights its role in securing and trusting decentralized IoT networks. The broader concern for "security"

(661 occurrences, 12793 total link strength) reflects the wide-ranging focus on protecting IoT systems. The emphasis on "quality of service" (567 occurrences, 11215 total link strength) and "5G mobile communication systems" (525 occurrences, 10474 total link strength) underscores the need for high-performance and reliable networks, enabled by advanced telecommunication technologies.

The emphasis on "antennas" (503 occurrences, 10398 total link strength) and "learning systems" (472 occurrences, 9472 total link strength) indicates the importance of robust technical infrastructure and adaptive capabilities in IoT. The inclusion of "reinforcement learning" (469 occurrences, 9411 total link strength) shows growing interest in applying this AI technique in IoT, potentially for decision-making and optimization processes. Overall, this analysis highlights the diverse and dynamic nature of IoT research, where advancements in AI, blockchain, and telecommunications intersect with applications in energy management, security, and urban development.

5.2.5. Co-Authorship

Co-authorship analysis is a pivotal technique in bibliometrics, providing insights into the collaborative nature of scientific research. It helps in understanding the patterns and dynamics of academic collaboration and can highlight the impact of teamwork on the progression and dissemination of knowledge within a field.

In bibliometrics, co-authorship analysis is primarily used to map and assess the collaborative structures and networks in scientific research (Glänzel & De Lange, 2011). The analysis can reveal various dimensions of collaboration, such as the geographical distribution of authors, institutional affiliations, and the intensity and frequency of collaborations between researchers, institutions, or countries.

The importance of co-authorship networks in scientific research has been highlighted in several studies. Milojević (2014) emphasized that the structure and evolution of research teams significantly impact the quality and impact of scientific output. This study demonstrated that larger, more diverse teams tend to produce more frequently cited research. Furthermore, Newman (2001) analyzed the network structure of co-authorships in the field of physics and found that the collaboration networks exhibit small-world properties, indicating a high degree of interconnectedness among researchers.

The evolution of collaboration networks over time is also a key area of interest. Wagner and Leydesdorff (2005) explored the dynamics of global research collaboration networks, noting that international collaborations are increasing over time and are linked to higher citation impacts. Hossain and Khan (2012) utilized social network analysis to study co-authorship patterns, revealing that collaborative networks often follow a power-law distribution, suggesting the existence of a small number of highly connected researchers within any given field.

Co-authorship analysis is not only limited to understanding the social structure of scientific collaboration but also aids in identifying emerging trends and domains in research. According to Katz and Martin (1997), co-authorship is a manifestation of the social nature of the scientific endeavour and a means to foster the diffusion of knowledge. This perspective is particularly relevant in interdisciplinary research, where collaboration across fields can lead to innovative breakthroughs.

In conclusion, co-authorship analysis serves as a powerful tool in bibliometrics for understanding the collaborative nature of scientific research. By analyzing patterns and trends in co-authorship networks, researchers can gain insights into the social structure, evolution, and impact of scientific collaboration.

5.2.5.1. Influential Authors

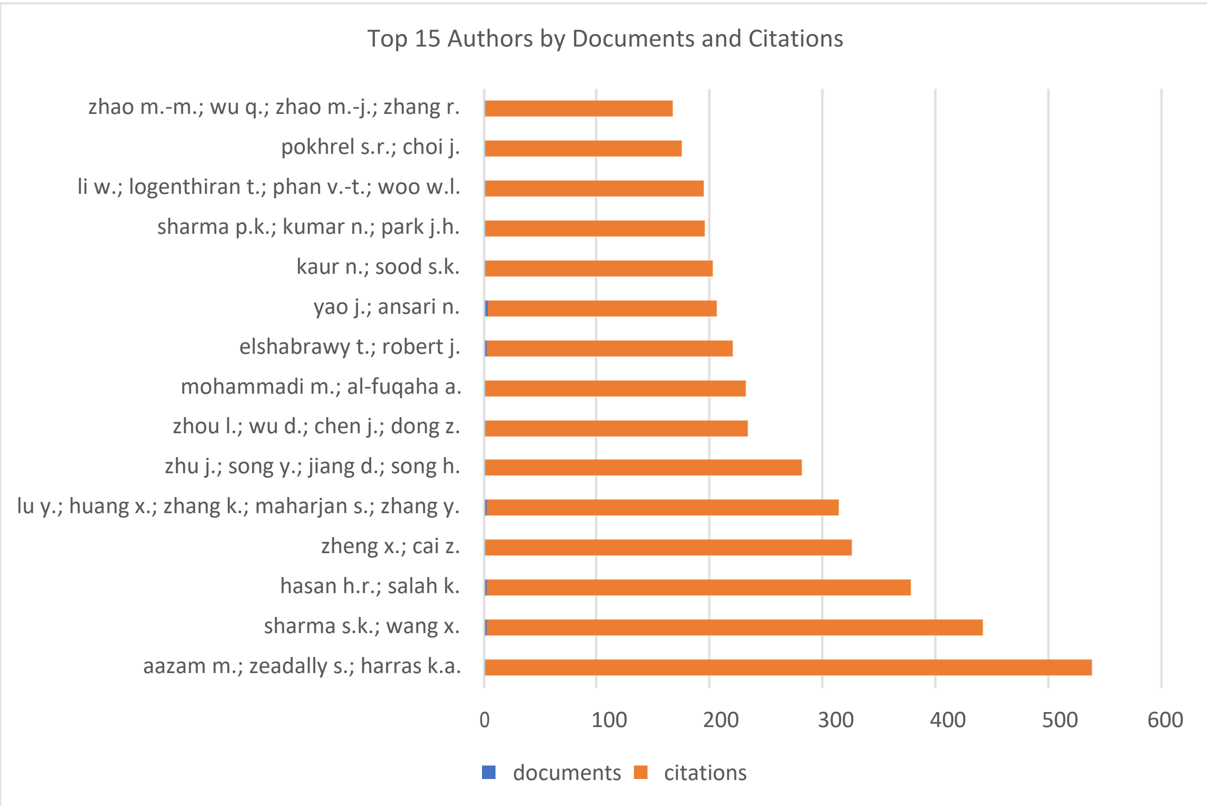


Figure 5.2.5.1 - Top 15 Authors by Documents and Citations

The field of IoT and smart cities research is marked by significant contributions from various collaborative groups, each bringing a distinct impact to the domain.

Aazam M., Zeadally S., and Harras K.A. have authored 2 documents that have collectively garnered 537 citations, indicating their work's significant influence per publication and its key role in shaping current methodologies in IoT for smart cities. Sharma S.K. and Wang X., with 3 documents and 439 collective citations, demonstrate consistent and impactful contributions, suggesting their strong reputation in their area of expertise.

Hasan H.R. and Salah K. have also made substantial contributions, with their 3 documents receiving 375 citations. This implies that their work introduces innovative concepts or technologies in IoT-based smart cities. Similarly, Zheng X. and Cai Z., with 324 citations from just 2 documents, have made influential contributions, reflecting the high importance and relevance of their work in the research community.

The group comprising Lu Y., Huang X., Zhang K., Maharjan S., and Zhang Y. has achieved 312 citations from 3 documents. This underscores the collaborative and interdisciplinary nature of IoT research. Another significant contribution comes from Zhu J., Song Y., Jiang D., and Song H., whose 2 documents have attracted 280 citations, indicating their research's significant impact and reception within the academic community.

The duo of Zhou L., Wu D., Chen J., and Dong Z. has garnered 232 citations from 2 documents, suggesting their substantial contributions to IoT. Mohammadi M. and Al-Fuqaha A. have also made notable advancements in IoT, as evidenced by their 230 citations from 2 documents, possibly focusing on foundational concepts or applications.

Elshabrawy T. and Robert J., with 3 documents cited 218 times, demonstrate an influential role in IoT research, contributing significantly to smart city technologies. Yao J. and Ansari N., through their 4 documents amassing 203 citations, indicate a broad and sustained impact in the field. Kaur N. and Sood S.K., with their 2 documents cited 201 times, show a notable impact, particularly in the context of smart cities.

The trio of Sharma P.K., Kumar N., and Park J.H. have also made influential contributions with 194 citations from 2 documents. Li W., Logenthiran T., Phan V.-T., and Woo W.L., with 193 citations from 2 documents, have made noteworthy contributions, indicating the high relevance and impact of their work. Pokhrel S.R. and Choi J., with 174 citations from 2 documents, and Zhao M.-M., Wu Q., Zhao M.-J., and Zhang R., with 166 citations from 2 documents, have significantly influenced IoT-based smart city research, likely introducing new insights or methodologies.

This analysis underlines the collaborative and interdisciplinary essence of IoT and smart cities research. The high citation counts per document across these groups signify that their contributions are not only prolific but also substantial in quality and relevance, continually shaping the evolving field.

5.2.5.2. Influential Countries

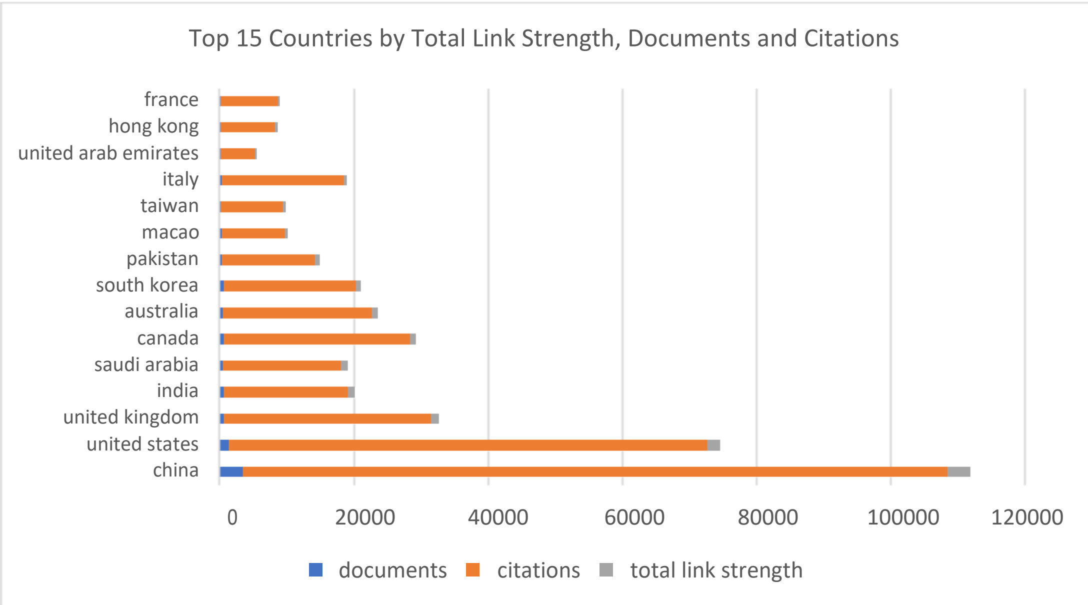


Figure 5.2.5.2.a - Top 15 Countries by Total Link Strength, Documents and Citations

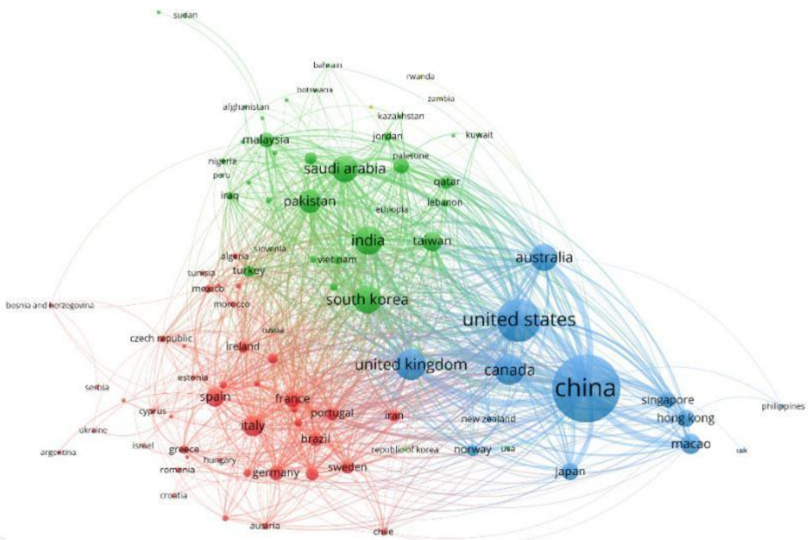


Figure 5.2.5.2.b - Network View of Countries

The global landscape of IoT research is marked by significant contributions from various countries, each showcasing unique strengths and collaborations.

China stands out as a leader in IoT research, with 3514 documents and 105001 citations, indicating a dominant presence in the field. The total link strength of 3337 highlights China's high level of collaboration and interconnectedness within its research network. The United States, with 1436 documents and 71236 citations, maintains a significant position in IoT research. Its total link strength of 2000 signifies substantial collaboration and influence.

In Europe, the United Kingdom demonstrates strong research capabilities in IoT, with 731 documents and 30781 citations, and a robust link strength of 1282, reflecting well-established academic and research networks. India's growing presence in IoT research is notable, with 633 documents and 18488 citations, and a total link strength of 1051, highlighting its increasing collaboration and impact.

Saudi Arabia, contributing 545 documents and 17521 citations, shows a significant presence in the field, with a link strength of 1036 indicating solid collaboration. Canada's impactful research is evidenced by its 696 documents and 27661 citations, and a link strength of 1013 underscores a well-connected research community. Australia, with 567 documents and 22113 citations, demonstrates strong influence and collaboration in IoT research, as indicated by a link strength of 883.

South Korea's robust presence in IoT is marked by 614 documents and 19692 citations, with a link strength of 865, signifying significant academic collaboration. Pakistan, contributing 420 documents and 13797 citations, reflects its growing research impact, and a link strength of 832 suggests an expanding network. Macao, though smaller in scale with 320 documents and 9410 citations, shows focused and impactful research efforts, evidenced by a link strength of 510.

Taiwan, with 294 documents and 9231 citations, demonstrates its significant role in IoT research, and a link strength of 458 suggests active collaboration among researchers. Italy’s contribution of 337 documents, earning 18282 citations, and a link strength of 394, indicates solid contributions and strong research linkages. The United Arab Emirates is making notable strides with 187 documents and 5082 citations, and a link strength of 362, indicating growing influence and collaboration. Hong Kong's 228 documents and 8080 citations, along with a link strength of 353, show its emerging strength in IoT research.

France, with 199 documents and 8545 citations, and a link strength of 332, indicates a focus on quality research and a well-connected community.

This analysis underscores the diverse and global nature of IoT research, highlighting the contributions and collaborations across countries. The total link strength in each case not only signifies the volume of research but also the depth of interconnections within the global research network, crucial for the advancement of IoT technologies.

5.2.5.3. Influential Organisations

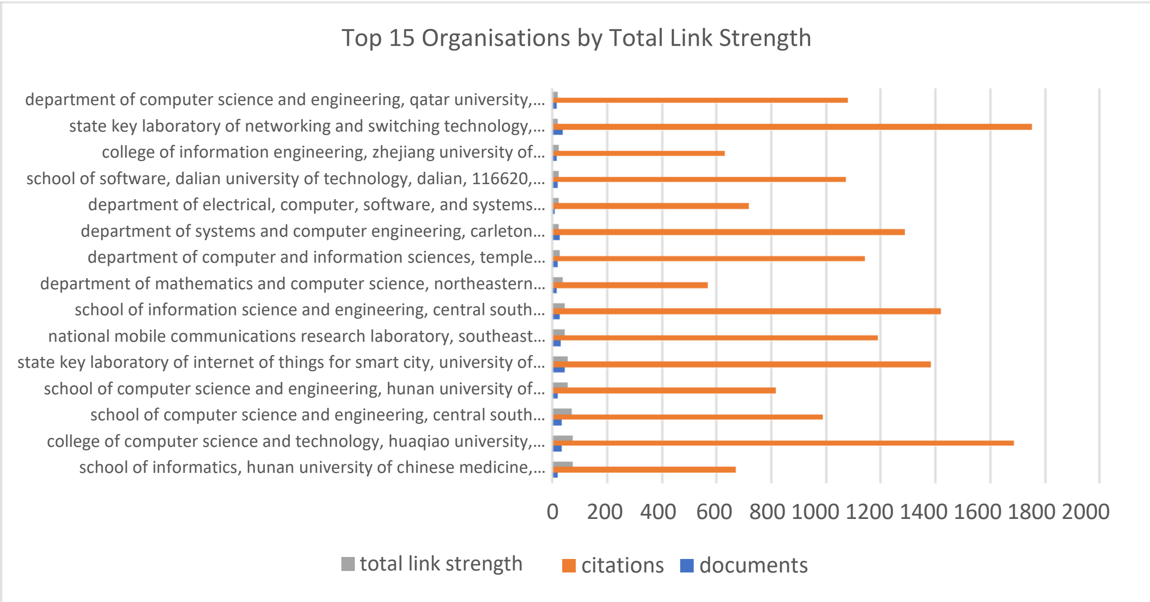


Figure 5.2.5.3.a - Top 15 Organisations by Total Link Strength

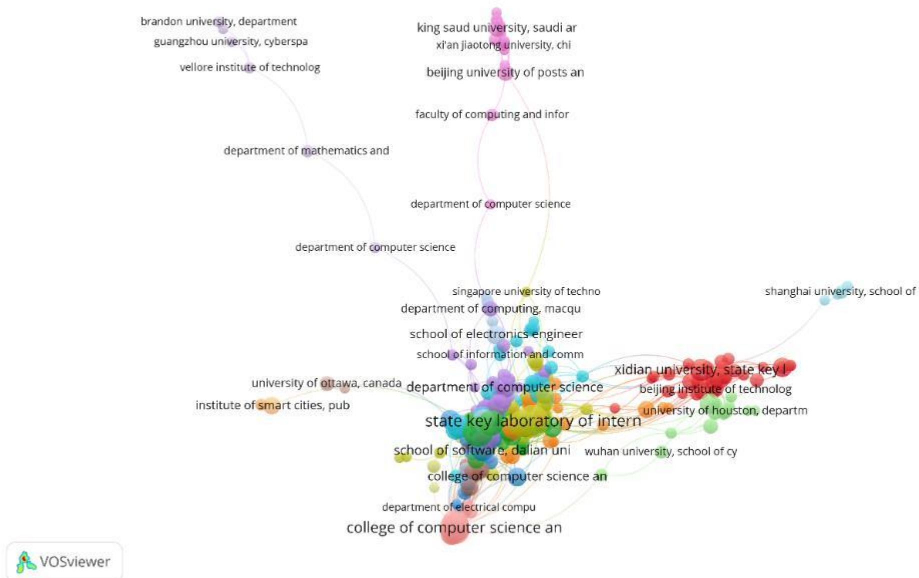


Figure 5.2.5.3.b - Network View of Organisations

The landscape of IoT research is marked by significant contributions from various academic institutions worldwide, each showcasing unique strengths and collaborations.

In China, the School of Informatics at Hunan University of Chinese Medicine in Changsha stands out with 23 documents and 673 citations, reflecting a focused approach to IoT research and active collaboration, as indicated by a total link strength of 77. The College of Computer Science and Technology at Huaqiao University in Xiamen contributes 37 documents and 1689 citations, demonstrating a significant impact in the field, supported by a link strength of 75. Central South University's School of Computer Science and Engineering in Changsha, with 35 documents and 991 citations, shows a strong presence in IoT research, backed by a link strength of 72. Similarly, the School of Computer Science and Engineering at Hunan University of Science and Technology in Xiangtan, with 23 documents and 818 citations, exhibits noteworthy research, underscored by a link strength of 60.

The State Key Laboratory of Internet of Things for Smart City at the University of Macau, Macao, is a key player with 48 documents and 1385 citations, revealing a link strength of 58. Southeast University's National Mobile Communications Research Laboratory in Nanjing contributes 32 documents with 1192 citations, showing substantial research impact and a link strength of 49. The School of Information Science and Engineering at Central South University in Changsha, with 29 documents and 1423 citations, indicates a strong research focus, supported by a link strength of 46.

In the United States, the Department of Mathematics and Computer Science at North-eastern State University in Tahlequah presents 18 documents with 569 citations, reflecting focused research and a link strength of 39. Temple University's Department of Computer and Information Sciences in Philadelphia contributes 21 documents with 1142 citations, highlighting a significant presence in IoT research and a link strength of 27. Carleton University's Department of Systems and Computer Engineering in Ottawa, Canada, with 29 documents and 1289 citations, demonstrates robust research output, underlined by a link strength of 26.

The Department of Electrical, Computer, Software, and Systems Engineering at Embry-Riddle Aeronautical University in Daytona Beach, United States, with 10 documents and 720 citations, shows a strong focus on IoT research, supported by a link strength of 25. The School of Software at Dalian University of Technology in Dalian, China, with 21 documents and 1075 citations, exhibits strength in IoT research, evidenced by a link strength of 24. The College of Information Engineering at Zhejiang University of Technology in Hangzhou, China, contributes 18 documents and 633 citations, indicating growing influence in IoT, with a link strength of 24.

Beijing's State Key Laboratory of Networking and Switching Technology at the University of Posts and Telecommunications, with 41 documents and 1752 citations, signifies substantial research impact, backed by a link strength of 22. Qatar University's Department of Computer Science and Engineering in Doha, with 18 documents and 1080 citations, shows an active role in IoT research, reflected by a link strength of 21.

These institutions represent a diverse global distribution in IoT research, highlighting their substantial contributions and collaborations within the academic community. The total link strength in each case not only indicates the volume of research but also the depth of interconnections within the research network, essential for the advancement of IoT technologies.

5.3. Emerging Trends and Underexplored Themes in IoT based Smart City Research

Based on the analysis of publication titles in the dataset related to IoT and Smart Cities, several specific topics and emerging areas have been identified. The frequency of certain keywords provides insights into less explored or emerging themes in this field.

5.3.1. Specific Topics with Fewer Publications:

"Forum," "Contingencies," "Scavenger," "Prognostics," and "Micro location". These keywords appear infrequently in the literature, indicating they are less explored within IoT and Smart Cities. Their sporadic appearance over the years suggests a potential niche for future research. For instance, "Prognostics" and "Micro location" might have seen occasional mentions post-2015, reflecting a slow yet steady interest.

5.3.2. Emerging but Less Explored Areas:

"Cloud sensor," "Internet of things equipped," "Vote based," and "Incentive driven". These terms hint at emerging areas that haven't been widely covered yet. They are likely to represent new technologies or approaches in IoT and Smart Cities. For example, "Cloud sensor" and "Incentive driven" may have gained some traction in recent years (post-2018), signalling the evolving nature of IoT applications.

5.3.3. Broad Themes with Limited Coverage:

"Carbon aware" Initiatives, "Creating" and "Introducing" New Technologies. This category suggests a gap in the development and introduction of new technologies and sustainable practices within IoT and Smart Cities. The sporadic use of these terms, particularly "Carbon aware," might point towards an emerging focus on sustainability post-2020.

5.3.4. Potential for Interdisciplinary Research:

"Bettering Lives," "Cybermatics". These keywords suggest an intersection with other fields, hinting at potential areas for interdisciplinary research. The occurrence of "Cybermatics" may have seen an uptick around 2017-2019, coinciding with the rise in digital transformation trends.

5.3.5. Analysis and Future Trends:

This keyword analysis underscores several underrepresented areas in IoT and Smart Cities research, offering a roadmap for future investigation. The temporal emergence of these themes suggests a gradual shift in research focus, aligning with technological advancements and societal needs. The evolution of these keywords over time also highlights the dynamic nature of research interests, with newer concepts like "Incentive driven" technologies and "Carbon aware" initiatives gaining ground more recently.

Integration of AI and IoT for Predictive Analytics. The convergence of IoT AI and machine learning will likely continue to grow. Research might focus on developing predictive analytics for urban planning, traffic management, and energy consumption, leveraging the vast amount of data generated by IoT devices. 5G and Beyond Wireless Technologies. As 5G networks become more widespread, research into how these high-speed, low-latency networks can support and enhance IoT applications in smart cities is expected to increase. Future networks, potentially 6G and beyond, will also be a key focus, offering even greater capacities and enabling more complex, real-time IoT applications.

Sustainable and Green IoT Solutions. With growing concerns about climate change and sustainability, there will be a heightened focus on developing energy-efficient IoT solutions. This includes research into low-power sensors, green communication technologies, and IoT applications for monitoring and reducing environmental footprints. Enhanced Security and Privacy Measures as IoT devices become more pervasive, security and privacy concerns will become more critical. Research will likely focus on developing robust security protocols and privacy-preserving techniques, particularly in the context of smart city applications where sensitive data is often involved. The role of edge computing in processing IoT data closer to the source will become more prominent. This reduces latency and bandwidth use, making IoT applications more efficient. Research may focus on optimizing edge computing architectures and algorithms for IoT data processing.

Smart Infrastructure and Urban Mobility. IoT applications in smart infrastructure monitoring (like bridges, buildings, and roads) and urban mobility solutions (such as smart traffic control, autonomous vehicles, and public transit optimization) will continue to be significant research areas. Digital Twins for Urban Planning. The concept of digital twins - virtual replicas of physical entities - will likely see increased application in urban planning and management. This involves creating digital models of city infrastructures and systems to simulate and analyze real-world scenarios. Human-Centric IoT Applications. There will be a shift towards more human-centric IoT applications, focusing on enhancing the quality of life, health, and well-being of urban residents. This includes smart healthcare systems, enhanced accessibility features, and personalized urban experiences.

Interoperability and Standardization. As smart city solutions become more complex, the need for standardization and interoperability among different IoT systems and devices will become more critical. Research might focus on developing universal standards and protocols to ensure seamless integration of diverse IoT systems. Public Participation and IoT. Engaging citizens in the IoT ecosystem, either through participatory sensing or through public feedback mechanisms, will become more prevalent. This can lead to more inclusive and responsive smart city initiatives. These trends indicate a move towards more integrated, sustainable, secure, and human-focused smart city solutions, leveraging advanced technologies and fostering greater collaboration and standardization.

In conclusion, this analysis not only identifies the current gaps in IoT and Smart City research but also projects potential growth areas. As technology evolves and societal challenges become more complex, these emerging and underrepresented themes are likely to gain more attention, shaping the future landscape of IoT and Smart City research.

5.4. Conclusion

This chapter represented the heart of our analytical endeavours in this study. In this chapter, we engaged in a comprehensive examination of the data collected, employing quantitative techniques to mine and analyze trends over time. We explored various research themes, delved into emerging topics, and conducted an extensive keyword analysis. This chapter not only presented the data and findings but also interpreted them within the context of our research objectives, offering interdisciplinary insights. The findings from this chapter have significantly contributed to our understanding of IoT and Smart Cities, shedding light on the complexities and nuances of these fields.

As we move forward, Chapter Six will build upon the findings of our analysis to discuss their implications and applications. This chapter aims to synthesize the insights gained from the data analysis and explore their practical and theoretical relevance. We will discuss how these findings can inform future research directions, policy-making, and practical implementations in the realm of IoT and Smart Cities. The chapter will also address the limitations of the current study and suggest areas for further investigation. By doing so, Chapter Six seeks to bridge the gap between academic research and real-world applications, offering a roadmap for future advancements in the field.

Chapter Six: Summary and Recommendations

6.1. Introduction

In conclusion, the study has proven that bibliometric analysis is a rigorous scientific approach that holds value for both established and rising academics seeking to conduct a comprehensive examination of expansive and diverse domains within the field of business research. The study also demonstrated that the bibliometric methodology has experienced significant growth in popularity in recent years, primarily due to the widespread availability and utility of bibliometric software and databases. These tools facilitate the collection and evaluation of extensive scientific data in the field of business research, including emerging and highly informative domains such as artificial intelligence and big data (Makarius, Mukherjee, Fox, & Fox, 2020; Mustak, Salminen, Ple, & Wirtz, 2021).

The paper primarily focuses on conducting a comprehensive bibliometric analysis for IOT-based smart cities. It aims to provide a collegial and pragmatic approach by presenting the key components of this analysis. These components include introducing the bibliometric methodology, explaining the different techniques involved, unpacking the enhancements made to bibliometric analysis, and providing the relevant procedures. This study emphasizes the need to carefully select approaches and make informed judgements at each stage of doing bibliometric analysis. These choices significantly impact the outcomes achieved and the conclusions that can be derived from the analysis. However, it is crucial to acknowledge that while bibliometric analysis is a valuable approach for summarizing and synthesizing literature, it is not exempt from certain constraints.

The bibliometric data obtained from scientific databases like Scopus may contain inaccuracies that can potentially impact the accuracy of any subsequent analysis conducted utilizing this data. In order to address inaccuracies, researchers must diligently cleanse the bibliometric data they obtain, a process that involves eliminating duplicate and erroneous entries. Furthermore, it is important to acknowledge that the bibliometric methodology possesses inherent limitations. The subjective nature of bibliometric qualitative claims is noteworthy, as bibliometric analysis primarily focuses on quantitative measures. Consequently, the relationship between quantitative and qualitative outcomes in bibliometrics is frequently ambiguous (Wallin, 2005). Scholars should use caution when making qualitative judgments on bibliometric observations and, when needed, enhance them with content analysis (Kumar, 2019). Furthermore, it should be noted that bibliometric studies have limitations in providing long-term forecasts of the research field (Wallin, 2005).

Therefore, it is advisable for researchers to exercise caution and refrain from making excessively ambitious claims regarding the research field and its long-term influence. Despite the aforementioned constraints, the utilization of the bibliometric approach has the potential to enable scholars to overcome apprehensions associated with handling extensive bibliometric datasets and embark on ambitious retrospectives of IoT-based smart cities. Undoubtedly, the utilization of bibliometric analysis in science can effectively contribute to the advancement of knowledge not only in the realm of IoT-based smart cities but also in several other disciplines. We are making a brief yet meaningful advancement in that particular path.

6.2. Exploring the Evolution and Future of IoT-Based Smart Cities: A Decade of Technological Progress and Emerging Research Themes (2013-2023)

The last decade has witnessed a remarkable transformation in urban landscapes, primarily driven by the integration of the IoT in city infrastructures, leading to the advent of 'smart cities'. This comprehensive analysis, spanning from 2013 to 2023, delves into the evolving landscape of IoT in smart cities, examining key developments, emerging research themes, and future directions in this burgeoning field.

6.3. The Emergence and Growth of IoT in Smart Cities (2013-2023)

The journey of IoT in smart cities began with foundational research that set the stage for subsequent advancements. As outlined by Kitchin (2014), initial studies focused on establishing the basic frameworks for IoT integration, emphasizing network security, efficient resource management, and data analytics. This period saw significant contributions from researchers like Al-Fuqaha et al. (2015), who explored IoT protocols and technologies. By the mid-2010s, the research domain expanded, embracing advanced applications of IoT in urban environments. Key areas of interest included deep learning for data analysis (Al-Fuqaha et al., 2015), blockchain for enhanced security and privacy (Christidis and Devetsikiotis, 2016), and the incorporation of 5G technologies for improved connectivity and data transmission (Zhang et al., 2020).

6.4. Key Research Areas and Shift in Focus

The research during this period reflects a shift towards more nuanced and specialized areas within the IoT and smart city domain. The focus on energy efficiency (Gubbi et al., 2013), quality of service (QoS), and network architecture (Al-Fuqaha et al., 2015) signify an evolving understanding of the complexity and requirements of IoT systems in urban environments.

6.5. Emerging Research Themes and Keywords

The latter part of the decade saw the emergence of new keywords and research themes, illustrating the dynamic nature of the field. While "Internet of Things" and "Smart City" remained dominant keywords, new terms like blockchain, edge computing, and deep learning began gaining prominence, reflecting the field's response to technological advancements and urban challenges.

6.6. Underexplored Areas and Future Research Opportunities

Despite extensive research, specific areas within the IoT and smart city domain remain underexplored. Emerging but less explored areas, such as "cloud sensor" and "internet of things equipped," indicate niche fields that have not yet been fully developed. Themes like "carbon aware" initiatives and the development of new technologies or frameworks also suggest potential gaps in the existing literature. These areas offer promising avenues for future research, particularly in the context of sustainable urban development and the standardization of IoT technologies.

6.7. Evolving Citation Patterns and Research Publications

An analysis of citation patterns reveals the growing influence and diversification of IoT and smart city literature. Earlier foundational works have given way to more specialized, application-oriented research, indicating a maturing of the field. This trend is further evidenced by the increasing volume of publications over the decade, highlighting the expanding global interest and research community in smart cities.

6.8. Interdisciplinary Research and Future Directions

The future of IoT-based smart cities lies in effectively harnessing interdisciplinary research. Combining technology with urban planning, environmental science, and policy-making is crucial to addressing the complex challenges of modern urban environments. This approach can lead to more sustainable, equitable, and human-centric urban development.

6.9. Limitations of the Study

The study on IoT and Smart Cities, while insightful, has limitations. The reliance on bibliometric analysis may not fully capture practical implementations and could miss non-academic literature. Technological advancements post-data collection might outpace the study's findings. The focus on specific keywords might exclude relevant studies, introducing potential bias. The analysis, mainly quantitative, might not provide in-depth qualitative insights. Also, data availability issues could lead to a regional bias in the research. These limitations highlight areas for future research to gain a more comprehensive understanding of IoT and Smart Cities.

6.10. Conclusion

The past decade has laid a robust foundation for IoT-based smart cities, marked by technological advancements, broadened research themes, and an increasing emphasis on sustainable and human-centric development. Looking ahead, the field is poised for further growth, with opportunities for interdisciplinary research, sustainable urban development, and the exploration of emerging technologies. As we step into the future, IoT-based smart cities will continue to evolve, reflecting the changing needs and aspirations of urban societies.

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