Bibliometric Analysis: The Use of Blockchain Technology in Smart City Mapping Concept

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Abstract. Research on the adoption of blockchain technology in supporting the application of the smart city idea is extensively carried out to keep up with the development and difficulty of more intricate city management. This study aims to review research trends in the use of blockchain technology in the concept of Smart City mapping through research published on the Scopus database in 2016 - 2022. Three hundred forty-two (342) documents taken from Scopus with the keywords "smart city" and "blockchain technology" for 2016 to 2022 were analyzed using a bibliometric approach. Articles were analyzed based on the number of publications per year, country, author, affiliation, source, and funding. CiteSpace analyzed connectivity trends between keywords, authors, and countries. The results showed that Sustainable Smart Cities, Energy Trading, and On-demand Protocol dominated ten (10) clusters. Broadly speaking, it also discusses sustainable smart cities and energy trading using blockchain technology. The most dominant authors in this study trend are Jabalbarezisarbijan. Meanwhile, analysis of the Scopus database revealed three dominating countries, namely India (72), China (63), and the United States (47). At the same time, the institution, according to the most dominating institutional publication trend, is Brandon University. Then, blockchain technology substantially impacts the advancement of infrastructure within the domains of smart cities, intelligent transportation systems, electric vehicles, and renewable energy. This current study proposed the trajectory of advancement for the use of blockchain technology in smart city governance, thereby illuminating the future of the smart city concept.

Keyword: bibliometrics; blockchain technology; smart city; smart sustuinable

1 Introduction

In the contemporary digital era, there is an ongoing advancement of technology, particularly in the domain of urban governance. Some cities have undergone a paradigm shift in modern city governance [1]. The smart city paradigm elevates the overall benchmark of living in metropolitan regions through the utilization of technical breakthroughs [2], along with enhancements in *Information and Communication Technology* (ICT) [3]. In its role, smart cities offer many further infrastructure advancements, such as smart transportation, energy

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grids, and government electronic services, such as healthcare, licensing, and approvals [4]. Although smart cities have advanced infrastructure, however, there is still a space for development and issues in the ecosystem, such as data security, privacy, and effective information sharing [5], [6]. As technology progresses, the volume and intricacy of data collected tend to increase, leading to a greater sense of complexity and overload. However, today's database technology must be able to manage and store more data securely and effectively. Therefore, a more robust security system is needed to carry the smart city concept more maturely. There is a new technology that is starting to be applied around the world to overcome these problems, namely blockchain technology.

Furthermore, blockchain technology is an example of a decentralized digital ledger that effectively safeguards transactional data from unauthorized access or tampering [7]. Blockchain technology has emerged as a contemporary approach to address intricate challenges inside the smart city framework. According to [8], the user's text defines *blockchain* as a collection of tools, technologies, and processes that can be utilized to tackle particular obstacles and for commercial purposes. However, [9] argued that blockchain technology is closely linked to the sharing economy and has the potential to significantly alter the development of smart cities. It is characterized by immutability, public consensus, and security mechanisms that distribute control among all citizens and government entities. Blockchain is regarded as an innovative development motor and an advantage in the concepts of smart cities due to its ability to increase efficiency, secure critical data flows, and enhance platform interoperability [4].

The last few studies on smart city infrastructure are expected to become a new ecosystem to improve customer service, and all innovative applications can be drastically improved with blockchain technology [10]. According to [11], cutting-edge blockchain technology needs further investigated in the context of smart city planning. Therefore, [12] explained that Blockchain technology is an emerging catalyst for technological revolution, including many foundational technologies and protocols, with the potential to influence smart city development significantly. Smart cities require essential property qualities that are provided by blockchain technology, like transparency, decentralization, consensus, immutability, and resilience [13]. Blockchain technology has a wide range of applications that can potentially address various issues in areas such as public and social services, risk management and financial services, cryptocurrencies, and the Internet of Things (IoT). In addition, blockchain technology significantly transforms the architectural framework of smart city networks, thereby establishing a sustainable ecosystem [1]. Hence, the integration of blockchain technology is essential for providing the sustainable advancement of smart city administration and enabling the formulation of rules that enhance quality assurance. A comprehensive, in-depth study and careful preparation are needed so that this innovation strategy can be optimally carried out. Therefore, this study examines the research patterns concerning the use of blockchain technology in the context of Smart City mapping. The analysis will focus on scholarly publications over the past seven years, as retrieved from the Scopus database.

2 Literature Review

Utilizing blockchain technology has exerted a substantial influence on the advancement of smart cities globally. This literature analysis examines blockchain technology's applications across several domains. According to [14], Blockchain technology provides an opportunity to create new decentralized and scalable solutions for developing smart cities by enabling paperless transactions. Implementing deployment strategies that integrate blockchain technology with integrated *information and communication technology* (ICT) in

Smart City is of utmost importance to attain optimal data integrity, scalability, and secrecy within and among smart cities [15]. However, the current infrastructure of trust in smart cities needs to be improved. Therefore, the utilisation of blockchain technology in trust infrastructures and smart city systems is suggested in [16], which employs smart transportation subsystems as objects, blockchain operational principles, and algorithms. Moreover, [17] mentioned that blockchain enables safer connections between many devices on the smart city network and promotes long-term growth through smart transportation, smart assets, smart utilities, and smart operations. Meanwhile, research by [18] revealed that the adoption of blockchain technology in smart cities influences the impact of the IoT on the mitigated citizen-user interactions (CUI) by specific factors such as trust, empowerment, and social impact. Thus, the significance of these factors increases as the implementation of IoT technologies continues within the framework of smart cities.

Implementing a blockchain-based peer-to-peer secure energy trading system holds significant importance in fostering sustainability within urban areas and communities, simulated by [19]; a study was undertaken to assess the suggested method and substantiate the claim that prosumers attain more happiness and utility. According to [20], integrating blockchain technology and the IoT can facilitate a broader range of commercial applications, enhancing integration and efficiency in corporate transactions. In addition, according to [21], blockchain technology can improve election infrastructure by providing its user's integrity, privacy, and security. In line with SpeedyChain's innovation [22], intelligent vehicles can securely exchange their data in a decentralized and interference-resistant fashion by utilizing blockchain technology, all while ensuring confidentiality, integrity, robustness, and non-rejection. It is, therefore, the implementation of a blockchain-driven peer-to-peer energy trading system holds significant importance in fostering sustainability within urban areas and communities.

Blockchain technology possesses the potential to facilitate the integration of smart cities, namely in the domains of Smart Environments and Smart Mobility. This is accomplished by enabling the verification of clean energy sources and providing information on the specific types of energy used for refueling [23]. This study showcases the successful deployment of a decentralized authentication mechanism for the Internet of Underwater Things (IoUT) utilizing Blockchain technology. The proposed mechanism exhibits qualities of resilience, transparency, and energy efficiency. Notably, it substantially reduces 74.63% in device energy consumption compared to conventional authentication methods. Additionally, it also yields significant improvements, such as a 41.9% reduction in end-to-end delays and a 21.6% increase in delivery rates. According to [24], integrating blockchain technology offers a viable solution for implementing Smart Energy Grids, enabling the seamless exchange of information and facilitating the buying and selling of energy among the various entities involved, including energy providers and citizens.

Furthermore, Blockchain technology makes malware undetectable. This technique is adopted by malicious software to circumvent the functionality applied for virus detection and presents the application of new virus techniques [25]. According to [26], a new blockchain-based Mobile Crowdsensing (MCS) framework can maintain privacy, secure sensing processes, and incentive mechanisms. According to [27], a new Blockchain-based auction mechanism has been proposed as a potential solution to the Mobile Crowd Sensing (MCS) issue: it enables the scheduling of charging services for uncrewed aerial vehicles (UAVs) while simultaneously enhancing the security of charging transactions. Additionally, according to [28], Blockchain technology can integrate a new set of components to enable FIWARE. The previous point supported by [29] stated that using Blockchain through distributed management of policies and authorizations can improve system security and integrate it into the FIWARE platform. The review indicates that there is limited discussion on the use of blockchain technology to enhance the smart city concept in existing research.

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Therefore, this current research represents a novel contribution to the existing research literature.

3 Research Method

Research using blockchain in smart cities has been carried out through various approaches. However, the bibliometric analysis approach still needs to be improved and expanded since the novelty of various studies conducted by researchers worldwide makes the presented data into more varied and complex. Therefore, this research used bibliometric analysis, a method used in analyzing trends or developments in specific fields. According to Boardus on [30], bibliometric analysis is a quantitative or statistical technique used to identify systematic patterns in diverse types of literature on a particular topic. This follows the opinion grounded by [31] who said bibliometrics encompasses a range of methodologies employed to evaluate the scholarly impact of research publications, which can be applied across several levels of analysis, ranging from individual authors, themes, and journals to broader subject areas, countries, and the global scale. Furthermore, Scopus comprehensively analyzes the outcomes derived from worldwide field investigations, particularly within social sciences. [32]. Data sources from this study were articles and conference articles taken from the Scopus database. Scopus was selected based on a deliberate evaluation of its reputation and quality, which has been internationally recognized by various research institutes and universities [33]. Furthermore, the researchers used CiteSpace software to process and visualize connectivity taken from Scopus. CiteSpace can produce visual maps that show patterns and relationships between topics in the scientific literature [34]. This visual map allows the users obtain a clearer picture of the structure and trends within a particular research field [35].

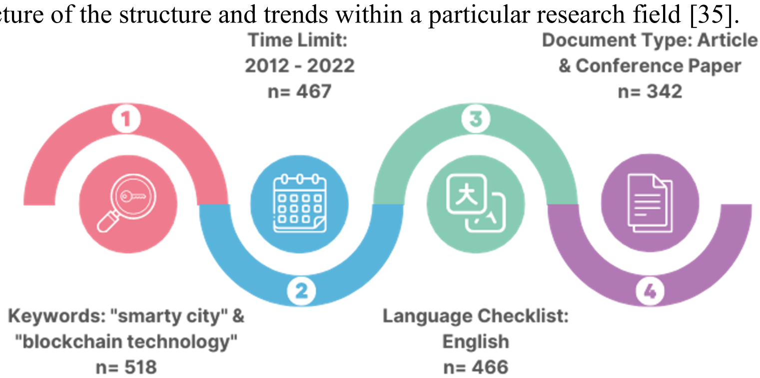

Fig. 1. Data Mining Step

There were four stages of the data mining process through Scopus. In the first stage, the researchers categorized searches using the keywords "smart city" and "blockchain technology" identified by category title, abstract, or keyword, resulting in 518 documents. In the second stage, the researchers limited the time by modifying the database search to seven (7) years from 2016 to 2022; This time range was chosen to obtain the latest references related to the issue of conflict resolution strategies. At this stage, the investigation resulted in 467 documents. Then in the third stage, to mitigate language bias in the data processing process, the researchers restricted document categorization solely to English language texts, resulting in 466 documents. In the last stage, the researchers determined the focus of the type of documents to be analyzed, namely the types of Articles and Conference Articles, which produce 342 documents. If based on an advanced query, returns the following data: (TITLE-ABS-KEY ("smart city") AND TITLE-ABS-KEY ("blockchain technology")) AND PUBYEAR > 2011 AND PUBYEAR < 2023 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar"))

4 Results and Discussion

4.1 Publications by Year

From 2016 to 2022, this topic's studies have experienced rapid development. Based on article search results using the Scopus database, the researchers found 342 articles that were relevant to the keywords and search strategies used. Further, 2016 was the first year of research on the use of blockchain technology in the concept of Smart City mapping, where this year, there is only one (1) research publication. The number of publications increased to six (6) in the following year. In 2018, there was a relatively rapid increase. Approximately, there were 30 publications. While in 2019, there were 66 publications which made this year the year with the highest increase from the previous year. However, in the following year, there was stagnation where there was no increase or decrease, which was as many as 66 publications. Then in 2021, it re-increased to 88 publications, making this year the year with the most publications. However, in 2022, there was a downward trend for the first time, with 85 publications.

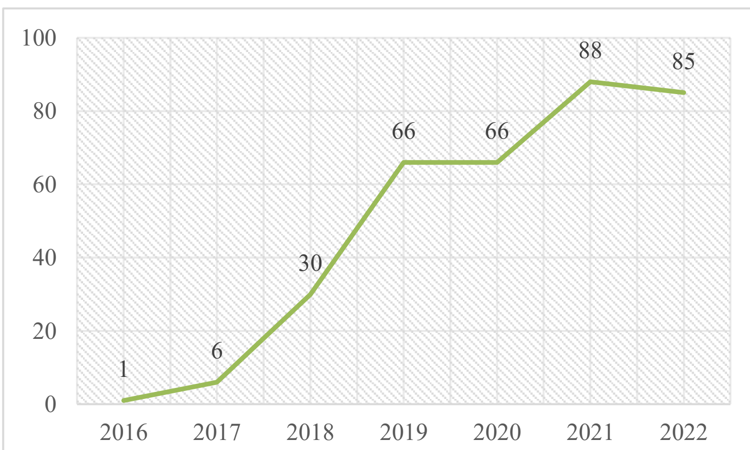

Fig. 2. Publication Trends per Year

With the rapid growth of urbanization, smart cities require intelligent solutions to various problems. According to [36], blockchain technology can help build infrastructure in smart cities. It also can help solve issues like weak IoT security, higher costs for equipment maintenance and upgrades, unreliable defenses against attacks, trust issues among Internet energy users, privacy leaks, and the inability to enforce trading market mode. This aligns with a study by [37], which suggested using blockchain technology to establish a solitary-rank payment system within a reputable urban setting. The proposal was endorsed as a pilot initiative in Moscow as part of the city's "Smart City – 2030" initiative. The research validated the viability of establishing and executing the notion of "smart" cities in Russia. This development is consistent with worldwide patterns and is substantiated by favorable hands-on encounters with the implementation of these technologies. This expertise could gain traction in Russia and contribute to resolve macroeconomic issues in numerous sectors.

Moreover, smart city innovations have been implemented in the transportation sector through car navigation systems to optimize travel routes and drive traffic. The users concerned about the security of their data frequently utilize established applications such as

Google Traffic or Waze; nevertheless, these systems continue to be unbearable to users. Personal data protection has been incorporated into the design of a vehicle navigation system utilizing blockchain technology [38]. Conversely, the *Intelligent Transportation System* (ITS) is implemented in smart city concepts to enable the autonomous operation of novel vehicles with minimal human intervention. Critical fob attacks, information spoofing, information loss, data manipulation, and surveillance are a few of the weaknesses that can be exploited by adversaries through ITS. For efficient data protection, blockchain offers a decentralized, tamper-resistant technology. This Blockchain technology minimizes information leakage and ensures interoperability by securely integrating service infrastructure and multipurpose smart vehicles [39].

To effectively address the issue of climate change, the growing integration of renewable source of energy and the shift towards electric mobility introduces intricacies to the electricity grid. Consequently, novel management strategies must be implemented to govern energy exchange effectively while upholding the principles of reliability and safety in grid operation. Electric vehicles (EVs) are a significant step towards an environmentally friendly mode of transportation. Concerning Electric Vehicles (EVs) and smart communities, consensus-driven, distributed, and decentralized Blockchain technology can introduce two-way electricity trading between vehicles and buildings and vice versa [40]. Research by [41] proposed secure and reliable energy exchange computation in a trustless peer network, thereby facilitating the deployment of EVs and promoting blockchain technology in routine activities like fueling electric vehicles via private and semi-private charging infrastructure. The potential cost reduction in general electric vehicle charging business models is underscored by the outcomes of a case study on implementing a blockchain framework involving multiple actors in Switzerland.

Blockchain technology revolutionizes the energy sector by transforming all currencies into digital formats, enabling individuals to manage efficiently and trade energy. Decentralized energy infrastructure facilitates microgrid trading energy transactions and the implementation of artificial intelligence (AI) through blockchain technology [42]. Blockchain technology and artificial intelligence (AI) facilitate trustworthy energy trading, remote monitoring, and remote monitoring. The European Commission released the "Energy Union Strategy" in 2015 to enhance energy production's security, sustainability, competitiveness, and economics. The potential catalyst for attaining the aforementioned conditions has been identified as blockchain technology [43]. On the other hand, a new IoT class called IoUT is considered more suitable and efficient if it applies Blockchain technology. This is supported by research [44] that uses blockchain technology to propose a decentralized authentication mechanism for IoUT that is energy-efficient, transparent, and robust. The outcomes demonstrate that underwater apparatus with constrained memory, energy, and processing capacity can utilize the proposed method. Compared to conventional authentication methods, the decentralized authentication model proposed for clustering networks substantially decreases by 74.63% reduce the energy consumption of devices. Furthermore, implementing the proposed strategy, the delivery rate is increased by 21.6% and end-to-end delay savings exceeding 41.9%.

4.2 Publications by Country

The Scopus database yielded 342 articles, among which certain countries exhibited the greatest quantity of publications, including India (72), China (63), United States (47), United Kingdom (22), Saudi Arabia (21), Canada (20), Australia (19), Spain (18), Italy (16), South Korea (16), United Arab Emirates, France (13), Pakistan (12), Malaysia (11), and others. Among the aforementioned countries, Asia is the continent with the most publications on using blockchain technology in the concept of Smart City mapping.

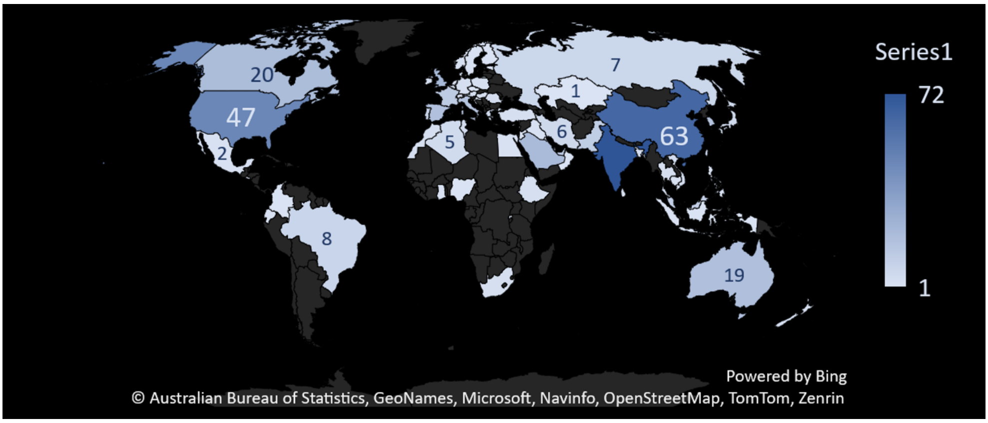

Fig. 3. Distribution by Country

India initiated the smart cities initiative in 2016. With the 'Smart' solutions that provide citizens with a reasonable quality of life and a clean, sustainable environment, this mission seeks to develop cities. To realize smart cities, the Indian government implements Blockchain technology. There are numerous methods in which the execution of Smart City initiatives is improved, including [45]; the use of Blockchain technology in carrying out Smart City has a positive impact on several aspects, such as smart contracts, health, education, secure data communication, citizen participation, economy and employment, property registration/auction, safety, renewable energy, and waste and sanitation.

Smart contracts utilize Blockchain technology to create more robust and easily accessible agreements. The integrity of the contract is maintained between the parties involved, however third parties can verify the contract using secure methods like cryptocurrency. Blockchain-certified contracts may result in cost savings in certain nations compared to the employment of notaries, an additional legal specialty that introduces substantial administrative expenses to conventional contract procedures. Utilizing Blockchain to secure contracts obviates the need for a notary and increases efficiency.

Regarding citizen participation, Blockchain has the potential to establish a loyalty and rewards platform built on blockchain technology. This platform will guarantee that appropriate members of society are duly compensated for their valuable inputs in advancing smart cities. In addition, decentralized and more secure voting platforms can be implemented in Blockchain technology, which offers a novel voting system by eradicating the intricacies and inefficiencies of conventional voting methods. Blockchain technology has the potential to generate electronic health records for individuals. It offers enhanced flexibility, security, and reliability for healthcare providers and patients. Patients are not required to provide multiple health records when seeking consultation with a consultant due to the decentralized structure of the records.

Furthermore, blockchain technology also proves beneficial in the realm of education. For instance, it enables the secure storage of students' credentials as educational documents and facilitates their sharing with stakeholders via suitable approval mechanisms. This also eliminates the requirement for authentication, given the records' perpetual availability and validity.

Prolonged procedures, exorbitant expenses, and substandard land certificates are prevalent challenges within the Property Registration/Auction industry. This is potentially bypassable via the use of blockchain technology. Applying blockchain technology to property registration can resolve these issues, resulting in time and cost savings and improved recording precision. This system can contain all permissions, inspection reports, and other pertinent documents/certificates pertaining to land and property. Blockchain technology can expedite the integration of models of real-time differential pricing for renewable energy purposes, enabling the regulation of electricity supply, load balancing, and energy consumption limitation. Concurrently, within the Waste and Sanitation industry, an optimal waste management strategy is possible through integrating blockchain technology and IoT-based solutions, enabling precise monitoring of waste generation and disbursement levels. Additionally, these systems facilitate the imposition of penalties or rewards on waste management firms that do not meet the expected standards for time-based services [45].

4.3 Publications by Author

According to Figure 4, Srivastava, G., from Brandon University, authored the most documents about the application of blockchain technology in the context of Smart City mapping from 2016 to 2022, totaling five. The individuals who secured the second and third positions, with four (4) documents, were Javaid, N. from COMSATS University Islamabad, and Tanwar, S. from Nirma University. Some authors also possess three (3) documents: Jena, D., Kanhere, S.S., Kumari, A., Lunardi, R.C., and Balamurugan, S.

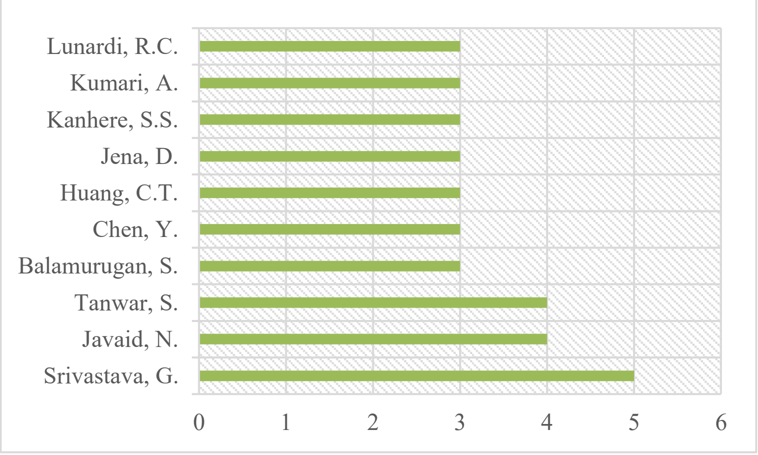

Fig. 4. Publications by Author

CiteSpace served as the platform for the researchers' collaboration network as illustrated in Figure 5. Visual mapping assisted the researchers in establishing more effective cooperative relationships by providing information regarding potential collaborators or cooperative research teams. A connectivity analysis was conducted using authors and cited authors from CiteSpace data. Ten clusters were identified, as follows: #0 Smart Sustainable City, consisting of 78 members with a silhouette value of 0.799; #1 Position Paper, comprising 58 members with a silhouette value of 0.826; #2 City Brain, encompassing 44 members with a silhouette value of 0.693; #3 Blockchain Consensus Protocol, comprising 37 members with a silhouette value of 0.85; and #4 Sub Communication Model, comprising 34 members Three highly regarded and frequently referenced authors are represented in this domain: Nakamoto S. (106), Dorri A. (48), and Zheng Z. (46).

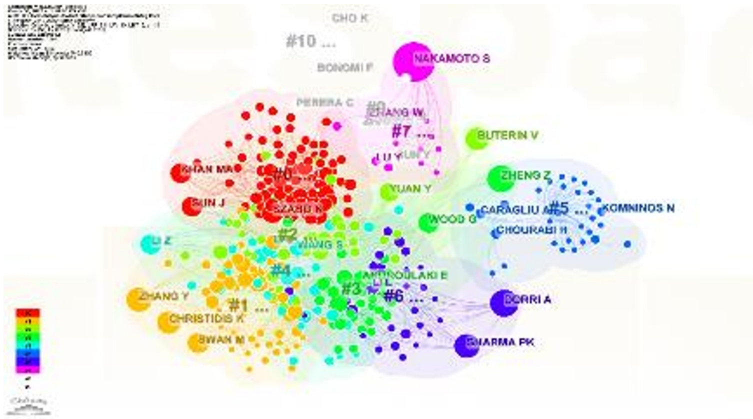

Fig. 5. Network Map by Author

4.4 Publications by Affiliates

The researcher's ten affiliates or institutions of origin are shown in Figure 6. Most researchers came from Brandon University, which were six (6) articles. They followed by four (4) institutions with five (5) articles each, namely the State University of New York System, King Saud University, UNSW Sydney, and Qatar University. Meanwhile, five (5) institutions have four (4) articles each, including the University of South Carolina, Binghamton University State University of New York, Air Force Research Laboratory, Machester Metropolitan University, and Universidad de Salamanca. Based on these data, it could be seen that the highest institution is dominated by the United States, as many as five (5) institutions. While the Asian and European continents contributed two (2) institutions each, and Australia contributed one (1) institution.

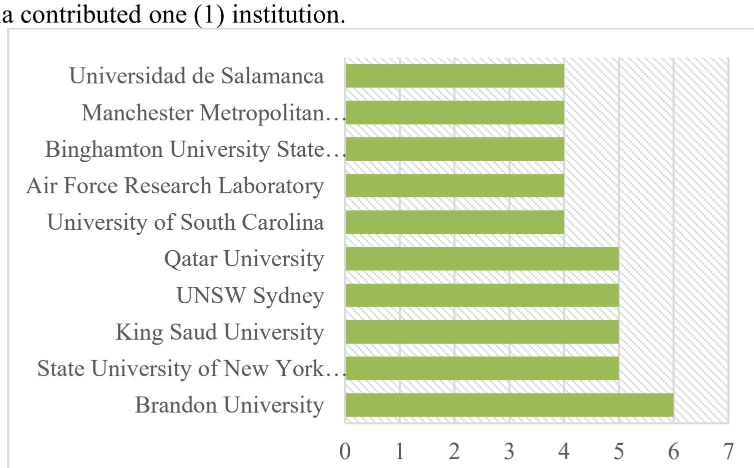

Fig. 6. Publications by Affiliates

4.5 Publications by Source

The ten most-cited scientific articles regarding the use of blockchain technology within the framework of Smart City mapping are as follows, as shown in Figure 7: The ACM International Conference Proceedings Series, which contains 16 articles in total: Advances In Intelligent Systems And Computing, which contains 14 articles; and Communications In Computer And Information Science, which contains 11 articles. In contrast, IEEE Internet of Things Journal and Wireless Personal Communications each hold the fourth and fifth positions with seven (7) articles, respectively. In contrast, IEEE Access, Lecture Notes In Computer Science, Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics, and Lecture Notes In Electrical Engineering secured the sixth through eighth positions, respectively, with six (6) articles. Future Generation Computer Systems and the International Journal of Advanced Computer Science and Applications each hold the ninth and tenth positions with five articles, respectively.

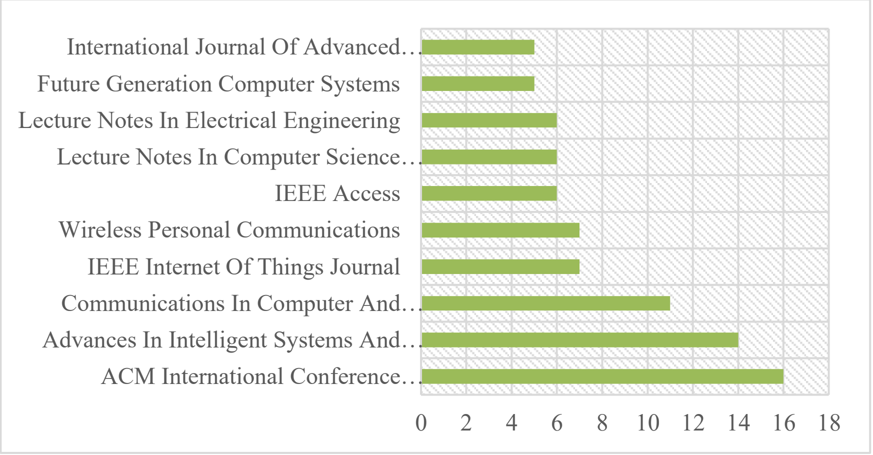

Fig. 7. Publications by Source

4.6 Publications by Funding

There are several donor agencies providing research funding to the authors, as shown in Figure 8, namely, National Natural Science Foundation of China (13), European Regional Development Fund (11), National Research Foundation of Korea (7), National Science Foundation (7), Horizon 2020 Framework Programme (6), Conselho Nacional de Desenvolvimento Científico e Tecnológico (5), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (5), Fundamental Research Funds for the Central Universities (4), Institute for Information and Communications Technology Promotion (4), Ministerio de Economía y Competitividad (4), dan Ministry of Science and ICT South Korea (4).

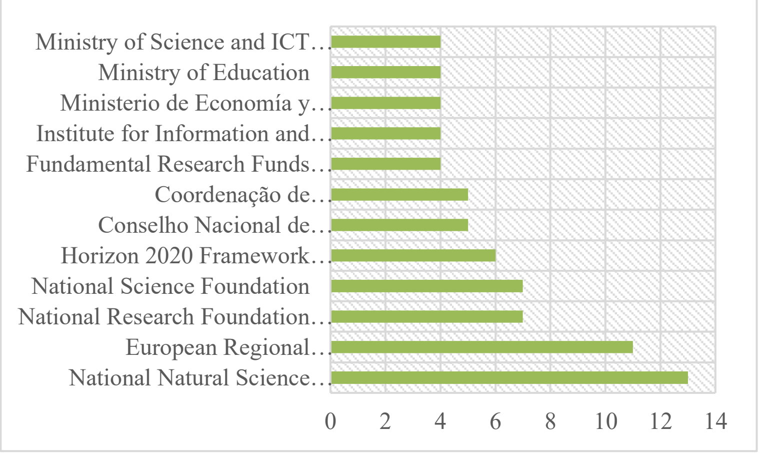

Fig. 8. Publications by Funding

4.7 Connectivity by Keyword

Figure 9 below is a keyword network map processed using CiteSpace using blockchain technology in the Smart City mapping concept based on the Scopus database from 2016 – 2022. From the data analyzed using CiteSpace, ten (10) interrelated clusters are formed.

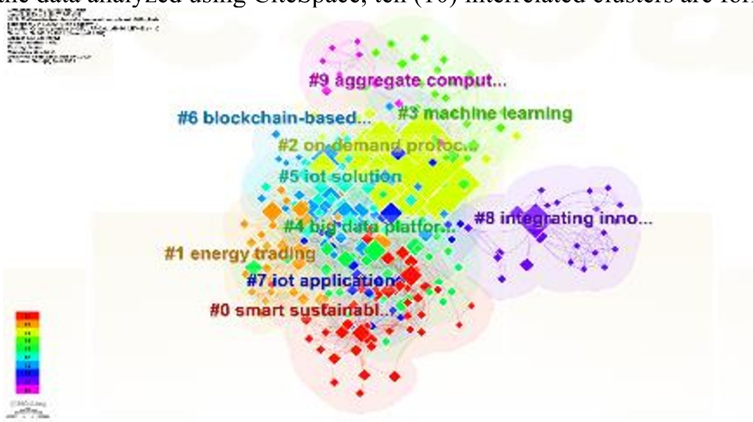

Fig. 9. Network Map by Keyword

The analysis revealed that the keywords in the research topic regarding the utilization of blockchain technology in the Smart City mapping concept can be categorized into nine (9) clusters, namely; #0 Smart Sustainable City; #1 Energy Trading; #2 on-demand protocol; #3 Machine Learning; #4 Big Data Platform; #5 IoT Solution; #6 Blockchain-based IoT Data Management; #7 IoT Application; #8 Integrating Innovation Diffusion Theory; and #9 Byzantine Behaviour. In Figure 9, the clusters formed tend to be centralized and related. It also demonstrated the close relationship between one cluster and another cluster in using blockchain technology in the concept of Smart City mapping. In addition, each cluster can be reviewed based on the analysis of the size, silhouette value, and average year of each cluster, as shown in Table 1.

Table 1. Clusters Formed by Keywords

Cluster ID	Size	Silhouette	Label (LLR)	Average Year
0	44	0.761	smart sustainable city (153.78, 1.0E-4)	2020
1	44	0.751	energy trading (79.38, 1.0E-4)	2019
2	43	0.89	on-demand protocol (55.66, 1.0E-4)	2017
3	39	0.767	machine learning (82.93, 1.0E-4)	2021
4	38	0.676	big data platform (145.83, 1.0E-4)	2019
5	36	0.858	iot solution (103.32, 1.0E-4)	2020
6	32	0.756	blockchain-based iot data management system (76.66, 1.0E-4)	2019
7	26	0.73	iot application (72.95, 1.0E-4)	2019
8	24	0.935	integrating innovation diffusion theory (86.23, 1.0E-4)	2017
9	10	0.934	aggregate computation (27.69, 1.0E-4)	2018

Based on the data above, a cluster is formed based on the number of existing members. The first cluster is formed because it has the most members, while the last cluster is formed because it has few members. The largest cluster has the most members at 44 and have 0.761 of silhouette value. This cluster occurred on average in 2020. In this cluster, the most cited articles belong to [46]. The most cited topics in this cluster are distributed ledger (18), sustainable development (13), and current (13). With a silhouette value of 0.751, the second greatest cluster also comprised 44 members. This cluster occurred on average in 2019. The most cited articles in this cluster are owned articles [19]. The most cited topics in this cluster are big data (16), artificial intelligence (15), and electric power transmission networks (12). Meanwhile, The silhouette value of the third greatest cluster, which comprises 43 members, is 0.89. This cluster occurred on average in 2017. In this cluster, the most cited articles belong to [47]. The most cited topics in this cluster are blockchain (313), smart cities (223), and the Internet of Things (136).

Meanwhile, the silhouette value indicated the consistency and homogeneity in each cluster. A cluster with a value closer to 1 indicates a higher level of homogeneity and consistency. The cluster with the highest silhouette value was cluster #8, with a value of 0.935, cluster #9 was positioned second with a value of 0.934, while cluster #2 was ranked third with a value of 0.89. At the same time, the cluster with the lowest silhouette value was cluster #4, with a value of 0.676. In addition, the 9 clusters can be analyzed based on their timeline or development period, as shown in Figure 10.

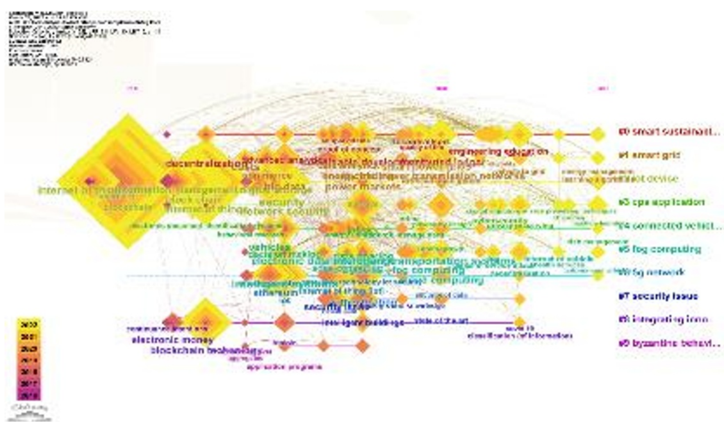

Fig. 10. Connectivity Timeline by Keyword

The timeline in the image above reveals clusters #0, #1, #2, #3, #4, #5, and #6 still ongoing into 2022. Meanwhile, those that stopped their development before 2022 were clusters #7, #8, and #9. The cluster with the most extended period is cluster #2, while the shortest cluster period is cluster #9. Based on the nets in Figure 11, it can be seen that the entire cluster continues to develop. Articles on the theme of the IoT and blockchain were reviewed from 2016 to 2022. Meanwhile, 2019 was the most populous year because of many discussion topics, such as sustainable development, data analytics, energy trading, power markets, privacy, data sharing, interchange, edge computing, authentication, internet buildings, and so on.

The sustainable smart city development process requires many processes in various aspects that require a superior security measures. Therefore, the discussion of blockchain technology arises in the entire cluster because blockchain that uses cryptographic techniques appears as a cutting-edge solution in the process of securing data to prevent data leakage and carry out data protection to face various challenges [48]–[52].

5 Conclusion

Based on the aforementioned explanation, the discussion about the use of blockchain technology in supporting the application of the smart city concept continues to grow occasionally. Sustainable smart city development requires many processes in various aspects that require a high level of a security system. Blockchain technology is used in sustainable smart city development because it offers a complete data security system. Data from Scopus stated that the first discussion related to this topic occurred in 2016. The results of bibliometric research showed that until 2022, 342 articles have been collected, which tends to increase yearly. In 2018, there was a significant increase. Concurrently, global discussions are taking place on this subject. India, China, and the United States are the three countries that dominate the discussion of this topic. Sristava, G. became the most contributing author by contributing 5 articles. The bibliometric visualization of the network map by keyword is divided into nine clusters, and the network map by author is divided into ten clusters.

A drawback to this study is that it only uses one database, namely Scopus, as a source of data acquisition, so it can only represent part of the discussion on this topic. Therefore, future studies are expected to use several databases such as Google Scholar or Web of Science to show more comprehensive developments. In addition, a combination of Systematic Literature Review (SLR) needs to be done to complement the bibliometric analysis and present a better picture qualitatively and quantitatively of research on the use of blockchain technology in the development of the smart city concept.

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