A Bibliometric Analysis of Electronic Voting Implementation and Trends Challenges and Future Directions in Election System

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Abstract *: Secure, transparent, and efficient elections are increasingly becoming a global concern, particularly in light of the growing demand for digital voting systems. Electronic voting (e-voting), which integrates digital technology into the electoral process, is considered a viable solution. However, its implementation continues to face significant technical, social, and policy-related challenges. This study applies bibliometric analysis to examine 491 journal articles using R-Studio, VosViewer, and Excel, aiming to map global research trends, challenges, and future directions in e-voting. Findings reveal that blockchain technology dominates e-voting research, focusing on enhanced security and transparency through decentralization. Four key research areas were identified: (1) Security, with an emphasis on cryptography and data protection; (2) Blockchain, as a solution to the problem of decentralization and vote integrity; (3) e-voting Implementation Process; and (4) Election Process, which considers social and policy aspects. The study highlights the vital role of blockchain in shaping secure and inclusive digital elections, and underscores the need for integrated technological and policy frameworks in future e-voting development.*

Keywords *: Bibliometric Analysis, E-Voting, General Election, Blockchain, Election System*

Abstrak : Pemilihan umum yang aman, transparan, dan efisien semakin menjadi perhatian global, terutama seiring dengan meningkatnya permintaan akan sistem pemungutan suara digital. Pemungutan suara elektronik (*e-voting*), yang mengintegrasikan teknologi digital ke dalam proses pemilihan, dianggap sebagai solusi yang layak. Namun, penerapannya masih menghadapi tantangan teknis, sosial, dan kebijakan yang signifikan. Studi ini menerapkan analisis bibliometrik terhadap 491 artikel jurnal menggunakan R-Studio, VosViewer, dan Excel, dengan tujuan memetakan tren penelitian global, tantangan, dan arah masa depan dalam bidang *e-voting*. Temuan menunjukkan bahwa teknologi *blockchain* mendominasi penelitian *e-voting*, dengan fokus pada peningkatan keamanan dan transparansi melalui desentralisasi. Empat bidang penelitian utama diidentifikasi: (1) Keamanan, dengan penekanan pada kriptografi dan perlindungan data; (2) *Blockchain*, sebagai solusi untuk masalah desentralisasi dan integritas suara; (3) Proses implementasi *e-voting*; dan (4) Proses pemilihan umum, yang mempertimbangkan aspek sosial dan kebijakan. Studi ini menyoroti peran penting *blockchain* dalam mewujudkan pemilihan umum digital yang aman dan inklusif, serta menekankan perlunya kerangka kerja teknologi dan kebijakan yang terintegrasi dalam pengembangan *e-voting* di masa depan.

Kata kunci : Analisis Bibliometrik, E-Voting, Pemilihan Umum, Blockchain, Sistem Pemilihan

INTRODUCTION

Elections are a fundamental element in modern democracies, being the main means for people to channel their political aspirations. Along with technological developments, electoral systems have begun to adopt innovations such as *e-voting* (Adeshina & Ojo, 2020; Alomari, 2016; Cserny & Nemeslaki, 2018; Darmawan, 2021; Gibson et al., 2016; Mamokhere & Mabeba, 2022; Omotayo & Adekunle, 2021), which is expected to increase efficiency, transparency and voter participation. Some studies, such as the one conducted by Ajibade (2023) , show that good information system design contributes to the success of *e-voting*. However, the implementation of this technology still faces significant challenges, especially in developing countries.

This phenomenon is increasingly relevant in Indonesia, one of the world's largest democracies (Aspinall, 2015; Fionna & Hutchinson, 2019; Slater, 2023), which faces logistical and security complexities in organizing elections (Aermadepa et al., 2024; Iskandar et al., 2025; Wibowo, 2023). The manual system currently used is not only time-consuming but also prone to fraud. Research by (Nallapareddy et al., 2024) underscores the potential of *web-based* solutions that can be customized to local needs, and use *blockchain-based* technology (Benabdallah et al., 2022; Shahzad & Crowcroft, 2019; Yi, 2019) although the implementation of such technology requires adequate infrastructure.

Although there has been a lot of research on *e-voting*, studies that integrate various aspects, such as technology, are still limited. Study (Baudier et al., 2021; Benabdallah et al., 2022; Daraghmi et al., 2024; Hajian Berenjestanaki et al., 2023; Khan et al., 2020; Kshetri & Voas, 2018; Rathee et al., 2021; Su & Su, 2023; Taş & Tanrıöver, 2020; Vladucu et al., 2023; Yi, 2019) or biometric reliability (Ahmad et al., 2020; Aniche et al., 2021; Faruk et al., 2024; Liu et al., 2023). However, there is no bibliometric study that provides a comprehensive overview of global and local trends, and their relevance to the Indonesian context.

This potential is an opportunity to contribute new perspectives. A bibliometric review enables a systematic analysis of the existing literature, identifying patterns, research gaps, and key challenges in *e-voting* implementation. This research aims to provide a comprehensive overview of global research trends, while exploring the potential for implementation in Indonesia. The uniqueness of this research lies in its methodological approach that uses bibliometric analysis to map the *e-voting* research landscape. By incorporating data from various reputable sources, this research not only enriches the academic discourse but also provides a solid foundation for future technology policy and implementation.

The main objective of this research is to identify trends, challenges, and research opportunities in the application of *e-voting* in general elections, and provide strategic recommendations for stakeholders. This research is expected to encourage the development of a more efficient and reliable electoral system, especially in Indonesia. This article contributes to the literature by providing new insights that are relevant and data-driven. This is not only important for academic development but also has practical implications in supporting democratic transformation in the digital era.

RESEARCH METHODOLOGY

We established the bibliometric analysis research method. The bibliometric analysis method is based on objective findings and quantitative techniques. This analysis can illustrate the structure of scientific knowledge development in a particular field, content distribution, and impact and metrics through scientific knowledge maps (Donthu et al., 2021). We analyse by thoroughly reviewing trends, citations, and thematic analysis, as well as contributions from key players, such as sources, authors, countries, and institutions (Guo & Zhang, 2022; Sonni et al.,

2024). Bibliometric analyses were conducted with performance analysis and science mapping analysis applied to the dataset. Performance analysis this section extracts public information about the dataset and the growth of the literature over the years shown in Table 1. We also discuss important aspects of the literature such as the most relevant authors, their country of origin, and their affiliations, which are included in all or part of the literature on the subject under consideration (Alshater et al., 2022; Guo & Zhang, 2022). Science mapping, on the other hand, focuses on the interactions, citation networks and collaborations between research components. This study aims to reveal the intellectual structure of the literature on the research topic, performance status and collaborative relationships between variables in the literature.

Before we present how the data was obtained and the analytical tools used, we conducted a brief brainstorming session with experts to identify efficient keywords. Next, we conducted a simple keyword analysis of the literature using the refinement option on the Scopus engine. This brainstorming session was very important as we could easily match the keywords from the literature with the keywords from the experts. This contributed significantly to the validity of the search data. After filtering, our search efforts eventually yielded 491 articles and conference papers using the keywords 'e-voting AND elections', covering the study period from 2019 to 2024, see table 1 below:

Table 1. Summary of the review

Description	Result
Main Information About Data	
Timespan	2019-2024
Sources (Journals, Books, etc)	310
Documents	491
Annual Growth Rate %	4,77
Document Average Age	3,28
Average citations per doc	5,894
References	12568
Document Contents	
Keywords Plus (ID)	1619
Author's Keywords (DE)	867
Authors	
Authors	1519
Authors of single-authored docs	30
Authors Collaboration	
Single-authored docs	31
Co-Authors per Doc	3,59
International co-authorships %	21,79
Document Types	
article	176
conference paper	315

Source: RStudio Data Processing Results, 2025

We used three bibliometric analysis tools: RStudio, VOSviewer, and Excel. RStudio was used to generate bibliographic data for the dataset. VOSviewer was used to perform network and

content analyses. VOSviewer allows users to create and visualise bibliometric networks these visualisations are often called maps that are used to perform various network analyses, such as co-authorship, co-occurrence, and co-citation. These networks of relationships can be organised by author, source, country, and keyword. VOSviewer is also used to perform bibliographic merging. We used Microsoft Excel to complement RStudio, on the existing method complementing two different tools, it requires validation to ensure the consistency of the information presented. Furthermore, to unify data that is multiple but has the same source such as author, and affiliation we use OpenRefine as an additional tool.

The analysis was conducted in three stages. Firstly, we conducted a general performance analysis. This section extracts public information about the dataset and the growth of the literature over the years shown in Table 1. We also discuss important aspects of the literature such as the most relevant authors, their country of origin, and their affiliations. We performed the analysis using Bradford's Law to discuss the primary sources. Secondly, we conducted a citation analysis. This section discusses, the most cited references and sources, along with the source and impact of the authors. Thirdly we conducted a network and content analysis using bibliographic, co-citation and co-occurrence analyses. Finally, we used hierarchical analysis (dendrograms) to ensure the most accurate clustering.

RESULTS AND DISCUSSION

The analysis shows that e-voting has been rapidly evolving as a research topic, with significant advancements especially related to the application of blockchain technology. Of the 10 most cited articles, almost all of them promote new concepts such as the use of blockchain to improve security, vote verification, and prevent manipulation in digital election systems. This reflects an increasing reliance on decentralized technology-based solutions that provide greater confidence in the integrity of the electoral process.

Dominance of Blockchain Technology in Global E-Voting Research

Table 2. Top Teen Cited Global Documents

Author	Title	Year	Journal	Citations
Shahzad B	Trustworthy *Electronic* Voting Using Adjusted Blockchain Technology	2019	Institute of Electrical and Electronics Engineers Inc.	178
Gao S	An anti-quantum *e-voting* protocol in blockchain with audit function	2019	Institute of Electrical and Electronics Engineers Inc.	71
Li Y	A Blockchain-Based Self-Tallying *Voting* Protocol in Decentralized	2022	Institute of Electrical and Electronics Engineers Inc.	67

	IoT			
Baudier P	Peace engineering: The contribution of blockchain systems to the *e-voting* process	2021	Elsevier Inc.	63
Daramola O	Architecture-centric evaluation of blockchain-based smart contract *E-voting* for national elections	2020	MDPI AG	48
Panja S	A Smart Contract System for Decentralized Borda Count *Voting*	2020	Institute of Electrical and Electronics Engineers Inc.	46
Shankar A	Privacy preserving *E-voting* cloud system based on ID based encryption	2021	Springer	42
Zaghloul E	D-BAME: Distributed Blockchain-Based Anonymous Mobile *Electronic Voting*	2021	Institute of Electrical and Electronics Engineers Inc.	42
Taş R	A Manipulation Prevention Model for Blockchain-Based *E-Voting* Systems	2021	Hindawi Limited	41
Patidar K	Decentralized *E-Voting* Portal	2019	Institute of Electrical and	40

Using Blockchain	Electronics Engineers Inc.

Source: Data analysed by the researcher using RStudio

Research on e-voting has shown the dominance of blockchain technology as a key solution to overcome the main challenges of organizing digital elections, especially related to security, transparency, and verification of voting results. From the data analysis, it is clear that most of the most cited articles in this field, such as the article written by(Shahzad & Crowcroft, 2019) entitled 'Trustworthy Electronic Voting Using Adjusted Blockchain Technology', show that blockchain is not only a solution sought by many researchers, but also seen as a breakthrough that can solve various critical problems in e-voting systems.

The article by Shahzad proposes the use of a modified blockchain to ensure higher security in the electronic voting process. With more than 170 citations, the article emphasizes the advantages of blockchain technology in maintaining data integrity, reducing the potential for manipulation, and increasing public trust in digital-based election systems. The dominance of this theme is reflected in the large number of articles focusing on blockchain applications, such as (Gao et al., 2019) with "An Anti-Quantum E-Voting Protocol in Blockchain with Audit Function" and (Li et al., 2022) with "A Blockchain-Based Self-Tallying Voting Protocol in Decentralized IoT", which show strong efforts to combine blockchain technology with other advanced security protocols to address potential threats such as quantum attacks.

The challenge of implementing secure and transparent e-voting on a large scale, such as in Indonesia, is also addressed by blockchain-based approaches These studies show that with blockchain, every vote can be recorded in an immutable digital ledger, making it almost impossible to manipulate after recording. Therefore, blockchain offers a very promising solution to increase security and trust in digital elections. Blockchain technology also enables the development of more decentralized e-voting systems, where no single entity has full control over election data. This reduces the risk of fraud or cheating that often occurs in centralized systems. An article written by (Baudier et al., 2021) on "Peace Engineering: The Contribution of Blockchain Systems to E-Voting Processes" also underlines that blockchain can provide a more fair, open, and publicly verifiable system, which is crucial for increasing voter participation and election legitimacy.

One important theme in blockchain-based e-voting research is the development of smart contract models. This concept has been promoted by several authors, including (Daramola and Thebus, 2020) in their article proposing the application of smart contracts for national elections. This model enables automatic setting of voting terms and conditions that are clear and transparent, and enables direct vote counting without intermediaries, thereby improving efficiency and accuracy in the calculation of election results. The study by (Zaghloul et al., 2021) also introduced a more user-friendly system, "D-BAME: Distributed Blockchain-based Anonymous Mobile Electronic Voting". Here, blockchain not only provides transparency, but also protects voter privacy in a way that enables anonymous voting, an important aspect of maintaining voter freedom and confidentiality in elections.

While blockchain offers a range of potential solutions to challenges in digital electoral systems, many studies have also highlighted implementation challenges, particularly with regard to scalability and the need for adequate infrastructure to support this technology in countries with limited digital infrastructure. Furthermore, although much progress has been made, the

adoption of blockchain-based e-voting in many countries still requires further testing and validation to ensure that this technology can be implemented effectively and securely at scale.

Bibliographic Coupling Analysis: E-Voting Research Network

Figure 1. Bibliographic coupling of 491 e-voting articles

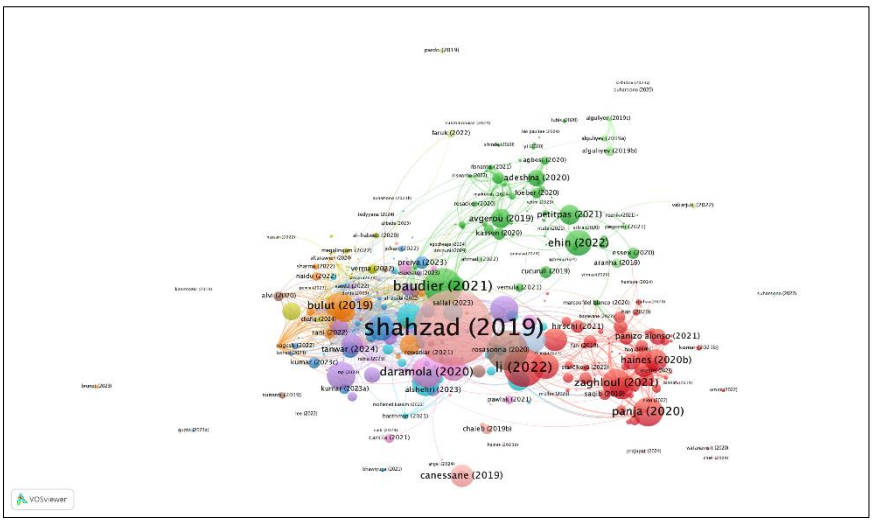


Figure 1 illustrates the bibliographic coupling of 491 e-voting articles, visualized using VOSviewer. This network map highlights the intellectual structure of the field by displaying connections between documents that cite common references. Each node represents an author, and the size of the node reflects the frequency and centrality of the author's work within the overall research network. The analysis reveals that Shahzad (2019) occupies the most prominent position, indicating its strong influence and extensive connectivity with other studies in the e-voting domain.

The network is divided into distinct color-coded clusters, each representing a group of studies with closely related themes or methodologies. For example, the red cluster appears to focus on security and privacy issues in blockchain-based voting systems, while the green cluster likely addresses technological development and system integration. Other clusters in purple, blue, and orange may reflect variations in research focus, such as legal frameworks, voter accessibility, or regional implementation strategies.

Identifying the Most Influential Authors in E-Voting Research

In the bibliometric analysis of e-voting research, the identification of the most influential authors provides important insights into individual contributions to knowledge development in this field. Based on the data obtained, several prominent authors stand out with their significant contributions through publications and citations.

Table 3. Authors' impact

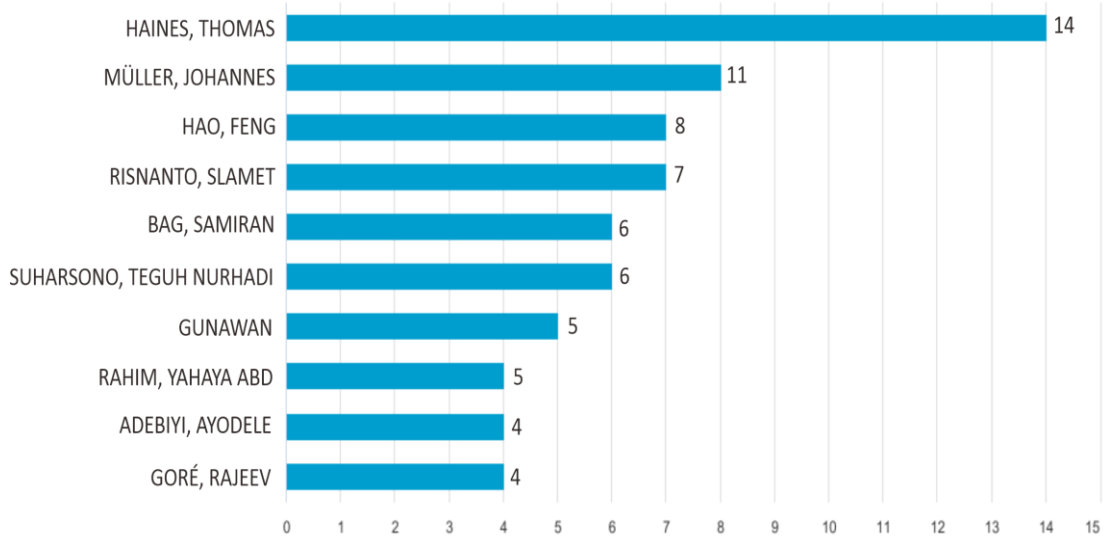
No.	Author	H Index	G Index	M Index	Total Citations	No. of Publica-tion	Publication Year
1	Haines Thomas	6	9	0,857	100	14	2019

2	Müller Johannes	5	8	0,833	82	11	202
3	Zhang Bingsheng	4	4	0,571	29	4	2019
4	Alguliyev Rasim	3	3	0,429	18	3	2019
5	Aliguliyev Ramiz	3	3	0,429	18	3	2019
6	Essex Alexander	3	3	0,429	27	3	2019
7	Hao Feng	3	8	0,429	71	8	2019
8	Marcos Del Blanco David Yeregui	3	4	0,429	30	4	2019
9	Rahim Yahaya Abd	3	4	0,429	24	5	2019
10	Risnanto Slamet	3	5	0,429	26	7	2019

The analysis shows that Thomas Haines is the most influential author in e-voting research with the highest H index (6) and a significant number of citations, reaching 100. The relatively recent publication year (2019) shows that although Haines has only recently started publishing his work, his contributions have greatly influenced the development of e-voting studies. Haines' work is widely published in reputable international journals, giving it a broad impact on future research. His G index of 9 also shows the high quality of his published works, indicating that his contributions are not only numerous, but also of high quality.

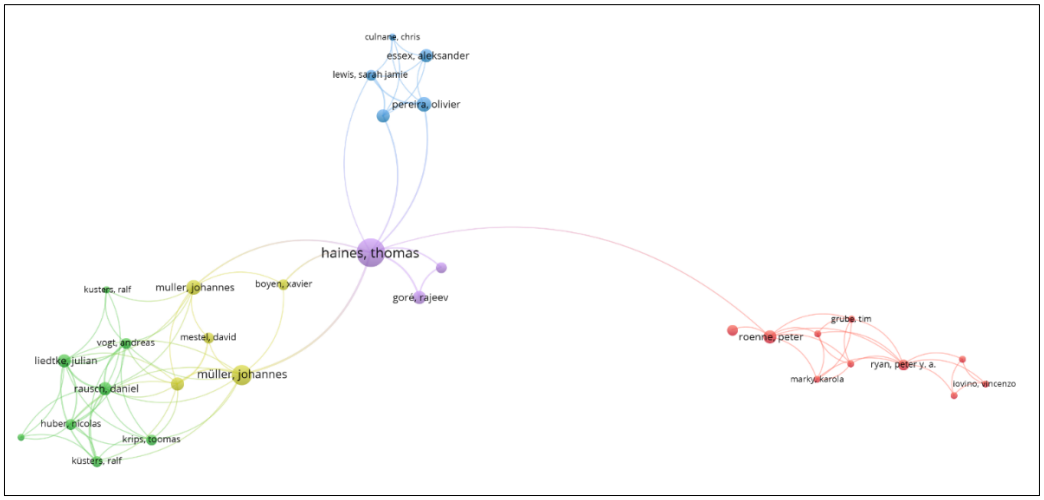
Besides Haines, Johannes Müller also takes the top spot with an H index of 5 and 82 citations. With a very high level of influence (G index of 8), Müller's research published in 2020 focuses on the development of blockchain-based e-voting protocols and privacy. This reflects a broader trend in e-voting research, where blockchain technology is becoming a key theme to increase trust and transparency in electoral processes. Müller's work has been widely recognized by the scientific community, making it one of the key references in e-voting studies.

Figure 2. Most relevant author in e-voting elections



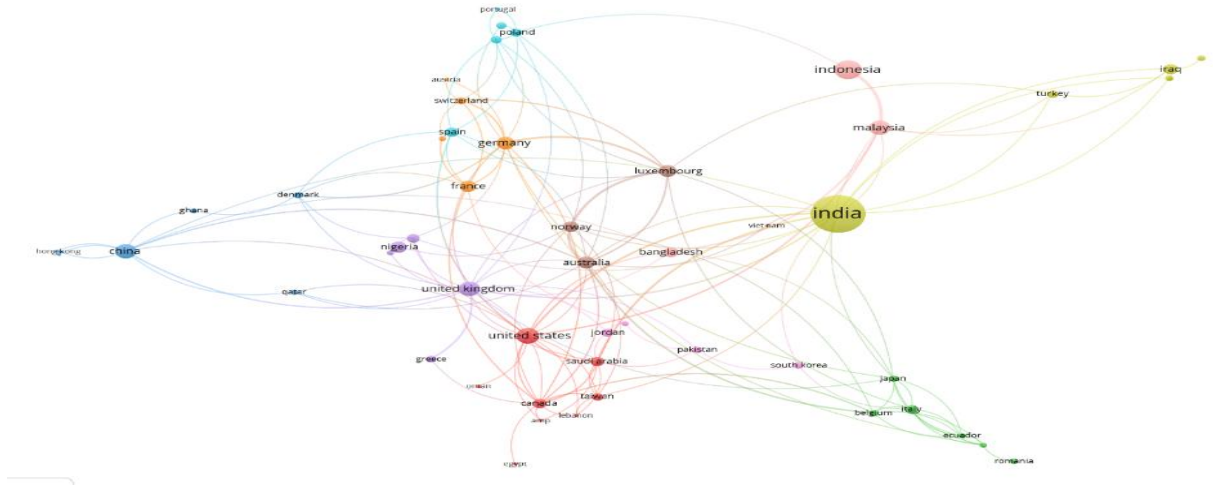
The next three authors with significant influence are Bingsheng Zhang, Rasim Alguliyev, and Ramiz Aliguliyev. Although their H index is slightly lower (3-4), they still have valuable contributions in e-voting related research. Their works are widely published in journals that promote distributed technologies and more scure and transparent voting systems. One of them is Dr. Bingsheng Zhang (Index H: 4) with his contributions in the use of blockchain and IoT to improve the efficiency of electronic voting. Rasim Alguliyev and Ramiz Aliguliyev (H Index: 3), who focus on smart contracts and blockchain architecture evaluation, have influenced studies on the application of e-voting to national elections. Although their citation count is lower compared to other authors such as Haines and Müller, their works are still important in contributing innovative concepts in the application of technology to e-voting, such as the use of blockchain for verification and prevention of vote manipulation.

Figure 3. Co-authorship by author



In addition to individual contributions, co-authorship analysis also shows strong collaboration between leading authors in e-voting research. Marcos Del Blanco David Yeregui, with a considerable number of publications (30 publications), collaborates intensively with other authors, signaling a strategic partnership in developing technology-based election system models. Most of the leading authors in this field, including Shankar A., Zaghloul E., and Patidar K., have focused on the security and privacy aspects of e-voting systems. Their research combining encryption techniques and blockchain mechanisms aims to address the key issues in e-voting, namely voter data protection and vote manipulation prevention. This shows that besides blockchain technology, the data security aspect is one of the biggest focuses in e-voting research.

Figure 4. Co-authorship by countries



The above findings underscore the central role that these leading authors play in shaping the future direction of e-voting research, especially by emphasizing the application of blockchain technology to create more secure and transparent electoral systems. As such, their work has not only made an impact on the development of e-voting theory, but also on its practical implementation in various electoral systems around the world.

Impact of Publication Sources on E-Voting Knowledge Dissemination

Research on e-voting is heavily influenced by publication sources that play an important role in the dissemination of knowledge and understanding of the implementation of this technology. In our bibliometric analysis, we can clearly see the influence of journals and conferences on the development and dissemination of research in the field of e-voting. Based on the data collected, we were able to identify the most influential publication sources and their impact on knowledge dissemination in this field. These findings highlight the important role that credible and influential publication sources play in shaping the direction of e-voting research. Through leading journals and international conferences, e-voting research can grow rapidly and gain wider recognition among the academic community, as well as influence e-voting implementation policies in various countries.

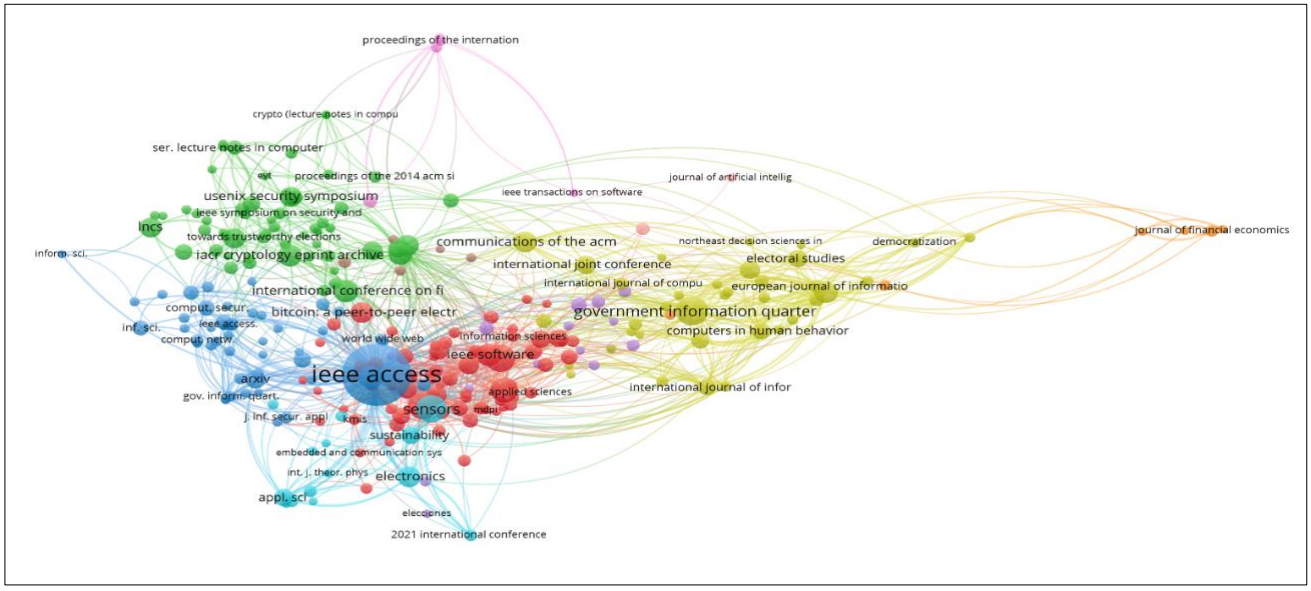
Table 4. Sources' impact

No.	Source	H Index	G Index	M Index	Total Citations	No. of Publica-tion	Publication Year
1	IEEE Access	8	9	1,143	398	9	2019
2	Communications in Computer and Information Science	5	7	0,714	56	7	2019
3	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial	5	7	0,714	99	32	2019

	Intelligence and Lecture Notes in Bioinformatics)						
4	Proceedings - IEEE Computer Security Foundations Symposium	4	6	0,571	57	6	2019
5	ACM International Conference Proceeding Series	3	3	0,429	17	11	2019
6	IEEE Security and Privacy	3	3	0,429	28	3	2019
7	IEEE Transactions On Dependable and Secure Computing	3	4	0,6	88	4	2021
8	International Journal Of Interactive Mobile Technologies	3	4	0,75	20	4	2022
9	Journal of Information Security and Applications	3	4	0,6	42	4	2021
10	Journal Of Physics: Conference Series	3	4	0,5	18	4	2020

The data in table 4 above shows that the most influential publication source is IEEE Access, with an H index of 8, a G index of 9, and a total of 398 citations. Published in 2019, IEEE Access has become a major platform for the dissemination of e-voting research. The journal focuses on technology and systems engineering, including security and integrity aspects in e-voting that rely on the latest technologies such as blockchain and cryptography. The dominance of IEEE Access shows how important publications in this journal are in shaping the development of e-voting research, as it provides wide visibility and reaches a larger international audience. IEEE Access contributes significantly to the dissemination of new concepts, and articles published in it often become key references in follow-up studies. In this regard, IEEE Access' influence is not only limited to e-voting techniques or technologies, but also to the application of security principles and secure and transparent digital-based election data management.

Figure 5. Co-citation of journal



Besides IEEE Access, journals such as Communications in Computer and Information Science and Lecture Notes in Computer Science also show significant impact. With an H index of 5 each, these two journals focus on the application of technology in various fields, including security systems and protocols used in e-voting.

Lecture Notes in Computer Science has a G-index of 7[B1.1], indicating that articles published in this journal are frequently cited and contribute significantly to the field. The publications cover a wide range of innovative topics related to e-voting, particularly the development and integration of new protocols incorporating blockchain technology and cloud-based security concepts. Similarly, the Proceedings of the IEEE Computer Security Foundations Symposium (H-index: 4) and the IEEE Transactions on Dependable and Secure Computing (G-index: 4) make notable contributions. These outlets emphasize the implementation of robust security protocols and mechanisms within e-voting systems, focusing on safeguarding voter data from potential manipulation or tampering.

In addition to scientific journals, proceedings from international conferences such as the ACM International Conference Proceedings Series also show a significant impact in the dissemination of knowledge about e-voting. These conferences provide a platform for researchers to share their latest findings and get direct feedback from the academic community. With an H index of 3 and 17 citations, this conference brings together researchers who focus on blockchain and cryptography in the context of e-voting, and serves as a meeting point for innovative ideas regarding the implementation of technology-based election systems. The International Journal of Interactive Mobile Technologies (Index G: 4) published in 2022, although more recent, demonstrates the importance of topics such as the development of e-voting applications for mobile devices. With the growing popularity of mobile devices, publishing in journals such as this helps to accelerate the dissemination of relevant research in mobile-based digital electoral systems that can be more widely accessed by the public.

Table 5 Core Sources by Bradford's Law

No.	Sources	Rank	Frequency	Cumulative Frequency	Zone

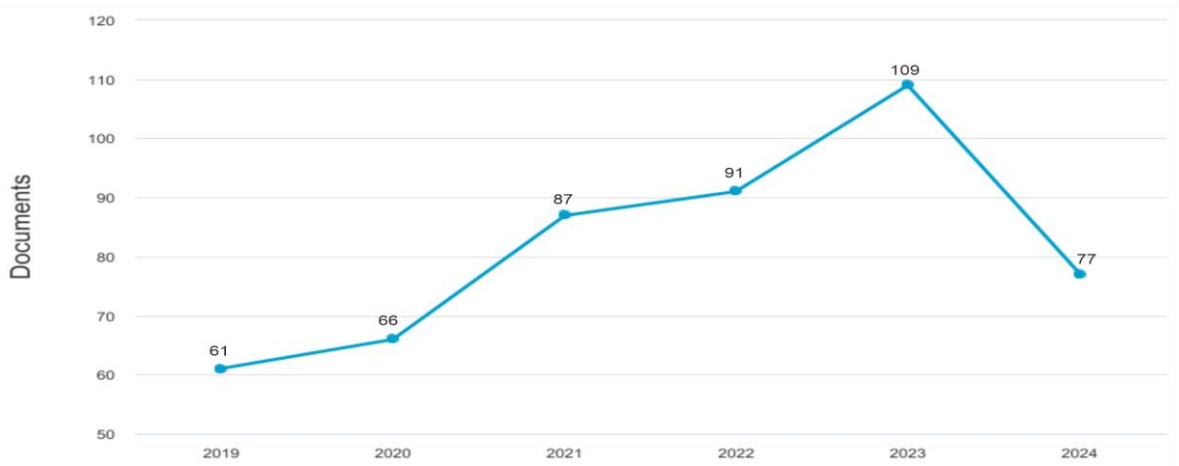
1	Lecture Notes In Computer Science	1	32	32	1
2	Lecture Notes In Networks And Systems	2	19	51	1
3	ACM International Conference Proceeding Series	3	11	62	1
4	IEEE Access	4	9	71	1
5	AIP Conference Proceedings	5	7	78	1
6	Communications in Computer and Information Science	6	7	85	1
7	Journal of Theoretical and Applied Information Technology	7	6	91	1
8	Proceedings-IEEE Computer Security Foundations Symposium	8	6	97	1
9	CEUR Workshop Proceedings	9	5	102	1
10	Lecture Notes in Electrical Engineering	10	5	107	1
11	14TH International Conference on Advances In Computing, Control, and Telecommunication Technologies, ACT 2023	11	4	111	1
12	Electronics (Switzerland)	12	4	115	1
13	IEEE Transactions on Dependable and Secure Computing	13	4	119	1
14	International Journal of Interactive Mobile Technologies	14	4	123	1
15	Journal of Information Security and Applications	15	4	127	1
16	Journal Of Physics: Conference Series	16	4	131	1
17	Advances In Intelligent Systems and Computing	17	3	134	1
18	Artificial Intelligence, Blockchain, Computing and security - Proceedings of The International Conference on Artificial Intelligence, Blockchain, Computing and Security, ICABCS 2023	18	3	137	1
19	Cluster Computing	19	3	140	1
20	IEEE Security and Privacy	20	3	143	1
21	International Journal of Electronic Governance	21	3	146	1
22	International Journal of Innovative Technology and Exploring Engineering	22	3	149	1
23	Proceedings of 15TH International Conference on Telecommunication Systems, Services, And Applications, TSSA 2021	23	3	152	1
24	Proceedings - 2022 4TH International Conference on Advances in Computing, Communication Control and Networking, ICAC3N 2022	24	3	155	1
25	Proceedings of the ACM Symposium on	25	3	158	1

	Applied Computing				
26	Security and Communication Networks	26	3	161	1
27	Smart Innovation, Systems and Technologies	27	3	164	1

Year-on-Year Growth of E-Voting Publications

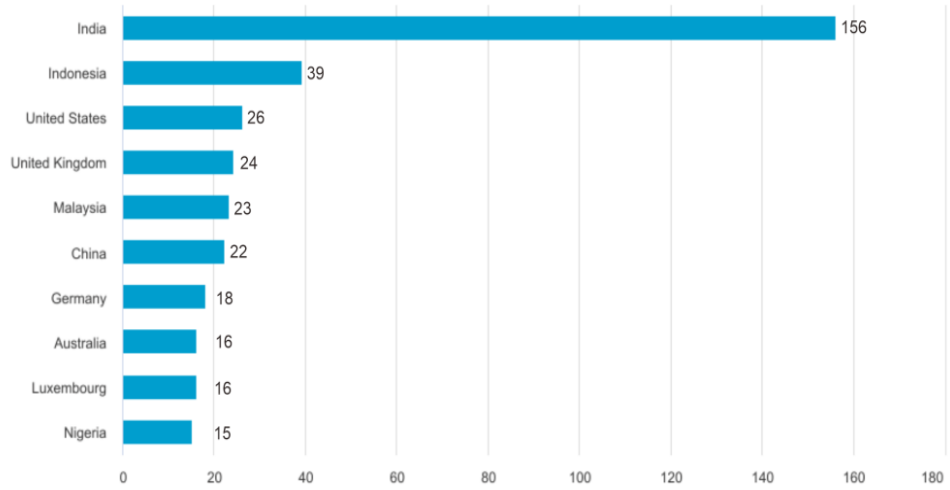
The analyzed data shows a significant growth in e-voting publications from year to year. This is reflected in the graph depicting the increase in the number of articles published from 2019 to 2023. Although e-voting is a relatively new topic in the scientific literature, more and more researchers are interested in exploring the potential application of this technology in electoral systems.

Figure 6. Document Growth by year



2019 marked the beginning of a surge in publications, with articles starting to appear in many technology and security journals. During this year, blockchain technology began to gain attention as a key solution to integrity and transparency issues in digital elections. The years 2020 to 2021 saw a sharp increase in the number of publications. This is closely related to the growing need for digital solutions for more secure, efficient and transparent electoral processes, especially after the COVID-19 pandemic that accelerated digitization in almost all sectors, including elections. The years 2022 and 2023 represent the peak growth of e-voting publications, indicating that this research is growing and being studied in many countries. This increase in the number of publications is influenced by various external factors, such as the pandemic accelerating the adoption of technology in various sectors, including elections. In addition, advances in technologies such as blockchain, cloud computing, and encryption are also driving more research in this area, which aims to ensure security and transparency in digitally-based elections.

Figure 7. Most relevant countries



The data from figure 6 shows the most relevant countries in e-voting research. These countries are pioneers in the development and implementation of e-voting technology, as well as being major centers of academic research focused on digital electoral systems. 2019 marked the start of a surge in publications, with articles starting to appear in technology and security journals. This year, blockchain technology began to gain attention as a key solution to integrity and transparency issues in digital elections.

Figure 8. Frequent Word Clouds[

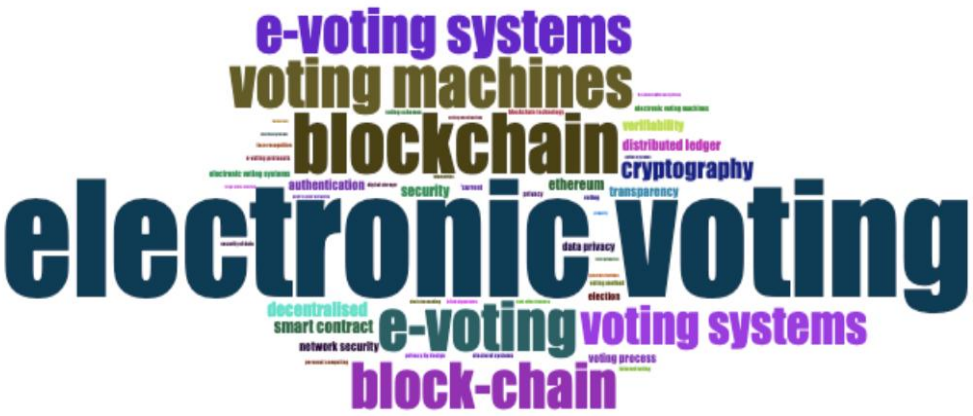


Figure 8. Frequent Word Clouds highlights the most commonly used terms in the literature related to electronic voting, offering insight into the main themes and technological focuses of current research. The term "electronic voting" appears as the most prominent, reflecting the central attention given to the transformation of traditional electoral processes through digital technologies. This suggests a growing scholarly concern with enhancing accessibility, efficiency, and accuracy in voting systems.

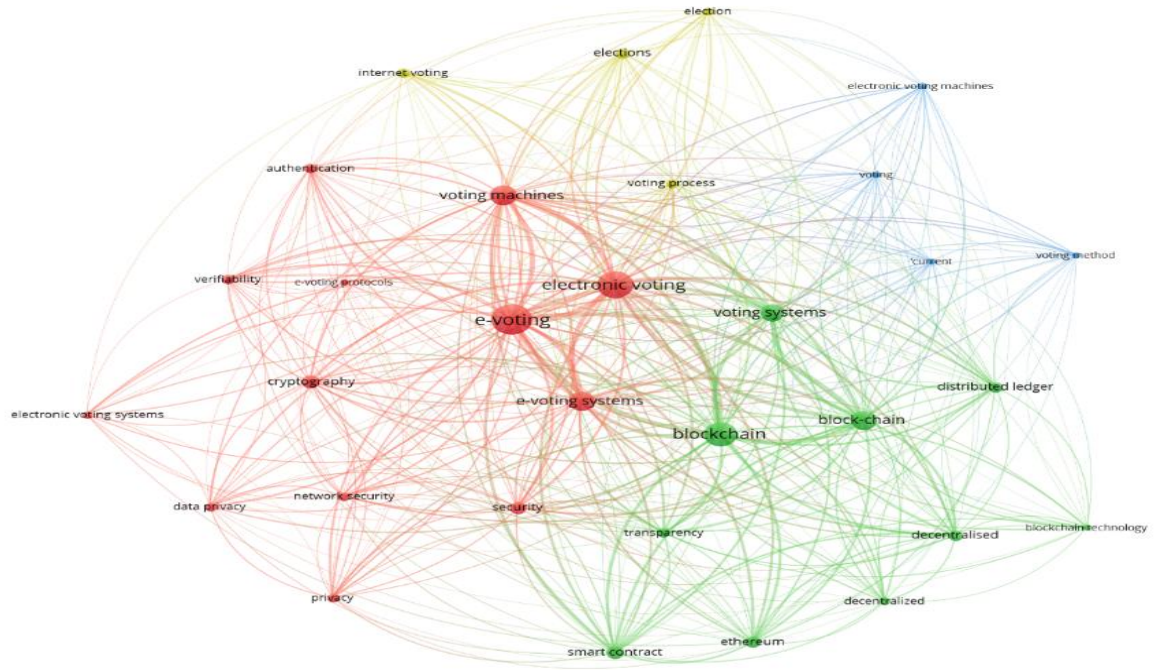
The prominence of the term "blockchain" underscores the increasing emphasis on transparency and data security within electronic voting frameworks. Similarly, terms such as "e-voting", "voting machines", and "e-voting systems" point to widespread interest in both the

conceptual foundations and the technical infrastructure of digital voting platforms. These terms also suggest that researchers are not only focusing on the voting process itself, but also on the systems and devices that enable it.

The appearance of terms like "cryptography", "decentralised", and "smart contract" highlights the growing importance of supporting technologies that ensure the reliability and trustworthiness of digital elections. These elements are essential for addressing concerns related to data integrity, voter privacy, and system automation.

Keyword Trends and Thematic Focus of E-Voting Research

Figure 9. Keyword co-occurrence



The co-occurrence analysis also showed a strong relationship between blockchain keywords and security, privacy, and transparency. These relationships suggest that blockchain is often used as a key solution to address e-voting challenges, especially in relation to security, privacy, and transparency of election results. Researchers are also increasingly linking blockchain with decentralization, reflecting a paradigm shift towards a more open and secure electoral system, where control is not centralized to a single entity or electoral body. This can strengthen the integrity of the system and reduce the potential for manipulation. These findings show a clear direction of e-voting research, which increasingly favors technology-based solutions to address security and trust issues in electoral systems, as well as creating systems that can be widely implemented in countries with various challenges.

Looking at the keyword frequency from year to year, it can be seen that there is a clear trend towards the increasing use of blockchain and security terms in e-voting research over time. This trend highlights a shift in focus in research that increasingly prioritizes decentralized technologies and deep security concerns. 2019: The first year that saw a significant spike in e-voting publications. In this year, many researchers began to focus on blockchain as a key solution to security issues in digital elections. This was the starting point where blockchain technology began to be recognized as a potential solution that addresses issues of transparency and vote

manipulation. 2020-2021: In these years, research increasingly focuses on developing security protocols and further testing the applicability of the technology in e-voting systems. The increased use of the keywords privacy and authentication indicates that researchers are increasingly recognizing the importance of personal data protection and voter identification in digital voting systems. 2022-2023: In this period, the frequency of using the keywords decentralization and transparency increases rapidly. This reflects that researchers are beginning to focus on how to implement systems that enable full transparency and decentralization in elections to minimize the potential for abuse of power and fraud.

Clustering of Research Themes: Security, Blockchain, and Election Systems

Based on the data obtained from the clustering analysis of keywords in e-voting research, the results show the existence of four main thematic clusters that are interlinked with the topics of security, blockchain, and electoral systems. Each of these clusters reflects a specific research focus, which gives an idea of how researchers approach important issues in e-voting implementation. The following is an in-depth description of each cluster:

The first cluster found in this analysis focuses on the theme of Security in e-voting systems. Keywords that appear with high frequency in this cluster include authentication, cryptography, data privacy, network security, and verification. Security is the most central theme in e-voting research, which shows that researchers are very concerned about the importance of voter data protection and the integrity of election results. Authentication and cryptography are fundamental components to ensuring that only legitimate voters can cast their ballots, as well as keeping the votes cast secure and not manipulated. Data privacy is a strong concern for the protection of voters' personal information, which is crucial in maintaining public trust in digital electoral systems. Network security refers to protection against cyber-attacks that could threaten the viability and reliability of e-voting systems. Verifiability is an important issue to ensure that every vote cast can be verified without compromising voter privacy.

The second cluster focuses on Blockchain, which is emerging as a key technology being adopted in e-voting research. Keywords in this cluster include blockchain, decentralization, distributed ledger, ethereum, smart contracts, and transparency. E-voting research shows a clear shift towards the use of blockchain to ensure transparency and reduce the potential for manipulation in the election process. Blockchain and distributed ledgers stand out as key technological solutions to create a decentralized election system, where election data is not under the control of a single entity, reducing the risk of abuse or fraud. Ethereum and smart contracts are essential components that enable the creation of an automated election system with clear and transparent rules, and reduce the possibility of human interference in the vote counting process. Transparency is emerging as one of the key benefits of blockchain implementation, giving the public the ability to openly verify the integrity of election results. This cluster confirms that blockchain serves not only as a security technology, but also as a tool to create public trust through transparency and decentralization. The blockchain-based system provides a solution to improve the integrity of the election system and reduce the potential for vote manipulation.

The third cluster focuses on topics that are more practical and relate to current e-voting implementations. Keywords found in this cluster include electronic voting machines, voting methods and current. This cluster reflects research that is more focused on how the current electoral system can be improved with digital technology, as well as the challenges faced in implementing e-voting. Electronic voting machines and voting methods show that a lot of research focuses on developing hardware and software that can be used for more efficient electronic voting.

The emphasis on the present shows that this research is highly relevant to the current situation, leading to the analysis and evaluation of how e-voting systems can be implemented in elections in different countries. The cluster further highlights the technical and logistical aspects of e-voting implementation, which include challenges in the development of tools that suit local and global needs, as well as the effectiveness of existing systems.

The fourth cluster deals with Elections and the Voting Process. Keywords in this cluster include election, elections, internet voting, and voting process. Research in this cluster often focuses on the social, political and legal aspects of e-voting implementation, including its impact on democratic processes and electoral policies. Election and elections focus on the application of e-voting systems in national and local elections, as well as the potential to increase voter participation and reduce logistical costs. Internet voting and voting processes shows interest in exploring internet-based voting, which offers easy access for voters around the world, but also faces challenges related to security and privacy. This cluster focuses more on the policy dimensions and social implications of implementing e-voting, and how it can affect democracy and electoral processes in different countries.

This research aims to provide a deeper understanding of the development of e-voting research by using a bibliometric approach. Some of the sub-issues raised in this research, such as the dominance of blockchain technology, the focus on security, and the clustering of themes, provide insights into how e-voting research is evolving and what challenges must be faced in the implementation of digital voting systems. The key findings in this research encompass several central themes evolving in the literature, each of which points to future directions and potentials for e-voting systems.

One of the most striking findings is the dominance of blockchain in e-voting research. Blockchain technology is emerging as a key proposed solution to improve the security, transparency, and integrity of votes in digital elections. Previous research such as that conducted by (Shahzad & Crowcroft, 2019) , which proposes the use of blockchain to increase voter confidence through a decentralized system, shows that blockchain is indeed promising in reducing vote manipulation and providing transparency. This is also supported by the findings in this study which show that blockchain is not just a security technology, but also provides the transparency needed to verify election results without interference undermining the integrity of the system. However, deepen the discussion for it showcase the critically the contents and information the main challenges faced are scalability and implementation costs, which are often a barrier to the adoption of this technology[B1.1], especially in countries with limited infrastructure, as mentioned in the study by (Gao et al., 2019).

This suggests that while blockchain technology has great potential, its implementation should be tailored to each country's conditions and capacity. The research findings also underscore the importance of security in e-voting systems. The main focus of research in this regard has been on the development of crypto and encryption protocols to protect votes and ensure only authorized voters can cast ballots. Privacy issues are also a major concern, with much research focusing on protecting voters' personal data from attacks and data theft. These findings are consistent with the results of a study (Faruk et al., 2024) that highlighted the importance of authentication and verification in securing digital electoral processes. Despite many innovations in terms of security protocols, challenges related to cyber-attacks remain a significant threat, especially with the increasing complexity of attack techniques against the digital infrastructure used in e-voting. This shows that while technology can provide solutions, developing and testing more secure systems is a step that should not be overlooked.

Furthermore, analysis of the clustering of themes in this study shows four main themes that continue to dominate e-voting research: security, blockchain, election process, and technology implementation. Security, as revealed in the first cluster, remains a top priority, with research focusing on increasing voter confidence through reliable and secure systems. Meanwhile, in the second cluster, research on blockchain continues to grow, with an emphasis on applying decentralized technology to prevent vote manipulation and increase transparency. The use of smart contracts and other decentralized technologies demonstrates how blockchain can automate the election process, improve the efficiency and accuracy of election results, and reduce the potential for human error in the vote counting process.

However, the electoral process and technology implementation clusters in this study point to another challenge that must be faced in the implementation of e-voting, which is related to the social and cultural appropriateness of the implemented system. As explained by (Faruk et al., 2024; Halwan et al., 2022). While technological innovations such as blockchain offer promising solutions for secure and transparent e-voting, their effective implementation depends heavily on local context particularly infrastructure, policy frameworks, and public trust in technology. In countries with limited governance capacity and low digital trust, adopting e-voting poses additional challenges. This study underscores that integrating technology with adaptive policy is essential, especially where institutional readiness is limited. The expansion of e-voting globally will require not only technical advancement but also practical governance strategies and strong political commitment to ensure legitimacy and sustainability

This research makes a significant contribution to enriching the understanding of e-voting implementation by highlighting blockchain's dominance, focus on security, and challenges in the implementation of digital election technology. The main significance of the findings lies in strengthening the understanding of how blockchain technology, as a decentralized tool, can address key challenges in digital election systems, such as transparency, vote integrity, and voter data protection. In addition, the findings highlight the importance of developing stronger security protocols to protect voters' votes from external and internal threats, which reinforces the urgency to adopt more secure systems in elections. However, this study also has some weaknesses, especially in terms of geographical limitations and coverage of the local context. The analysis focuses more on the existing literature, without fully considering the practical challenges faced by countries with limited digital infrastructure, such as in many developing countries. Further research is needed to explore how local policies, public trust, and socio-economic conditions may affect the successful adoption of e-voting in a more holistic and context-based manner. These limitations create gaps in research that do not fully address external variables that may affect the practical implementation of e-voting in different countries.

CONCLUSIONS AND RECOMMENDATIONS

This study aims to analyze the trends, challenges and future directions of e-voting implementation through a bibliometric approach, focusing on key issues faced in the development of digital electoral systems, such as security, blockchain and transparency. As interest in the adoption of technology in electoral systems increases, this research explores the dynamics in the existing literature, as well as identifying solutions that have been proposed in international research. The main findings of this literature review show that blockchain dominates research on e-voting showcase the consistency of stated information and results however offering a more deeper insight, in correlation with the future of research in e-voting, mainly due to its ability to increase transparency and reduce the potential for vote manipulation through decentralization and more secure vote verification. In addition, security and privacy

aspects remain key themes, with many studies focusing on encryption techniques and voter data protection. Network security, authentication, and vote verifiability are other important issues that need to be addressed for e-voting systems to be widely accepted and implemented. The findings contribute to the understanding of how technologies such as blockchain can be used to solve the challenges faced in digital elections, as well as how the integration between technology and policy can create a more transparent, secure, and efficient electoral system. The implications of this study also provide insights for policymakers and technology provide critical analysis for it will highlight specific actions and information developers regarding the direction that should take to effectively implement e-voting in different countries. But this study has limitations in terms of geographical coverage and may not fully represent the specific challenges faced by countries with lower technological infrastructure. Therefore, the recommendation for future research is to conduct further studies on the challenges of e-voting implementation in developing countries, as well as how local policies may affect the adoption of this technology. Further research, targeted studies are needed to explore how e-voting platforms can be designed to reflect specific cultural, institutional, and electoral norms, such as in rural Indonesia, sub-Saharan Africa, or conflict-prone regions, where election integrity and accessibility are persistent issues. Such context-driven research will be crucial for developing inclusive and resilient e-voting solutions.

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