DIGITAL ELECTORAL RECAPITULATION SYSTEMS AND GOVERNANCE MODELS: COMPARATIVE INTERNATIONAL EVIDENCE

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Abstract

This study compares the management of election recapitulation information systems in Indonesia with those implemented in the Philippines, Brazil, Estonia, and Kyrgyzstan to examine differences in governance, system design, security mechanisms, digital infrastructure, transparency, and public trust. Although these countries have adopted various election technologies, ranging from optical scanning and Electronic Voting Machines (EVM) to Internet voting (i-voting) and optical tabulation, comprehensive comparative studies that position Indonesia within this international context remain limited. This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines. Data were collected from the Scopus database and supported by credible reports, while CiteSpace was used to map research trends and identify knowledge gaps. The findings reveal significant differences in the maturity of election recapitulation systems. Estonia and Brazil have achieved advanced digital election management through integrated digital governance, secure verification mechanisms, and high public trust. The Philippines applies a hybrid model combining paper ballots with automated vote counting, whereas Kyrgyzstan continues to rely largely on manual procedures. Indonesia's Sirekap represents an intermediate stage of digital transformation but continues to face challenges related to security, OCR accuracy, infrastructure readiness, and public trust. The theoretical contribution of this study is the development of a Comparative Governance Framework for Election Recapitulation Information Systems, demonstrating that system maturity is determined not only by technological adoption but also by the interaction among governance, security, digital infrastructure, transparency, and public trust. This framework provides a foundation for evaluating and improving election recapitulation systems in emerging digital democracies.

Keywords: Elections; Indonesia; Information Systems; Recapitulation; Technology

1. Introduction

Various countries that have implemented election recapitulation information systems show that the use of technology in the vote tabulation process brings a number of important issues that need to be taken seriously. Countries such as the Philippines use an automatic vote counting machine (optical scan), retaining the ballot paper as physical evidence, while the results are sent electronically to the center (Yu, 2025). This hybrid model raises important issues related to data integrity, as digital processes must be ensured not to change physical results (Risnanto et al., 2022;

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Sahib & Alshamery, 2021). In Brazil, which uses electronic voting machines (EVMs) (Arifin et al., 2025), the entire voting and vote counting process is done electronically (Rahim & Achir, 2023).

This raises critical issues around cybersecurity, potential device vulnerabilities, and the importance of independent audits to keep systems trusted by the public (Albala et al., 2023). Meanwhile, Estonia, as a pioneer of internet-based i-voting, faces strategic issues related to network security, voter authentication, and digital identity protection (Nagarajan et al., 2025), considering that the entire process depends on a strong national digital ecosystem. Kyrgyzstan implements a biometric registration system and optical tabulation (Ohize et al., 2025), which raises important issues regarding biometric privacy, the reliability of optical tabulator devices, as well as technical challenges in transmitting data to central servers.

From these various practices, several important issues that consistently arise due to the adoption of digitalization are the security and integrity of the system, because all digital processes are vulnerable to manipulation or cyberattacks, transparency and accountability, so that the public and election participants can trace the process from the ballot to the final result, the reliability of technology and the readiness of infrastructure, especially in countries with geographical conditions or uneven connectivity, and public trust, which is a determining factor in whether technology is accepted or actually raises suspicion (Aranha et al., 2023; Chavan et al., 2024; Makka & Thota, 2024). In addition, the issue of legal framework and inclusivity also arises, especially to ensure that the use of technology does not create inequality for people who are less familiar with digital systems.

The functions of the government reflect the quality of governance; if the government is able to carry out all of its functions optimally, then the quality of government administration will also be seen as good (Firiansyah, I. 2025). In Indonesia, the use of recapitulation information systems such as Sirekap still functions as a transparency tool in the tiered manual recapitulation process, thus raising a number of important issues related to its effectiveness (Haryadi et al., 2022). Key challenges include technology and infrastructure reliability, especially in areas with limited connectivity; system security and data integrity, as potential scan errors, technical glitches, or cyber risks may affect public trust; and transparency and accuracy, where the mismatch between digital data and physical forms often triggers negative perceptions (Rahmadhani et al., 2025). In addition, public trust is a central issue because technical errors are often interpreted as fraud, while legal frameworks that still place digital systems as tools to produce legitimate results still rely on physical documents (Averin et al., 2023).

Various countries, including the Philippines, Brazil, Estonia, and Kyrgyzstan, have adopted different election recapitulation information system models according to their institutional capacity and level of electoral digitalization. However, previous studies have predominantly examined technological implementation, cybersecurity, or electoral administration within individual country contexts, with limited attention to cross-country comparative analyses using common governance dimensions. The Philippines, Brazil, Estonia, and Kyrgyzstan were selected as comparative cases because they represent different models and levels of electoral digitalization, ranging from hybrid systems that combine digital transmission with physical ballots to fully electronic and internet-based voting systems. This variation provides a relevant basis for comparing how differences in system design, institutional capacity, infrastructure, security

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mechanisms, transparency, and public trust shape the governance of election recapitulation information systems in Indonesia.

Consequently, there remains a significant research gap in understanding how governance arrangements, system design, security mechanisms, digital infrastructure, transparency, and public trust collectively shape the maturity of election recapitulation information systems. To address this gap, this study conducts a comparative analysis of Indonesia and four countries representing different levels of electoral digitalization, with the aim of developing a comprehensive governance perspective for evaluating and improving election recapitulation information systems.

2. Methods

This study uses the Systematic Literature Review (SLR) design by following the guidelines of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) so that the process of searching, selection, and synthesis of literature runs transparently and structured (Carrion et al., 2025; Faraji et al., 2025). Data is obtained from various academic databases, such as Scopus, and sourced from credible news data such as CNNIndonesia.com, and Tempo.co to enrich the empirical context. The inclusion criteria include articles that discuss the use of information systems in elections in various countries. Literature that meets the requirements is then analyzed using the Citecpace application to code, map themes, and visualize the relationships between concepts (Klarin, 2024; Younus et al., 2024).

Data Collection

The flow of article selection uses PRISMA guidelines in the implementation of Systematic Literature Review (SLR). The process begins at the identification stage, where reputable academic sources such as Scopus, Web of Science, IEEE, Springer, MDPI, ACM, SAGE, Oxford University Press, and Elsevier become the main data collection bases.

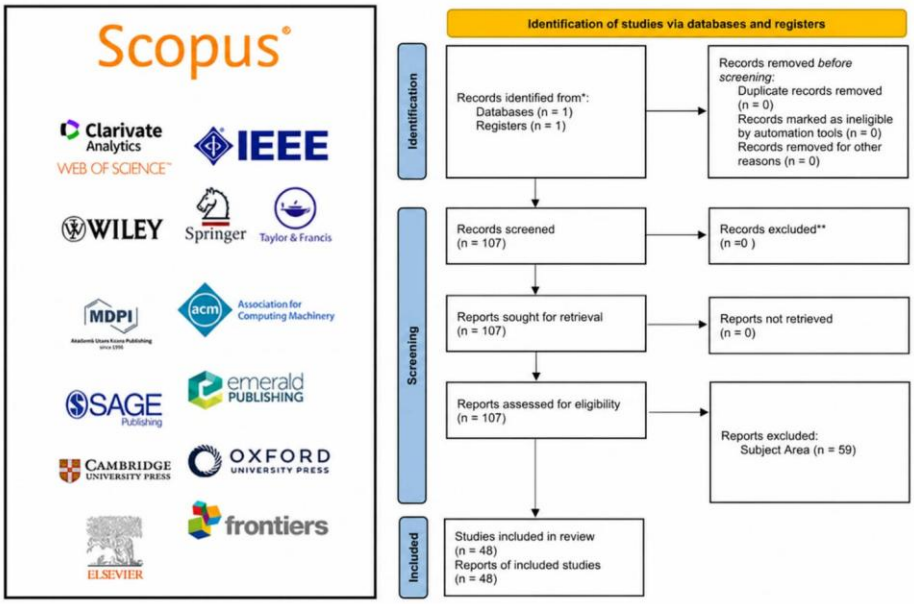

Figure 1. PRISMA Workflow Election Recapitulation Information System Articles
Source: processed by researcher, 2026

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From the initial search process, 107 article records were obtained from relevant databases and registers. At this stage, there are no duplicates or articles that must be removed before the filtering process. The next stage is screening, where all 107 articles go through an initial assessment process for titles, abstracts, and topic suitability. String pencarian menggunakan TITLE-ABS-KEY (("election recapitulation system" OR"vote recapitulation system" OR "electronic vote recapitulation" OR "vote counting system" OR "vote tabulation system" OR "election information system" OR "election management information system" OR "electoral information system" OR "electronic election system" OR "e-voting system") AND (information system OR digitalization OR digital transformation OR technology OR application OR platform)) AND PUBYEAR > 2019 AND PUBYEAR < 2026 No articles were eliminated at the initial screening stage, so all articles were continued to the retrieval stage and all reports were made accessible (n = 107). This stage is then followed by an eligibility assessment, where articles are examined in more depth based on the inclusion and exclusion criteria that have been set. At the eligibility stage, as many as 59 articles were eliminated because they were from 2020–2025, which was set according to the research limits. This resulted in 48 articles ready to be processed in this study. The last stage is included, which is the collection of final articles that meet all methodological and thematic requirements. Of the total selected articles, 48 articles were declared to meet the criteria and included as the main material in the SLR analysis.

3. Results and Discussion

To provide an overview of the research publication trends underpinning this study, it is necessary to examine the distribution of documents by year. The following graph illustrates the number of documents identified during the 2020–2025 period, thereby offering insight into the evolution of academic interest in the topic over time.

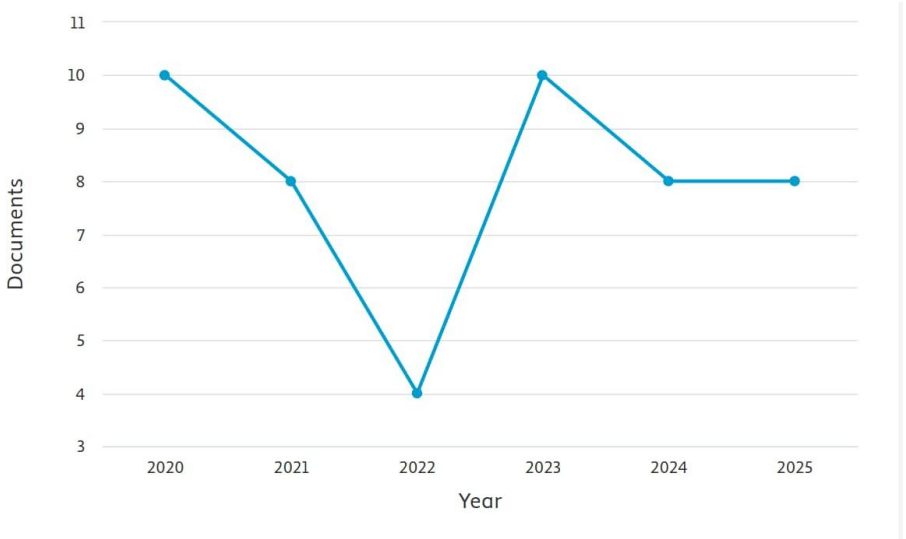

Figure 2. Dokumen by Year
Source: processed by researcher, 2026

The first image presents the development of the number of documents published from 2020 to 2025, with a total of 48 articles over the six years. This document is used to examine

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trends in research related to the use of digitalization in the electoral sector (Lawelai et al., 2025; Younus et al., 2023). This trend shows a fairly interesting fluctuating pattern. In 2020, the number of publications was at a high level of 10 articles, reflecting the beginning of a productive research period. However, in 2021, there was a slight decrease to 8 articles, which can still be categorized as stable. A significant decline occurred in 2022 when the number of publications declined sharply to only 4 articles, indicating a slowdown or decline in research activity in that year. However, this condition did not last long, because in 2023 the number of documents jumped dramatically again to 10 articles, marking a strong recovery in research productivity. Entering 2024 and 2025, the number of publications shows stability at 8 articles in each year, reflecting a more consistent rhythm of publication after going through a fairly sharp phase of ups and downs in previous years.

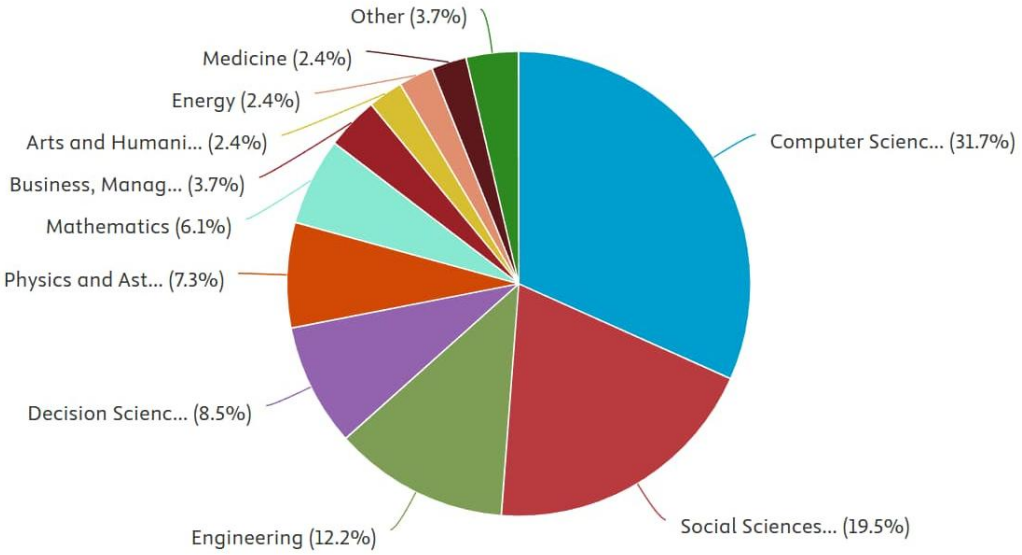

Figure 3. Dokumen by Subject Area
Source: processed by researcher, 2026

The second image illustrates the distribution of the 48 articles based on the scientific field that is the focus of the research. The presentation of documents by subject area is expected to allow one to see the focus of the study from related research (Lubis et al., 2025). The composition of the publication shows that Computer Science dominates significantly, with a contribution of 31.7%. This shows that topics related to computing, information technology, artificial intelligence, and digital systems are the main concerns in research activities. Furthermore, Social Sciences became the second largest field with 19.5%, which shows that studies related to humans, society, government, and social phenomena continue to play an important role—followed by the Engineering/Engineering sector with 12.2%, which indicates a considerable contribution to the themes of technological innovation and engineering.

The field of Decision Science came out with a contribution of 8.5%, reflecting attention to data-driven decision-making and systems analysis. Meanwhile, the fields of Physics and Astronomy accounted for 7.3%, and Mathematics accounted for 6.1%, both showing the role of basic disciplines in supporting the development of cross-field research. The Business and Management fields contributed 3.7%, while the Humanities, Energy, and Medicine fields were

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at 2.4% each, suggesting that although the proportion is small, the research still touches on the humanitarian, sustainable energy, and health aspects. Finally, the "other" category makes up 3.7% of publications, illustrating a diversity of topics that don't fully fall into the main categories.

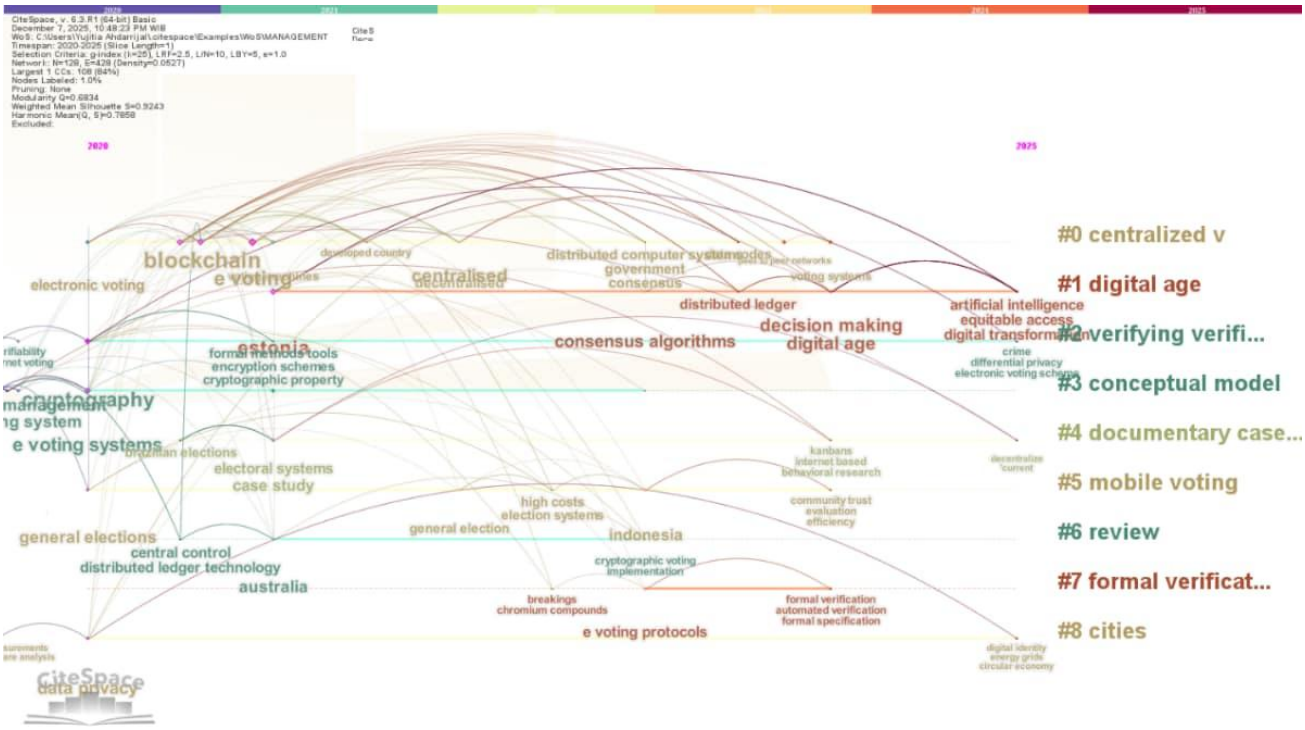

Figure 4. Data processing results with Citespace Application
Source: processed by researcher, 2026

The image is a visualization of a knowledge map that shows the interconnectedness of various keywords in research on e-voting systems, information security, blockchain, and digital transformation in the context of elections. Processing using the citespace application so that later we can see the distribution of research that can be used as a reference in data mapping (Luan & Feng, 2025; Song et al., 2023). On the left side of the visualization, keywords such as electronic voting, cryptographic protocols, e-voting systems, and data privacy dominated the initial study (around 2020). These themes reflect the world's research focus on the basic foundations of securing the digital electoral system. Such as research that has been conducted by (Lubis et al., 2025) which says that with digitalization, security protocols will be needed. Digital adoption in various fields allows cybercrime to occur. So there needs to be strict supervision on its implementation.

This context is very relevant to the topic of the study, as countries such as Estonia and Brazil have long developed mature security protocols in their vote recapitulation systems, which are much more stable than Indonesia's, which still faces challenges with the Sirekap system. According to research conducted by Ueshige & Sakurai (2025) and Velmet (2025), security protocols have been implemented in Estonia, given that digitalization has been implemented. In other words, the state has conceptualized the form of digital implementation to the maximum in various aspects (Xi & Wang, 2024). Meanwhile, in Indonesia, the implementation has not been optimal, including in the use of technology and the legal basis,

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which remain minimal (Haryadi et al., 2022; Rahmadhani et al., 2025). The Sirekap application needs to be refined in various aspects to support the implementation of a recapitulation system that satisfies all levels of society (Amir et al., 2025; Kendal, 2025).

In the middle of the knowledge map, there is a shift towards more advanced themes, such as blockchain, distributed ledger, and consensus algorithms, to technical applications in the context of elections, such as general elections, case studies, and centralised vs decentralised systems. This dynamic is very relevant to compare Indonesia's system with other countries, especially countries like Estonia that have implemented decentralized technology in their election systems (Setiawan, 2023). Meanwhile, Indonesia still uses a more centralized approach in Sirekap and relies heavily on C1 uploads by KPPS (Munawaroh, 2023). This correlation shows how developed countries in electoral digitalization have adopted mechanisms that encourage high reliability, while Indonesia is in the stage of strengthening the system (Habibi & Nurmandi, 2018).

On the right side of the map, keywords that have emerged in more recent years, such as decision-making, digital age, artificial intelligence, trust, formal verification, and equitable access, illustrate that global research is already moving towards the integration of smart technologies (Ndiaye et al., 2026), formal validation (Ranerup & Henriksen, 2019), and the building of public trust in digital electoral systems (Chavan et al., 2024). This is directly correlated with the actual issues in Indonesia related to trust in Sirekap, especially in the 2024 election, which is colored by debates about the accuracy of OCR, transparency of digital recapitulation, and the readiness of regional infrastructure. In comparison, Estonia and Brazil are already in the stage of formal verification and automated digital audits, while Indonesia is only entering the stage of developing internal validation capabilities. Based on data from CNN Indonesia in 2024, which reveals the ineffectiveness of the Sirekap application because the KPU does not understand the system (Cnnindonesia.com, 2024).

The clusters shown on the right side, such as #0 centralized v, #1 digital age, #2 verification, #3 conceptual model, and #8 cities, indicate the direction of an increasingly multidisciplinary world of research. These themes are very relevant when associated with the focus of this research, because the management of recapitulation information systems is no longer only about technology, but also about how the system is managed, verified, trust is built, and it is integrated with the geographical and social context of a country. Comparisons with Indonesia show that countries such as Estonia have implemented a mature digital governance model(Rodima-Taylor, 2021), while Indonesia is still strengthening the conceptual and management model of Sirekap implementation. The Tempo.co media also mentioned that the existence of Sirekap made the community unable to supervise the election to the maximum (Tempo.co, 2024).

The bibliometric analysis in this study was not intended to directly compare Indonesia's election recapitulation information system with those of other countries. Instead, it was employed to map the research landscape, identify major research themes, examine technological developments, and determine the countries that have been the primary focus of previous studies. The timeline visualization reveals a clear shift in research emphasis from topics such as electronic voting, blockchain, and cryptography toward more recent issues, including artificial intelligence, digital transformation, verification, and formal verification.

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Furthermore, countries such as Estonia and Australia emerge as dominant research contexts, whereas Indonesia appears only in a limited number of studies and is primarily associated with the implementation of cryptographic voting and security protocols. These findings indicate that studies specifically comparing Indonesia's election recapitulation information system with those implemented in other countries remain scarce.

This mapping served as the basis for selecting the comparative case countries, namely the Philippines, Brazil, Estonia, and Kyrgyzstan, which represent different characteristics and levels of electoral digitalization maturity. The comparative analysis was subsequently conducted through a Systematic Literature Review of articles that met the predefined inclusion criteria by examining governance arrangements, system design, security mechanisms, digital infrastructure, transparency, and public trust. Therefore, the bibliometric analysis provides an overview of the evolution of research and confirms the existence of a research gap, while the study's primary objective is addressed through a comparative synthesis that identifies the similarities and differences between Indonesia's election recapitulation information system and those implemented in countries with more advanced electoral digitalization.

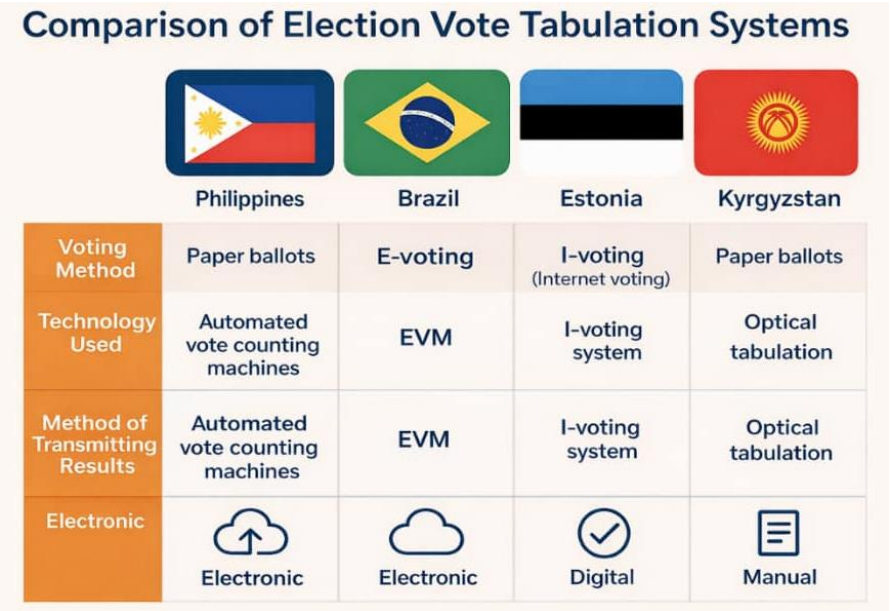

Figure 5. Results Of Researcher Data Processing
Source: processed by researcher, 2026

The image shows a comparison of the election recapitulation systems in four countries: the Philippines, Brazil, Estonia, and Kyrgyzstan, each of which uses different methods, technologies, and methods of transmitting election results. The Philippines, for example, continues to use paper-based voting, but its recapitulation process has been supported by automated vote-counting machines. Although the collection is still done manually, the counting and transmission of the results are done through an electronic system, thus speeding up the recapitulation process (Thakur, 2014). This system can be compared to Indonesia's Sirekap, which also relies on the digitization of the recapitulation stage, but still faces challenges in the accuracy of network scanning and distribution.

Brazil shows a higher level of digitalization by implementing full e-voting using Electronic

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Voting Machines (EVMs) (Shadab et al., 2023). The entire process, from voting to recapitulation, takes place electronically, and the results are transmitted over a network that has been secured by the government (Pegorini et al., 2021). This country is an example of how a fully computerized system can reduce the potential for human error and speed up calculations. The comparison with Indonesia shows a significant difference, because Indonesia has never used national e-voting and still relies on manual inputs that are then digitized.

Estonia is the most advanced country in terms of digitizing elections with the use of i-voting, which is remote voting based on digital identity (digital ID). The recapitulation technology used is an integrated i-voting system, which allows the results of the vote to be delivered digitally with a high level of security through multi-layered encryption and verification (Velmet, 2025). Estonia is an ideal example of how election information system management can be managed in a modern, secure, and efficient manner. Compared to Indonesia, which is still in the stage of partial digitization through Sirekap, Estonia shows the highest standards in the management of the digital recapitulation system.

In contrast, Kyrgyzstan still adopts paper-based voting methods and optical tabulation technology to scan ballots (Sheranova, 2020). The results of the recapitulation are still mostly done manually, showing a low level of digitalization compared to other countries. Kyrgyzstan can be used as a comparison for Indonesia in terms of the transition from manual to semi-digital systems. Although Indonesia is more advanced than Kyrgyzstan, both face similar challenges regarding data accuracy, validity of recap results, and consistency of manual and digital verification. This comparison shows that countries have different levels of technology use, ranging from fully digital (Estonia), partially digital (Brazil and the Philippines), to predominantly manual (Kyrgyzstan).

Figure 1. Comparative Framework of Election Recapitulation Information Systems

Comparison Aspect	Indonesia	Philippines	Brazil	Estonia	Kyrgyzstan
Voting Method	Paper ballot	Paper ballot	E-voting	Internet Voting (I-Voting)	Paper ballot
Recapitulation Technology	Sirekap (OCR-based)	Automated Vote Counting Machines	Electronic Voting Machine (EVM)	Integrated I-Voting System	Optical Tabulation
System Governance	Centralized by KPU	Centralized Election Commission	Centralized Electoral Authority	National Digital Governance	Centralized Election Commission
Security Mechanism	OCR validation, manual verification	Machine verification	Digital authentication and encryption	Digital ID, end-to-end encryption, formal verification	Optical verification and manual validation
Digital Infrastructure	Moderate	High	High	Very High	Moderate
Transparency	Public access through Sirekap, still	Electronic publication of results	Fully electronic publication	End-to-end digital transparency	Limited digital transparency

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Comparison Aspect	Indonesia	Philippines	Brazil	Estonia	Kyrgyzstan
	debated				
Public Trust	Moderate–Low	Moderate–High	High	Very High	Moderate
Main Challenges	OCR accuracy, infrastructure inequality, legal framework	Machine reliability	Cybersecurity and audit integrity	Privacy protection and cybersecurity	Manual verification and limited infrastructure

Source: processed by researcher, 2026

Comparative framework of election recapitulation information systems across Indonesia, the Philippines, Brazil, Estonia, and Kyrgyzstan. Unlike the bibliometric analysis, which was used to map the research landscape, this comparison directly addresses the research objective by examining six common dimensions: voting method, recapitulation technology, governance model, security mechanisms, digital infrastructure, transparency, and public trust. Using a unified comparison framework makes it possible to identify both the similarities and differences among countries in implementing election recapitulation systems.

The comparison demonstrates substantial variation in the level of electoral digitalization. Estonia represents the most advanced model, supported by a nationwide digital identity infrastructure, Internet voting, formal verification mechanisms, and high public trust. Brazil has also achieved a high level of digital maturity through the nationwide implementation of Electronic Voting Machines (EVMs), enabling electronic voting and automated vote tabulation. In contrast, the Philippines maintains paper-based voting while employing automated vote-counting machines to accelerate vote tabulation, representing a hybrid digital model. Kyrgyzstan continues to rely primarily on paper ballots and optical tabulation, reflecting a relatively low level of electoral digitalization.

Indonesia occupies an intermediate position in this comparison. Rather than implementing fully electronic voting, Indonesia digitalizes only the vote recapitulation stage through the Sirekap application. This approach improves the efficiency of result transmission while maintaining conventional paper ballots during voting. However, the comparison also highlights several persistent challenges, including OCR accuracy, unequal digital infrastructure, legal and regulatory limitations, and public trust in digital recapitulation. Compared with Estonia and Brazil, Indonesia has not yet implemented advanced mechanisms such as digital identity integration, formal verification, or comprehensive automated auditing. These findings indicate that future improvements should focus not only on technological enhancement but also on strengthening governance, cybersecurity, transparency, and institutional trust to achieve a more reliable election recapitulation information system.

4. Conclusion

The findings demonstrate that the management of election recapitulation information systems has evolved from emphasizing basic electronic voting security toward integrating advanced technologies such as blockchain, distributed ledger, artificial intelligence, and formal verification. This evolution indicates that modern election recapitulation systems require not

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only technological innovation but also robust governance mechanisms capable of ensuring transparency, accountability, cybersecurity, and public trust. Within this development trajectory, Indonesia remains in the institutional strengthening phase through the implementation of Sirekap, whereas Estonia and Brazil have achieved higher levels of digital maturity by integrating secure digital identities, automated verification, and comprehensive digital governance.

The comparative analysis further reveals that each country adopts a different pathway toward electoral digitalization according to its institutional capacity, technological infrastructure, and governance readiness. Estonia represents a fully integrated digital model, Brazil demonstrates centralized electronic voting, the Philippines applies a hybrid model combining paper ballots with automated tabulation, while Kyrgyzstan continues to rely predominantly on manual procedures. Indonesia occupies an intermediate position, having digitalized the vote recapitulation stage without fully transforming the voting process itself. These differences indicate that technological adoption alone does not determine the effectiveness of election recapitulation systems.

The main theoretical contribution of this study is the development of a Comparative Governance Framework for Election Recapitulation Information Systems, which synthesizes evidence from multiple countries and demonstrates that the maturity of election recapitulation systems is shaped by the interaction of six interrelated dimensions: governance arrangements, system design, security mechanisms, digital infrastructure, transparency, and public trust. Previous studies have primarily examined these dimensions separately or within individual country contexts. In contrast, this study integrates them into a unified comparative framework that explains variations in election recapitulation system maturity across countries. This framework extends the existing literature by providing a multidimensional perspective for evaluating and comparing election recapitulation information systems rather than focusing solely on technological implementation.

From a practical perspective, the proposed framework provides strategic guidance for improving Indonesia's Sirekap system. Future development should not only emphasize technological enhancement but also strengthen governance capacity, institutional regulations, cybersecurity, digital verification, infrastructure readiness, and mechanisms for building public trust. Consequently, sustainable digital transformation in election recapitulation requires an integrated governance approach that aligns technological innovation with institutional capability and democratic legitimacy.

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