

Review Article

Towards More Inclusive Elections: State of the Art and Challenges of Electronic Voting for People with Disabilities in Developing Countries

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ABSTRACT

Aim: This study examines the current state of electronic voting (e-voting) technologies and their implications for accessibility for people with disabilities, with particular attention to developing countries. It aims to identify key technological approaches, structural barriers, and design gaps affecting inclusive electoral participation.

Method: A systematic review was conducted using the *PRISMA* methodology, analyzing publications from 2018 to 2023 in databases such as Scopus, Web of Science, Science Direct, Wiley, and IEEE. The review focused on studies addressing e-voting technologies explicitly linked to accessibility and disability inclusion, excluding works that discussed electronic voting without reference to people with disabilities.

Results: The findings highlight *blockchain* technology as a promising solution due to its security and transparency features. However, major barriers remain, including the digital divide, lack of inclusive design, and absence of legal frameworks supporting electronic voting for people with disabilities. While some countries, such as Estonia, have successfully implemented remote voting, there are still no widespread solutions tailored to people with disabilities in developing regions.

Conclusions: The findings highlight the need for e-voting systems that integrate accessibility requirements from the design stage, ensuring usability, autonomy, and non-stigmatizing participation. Future research should advance toward pilot implementations of accessible e-voting systems in developing countries, combining biometric authentication and assistive technologies within inclusive public policy frameworks.

Keywords: Electronic voting, accessibility, blockchain, disability inclusion, developing countries.

INTRODUCTION

In the context of a globalized world where democracy stands as the cornerstone of

Editor: Solomon Mekonnen

Article History:

Received: February 18, 2025

Accepted: December 31, 2025

Published: March 18, 2026

Citation: Jomark Noriega, Ana Vargas, Jorge Castañeda, Augusto Bernuy, Towards More Inclusive Elections: State of the Art and Challenges of Electronic Voting for People with Disabilities in Developing Countries. *DCIDJ*. 2026, 37:1. doi.org/10.20372/dcidj.859

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most nations, the right to vote emerges as an incontrovertible principle. States are mandated to ensure the participation of all citizens, as this constitutes the foundation of any democratic regime. However, despite efforts to deploy resources and logistics, not all nations succeed in securing the inclusive participation of their electorate. This problem is particularly evident in the case of individuals with disabilities or those with conditions that prevent them from moving to exercise their right to vote.

The gap in inclusive suffrage highlights a significant issue: equitable access to voting. Although technological advancements have suggested that the development of electronic voting systems could facilitate the exercise of the right to vote for those unable to move, there are still considerable limitations and gaps in the current solutions.

To address this gap, the present work conducts a systematic review of contemporary literature worldwide, with the goal of identifying advanced technologies available in electronic voting for people with disabilities. This analysis aims to answer two critical questions: What are the advanced technologies in electronic voting available to people with disabilities? And what are the limitations and gaps existing in the advanced technological solutions for electronic voting targeted at this group? Through this approach, the study seeks to contribute to narrowing the gap in access to suffrage, promoting more inclusive participation in democratic processes globally.

METHOD

This study represents a systematic review that follows the *PRISMA* method (Moher et al., 2019). The search strategy covered several databases, including Google Scholar, Scopus, Science Direct, Web of Science, Wiley, and IEEE.

The specified inclusion criteria were articles published between 2018 and March 2023, in English or Spanish, with full text access. Exclusion criteria were applied to previous reviews, duplicate articles, and those without a relevant technological component. The search terms used were: “E-VOTING” AND (SYSTEM OR SCHEMES) AND ONLINE AND DISABLED PEOPLE.

The initial search resulted in 155 articles. Applying the *PRISMA* (Preferred Reporting Items for Systematic reviews and Meta-Analyses) method, 99 articles were excluded after a title review due to a lack of coherence with the topics of interest. An additional 14 articles were discarded after reviewing the abstracts for not adequately addressing technologies for electronic voting (e-voting) or technologies intended for people with disabilities. Then, 18 articles were excluded after full reading for focusing on medical or psychological aspects.

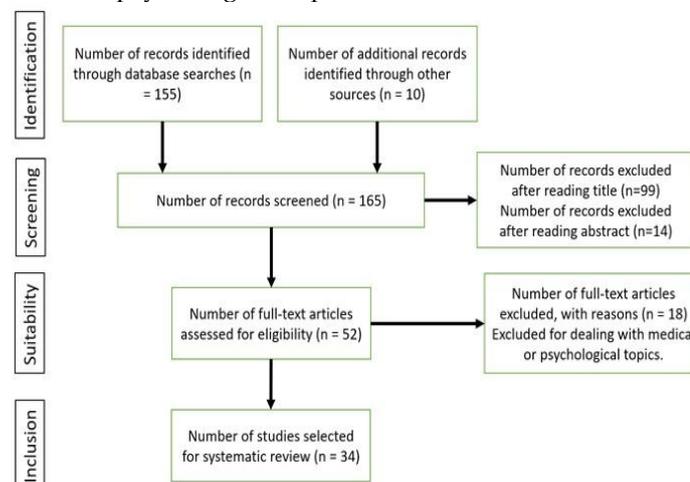


Figure 1: PRISMA Method

Furthermore, 10 references were manually added that were considered relevant due to their formality or because they were cited by the reviewed articles, focused on research about conditions for *e-voting*. This process is summarized in the *PRISMA* flow diagram (see Figure 1). Within this discussion, an *e-voting* model adapted for people with disabilities is proposed, focused on the context of the Peruvian state, but that could be adapted to other realities. This proposal takes into consideration both access to information and detailed knowledge of the electoral process by the authors. It is important to recognize that the development of this research could be influenced by the personal experiences and academic background of the authors. However, the importance of maintaining objectivity and impartiality in the study will be emphasized. To this end, the *PRISMA* method will be applied rigorously, with the goal of minimizing possible biases and ensuring the quality and relevance of the results obtained.

CURRENT RESEARCH

The right to free, direct, universal, secret, honest, and in certain cases, compulsory voting is fundamental in the constitutions of democratic governments, as evidenced in various legislations and international studies (Arshad et al., 2021; Fahri and Hardianto, 2022; Cámara de Diputados del Honorable Congreso de la Unión, 2021; Presidencia de la República de Ecuador, 1998; Rathore, 2022). Similarly, the Political Constitution of Peru establishes that votes must reflect “the authentic, free, and spontaneous expression of citizens,” ensuring that results are an exact and timely reflection of the voters’ will (Presidencia de la República del Perú, 1993). In Colombia, the Constitution emphasizes the state’s obligation to guarantee coercion-free, secret voting in individual booths, also facilitating the use of electronic or computer means for this purpose (Presidencia de la República de Colombia, 2011).

Defensoría del Pueblo del Perú (2018) has identified that the main difficulties for people with disabilities in voting relate to the transfer and access to polling places, as well as a lack of knowledge by electoral personnel about the specific needs for attention. According to the Instituto Nacional de Estadística e Informática (2019), the 2017 census revealed that 10.3% of the population has some type of permanent disability that affects their daily activities, with this percentage being 11.5% for women and 9% for men. Figure 2 illustrates the different degrees of disability and their distribution by age range, highlighting that 82.6% are of legal age and 57.1% are in the age group obliged to participate in electoral processes (Consejo Nacional de Discapacidad [CONADIS], 2022). Although people registered with CONADIS can request exemption from electoral fines due to their condition (Organismo Nacional de Procesos Electorales, 2021), this does not exempt them from the right to vote.

Table 1: Development of electronic voting in the World Last election or experience(years)

Status	<5	6-10	>10	Total
Implemented	6	-	3	9
Under study or partially implemented	11	3	5	19
Legally prohibited or halted	-	6	1	7
Total	17	9	9	35

Source: Department of Security of the Basque Government. (August 7, 2022)

However, cross-country comparisons regarding the electoral participation of persons with disabilities are constrained by significant variability in the availability and quality of official data. Differences in legal definitions of disability, civil registration systems, and national census methodologies affect the identification of eligible

voters with disabilities and limit the comparability of participation figures across jurisdictions. According to the *Voto electrónico en el mundo*. (<https://www.euskadi.eus/informacion/votoelectronico-voto-electronico-en-el-mundo/web01a2haukon/es/>), electronic voting has experienced significant evolution worldwide. To date, it has been officially implemented in nine countries, while seven have chosen to legally ban or suspend its use. In addition, there are studies and partial implementations ongoing in another 19 countries (see Table 1). Among the countries that have adopted this technology, Estonia stands out as the most advanced in terms of development and electoral participation through electronic voting.

Sreekanth et al. (2022) emphasize that in democratic societies, the constitutional right to vote is granted, allowing citizens to choose their representatives and thereby influence the destiny of their country. Despite the perception that a single vote may seem insignificant, history has shown that a small number of votes can induce significant changes. Thangavel et al. (2022) highlight that one of the purposes of electronic voting is to improve accessibility for people with disabilities. In this sense, De Silva et al. (2021) argue that the traditional voting method, in which visually impaired people are assisted, compromises their right to a secret vote. Pethig and Kroenung (2019) point out that approximately 15% of the world’s population has some disability, a figure that increases with aging. They identify two critical factors in the adoption of technologies: the perception of their usefulness and the awareness of the status acquired by using them. They emphasize the importance of evaluating any initiative aimed at people with disabilities to avoid stigmatization and potential rejection. According to Thangavel et al. (2022), the electoral process consists of four stages: composition, issuance, registration, and tabulation. The main challenge is “to maintain confidentiality, verify integrity, and ensure authenticity throughout the process.” They argue that *blockchain* technology could meet these requirements, treating each vote as a link in the chain with a unique cryptographic identity, and if the information of a link is altered, the chain would break, evidencing any attempt at fraud (Giraldo et al., 2021; Thangavel et al., 2022). Additionally, they propose that this model is scalable and its capacity can be increased using specialized tools such as Ethereum Mainnet, IBM’s Hyperledger Fabric, ReactJS, and ExpressJS. They suggest integrating facial recognition technologies through artificial intelligence and convolutional neural networks (CNN), retina and iris scanning for identity authentication, complemented with voice assistants, to improve the accessibility and security of the electoral process (Braz, 2021; Parihar et al., 2021; Sreekanth et al., 2022).

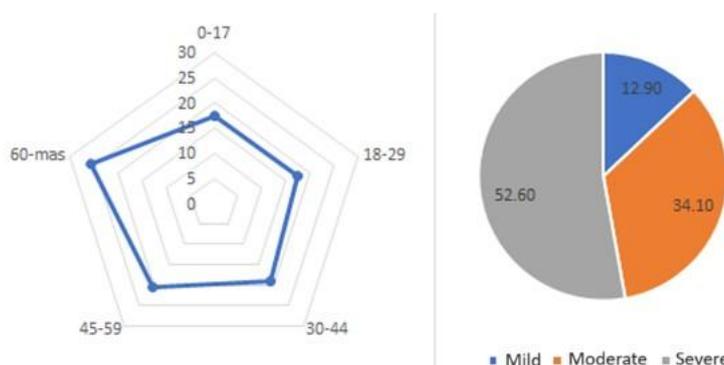


Figure 2: Percentage by Age and Degree of Disability Source: CONADIS Statistical Report April 2022

Rathore (2022) underscores the urgency of implementing electronic voting solutions in countries with large electoral populations, such as India, identifying high costs and potential manipulation risks as the main challenges of current systems, citing Ar-

shad et al. (2021) and Chima (2022). He proposes identity verification through one-time passwords (OTP) sent to registered mobile phones and suggests improving accessibility through audio interfaces for the illiterate.

Mamokhere and Mabeba (2022) contrast manual and electronic voting systems, noting that problems observed in the manual system during South Africa's national elections, such as multiple voting, could be mitigated with the adoption of electronic systems. They recommend conducting pilot tests based on experiences from the United Kingdom, which include internet, telephone, machine, and SMS (Short Message Service) voting, to assess limitations and advantages. Chigona et al. (2009) explored whether mobile internet could reduce social exclusion, including people with disabilities in developing countries. They found limited use of mobile internet among the most excluded, attributed to a lack of awareness about its possibilities, limiting its impact on economic and political aspects. Goodman et al. (2018) investigated the effects of eliminating paper voting, finding that exclusively electronic voting predominantly attracts voters with high technological knowledge. They suggest that dispensing with paper votes could marginalize those without technological skills. Hassan et al. (2022) argue that in emerging democracies, manual voting systems can be plagued by electoral fraud. For voting by people with disabilities, they propose the use of audio interfaces and highlight preliminary steps such as the electronic registration of voters, fingerprint validation systems, and the use of smart cards. They suggest starting with tests in non-public elections, gradually scaling up to broader adoption in Nigeria, which would facilitate citizen participation, identification of gaps, technological validation, and the development of governmental capacities.

Germann and Serdu'lt (2017) explored whether the validation of the electronic voting system could increase electoral participation. Through an experiment conducted in cantons of two Swiss cities, they compared the online electronic voting system with other methods, without finding significant differences. However, they underlined the importance of considering factors such as culture, previous experiences, and the efficiency of the postal service in Switzerland. They recommended focusing future efforts on strengthening the training of electoral personnel, keeping the electoral register updated, constantly implementing and updating cutting-edge technology, and permanently validating the process through controlled and incremental pilots before national implementation. They also suggested initiating studies in specific groups of voters, such as people with reduced mobility, military stationed abroad, and expatriates. Toapanta et al. (2022) indicated that for an electronic voting process to be acceptable according to international standards, it is necessary to invest in technology, train those involved in the process, establish agreements with telecommunications companies, use 128-bit encryption mechanisms, and security measures that mitigate cyber-attacks. They highlighted that access through mobile devices or computers connected to the internet could benefit people with limited mobility, those far from their polling place, or those deprived of freedom. Ehin et al. (2022) examined the electoral process in Estonia for nearly two decades, highlighting that internet voting in this country is part of a digitally advanced society, which is the key to its success. Almost half of all votes in recent elections were cast via the Internet, and digital gaps do not represent a major concern, as sociodemographic differences do not affect the use of the system. Although there is confidence in the system among voters, there is perceived risk of polarization. The authors presented five conclusions about the electronic electoral process in Estonia, detailed in Table 2. According to Braz (2021), the electoral process in Estonia begins with the identification of the voter through their digital ID card and security pins, using HSM (Hardware Security Module) encryption services and QR (Quick Response) codes to notify citizens. Although there have been political

conflicts related to electronic voting, these have decreased as citizen participation increased, to the point that abandoning the system would be very costly (Ehin et al., 2022).

Table 2: Conclusions from the analysis on electronic voting in Estonia.

Inference	Sustentation
Advanced and solid infrastructure and digital identity	Regular use of secure digital services in e-government means there’s no need for special voting systems.
E-voting, it is not a simplification for the processes electoral	The ongoing task is to refine technologies and legal structures, manage resources, and tackle disinformation, which complicates election management.
E-voting does not influence voter participation.	Voter turnout in Estonia’s 11 elections has been stable; ease of electronic voting engages willing participants but doesn’t necessarily motivate the disinterested.
Adoption of E-voting must be gradual.	Effective promotion and gradual adoption are essential. In Estonia, electronic voting uptake isn’t affected by demographics like wealth, location, or gender.
Confidence in the use of new technologies.	Estonia’s efficient digital governance ecosystem fosters familiarity with secure digital ID use, aiding in everyday tasks, including voting.

Source: Ehin et al. (2022)

Essex and Goodman (2020) argue that while there is a trend toward adopting electronic voting, it is imperative to establish regulations and security standards specific to each country. The lack of regulation in Canada has left municipalities to implement these processes. This regulatory gap, with respect to integrity, auditing, and transparency, could compromise citizen representativeness. Municipalities, in their effort to optimize budgets through electronic voting, and the absence of clear regulations, have developed solutions that vary significantly in design, architecture, and security mechanisms. Udhaya et al. (2019) suggest automating the electoral process through the use of Internet of Things (IoT) components and security mechanisms at each stage, from biometric validation with Aadhar card data, through the act of voting, to secure data storage in the cloud. They propose the use of an Arduino component, a radio frequency module, Raspberry Pi 3+, and a biometric reading module. Fahri and Hardianto (2022) note that the COVID-19 pandemic has posed additional challenges for electoral processes, as the in-person format of elections encouraged gatherings and, as a result, an increase in infections and in the number of fatalities. They propose electronic voting as a viable alternative in pandemic scenarios or similar situations, arguing that, from a constitutional perspective, the protocol for implementing electronic voting is consistent with the principles of direct, general, free, confidential, honest, and fair elections, and could serve as an alternative electoral policy in the future. Electronic voting offers potential benefits for making the electoral system more democratic, efficient, and secure, adapting to the current pandemic situation and facilitating access for people with disabilities. However, in Indonesia, it faces significant obstacles to its implementation due to systemic failures that prevent guaranteeing a secure and reliable system, in addition to limitations in infrastructure development and the digital divide among voters.

Okediran (2019) develops a technological architecture proposal aimed at facilitating electronic voting. This architecture allows the voter to register in advance and

receive a security code on their SIM (Subscriber Identity Module) card, which is exclusively linked to that user.

To vote, the voter can access a web portal from a PC and validate their identity through biometric recognition or vote remotely using a mobile phone to send an SMS with an image of their fingerprint. It is important to highlight that the data collected are centrally stored and transmitted through tunnels encrypted with SSL (Secure Sockets Layer) or TLS (Transport Layer Security), ensuring the protection of information through the RSA cryptographic algorithm. This mode of remote voting offers significant advantages for those voters who, due to disability or other reasons, cannot physically present themselves at polling centers. Muhammad and Ahmad (2021) highlight that in Indonesia, the use of ballots in elections represents high economic and human costs for the country. They mention that in the 2019 elections, there were approximately 527 deaths of officials due to exhaustion, and the prolonged scrutiny process opens doors to electoral fraud. They note that there have been some regional electronic voting pilots with moderate success and advocate for their expansion. They propose a model of in-person electronic voting with identity validation through biometric devices, seeking benefits such as speeding up the scrutiny, optimizing the budget, and improving the security, integrity, confidentiality, and transparency of the electoral process. De Silva et al. (2021) examine the needs of voters with visual disabilities in Sri Lanka, who traditionally required assistance to vote, limiting their constitutional right. They developed two adaptive devices: one with a button interface and another with a touchscreen, allowing the voter to operate them independently. Additionally, they incorporated audio functionality to facilitate their use. After testing with people with and without visual impairments, both devices were well-received, although the button interface showed a slight preference. Nonetheless, the need to improve the resolution of erroneous selections in the touchscreen interface and audio assistance was identified.

DISCUSSION

Electronic voting has not been widely implemented globally, with only a few countries in the process of adopting it. Estonia is the most emblematic case of its implementation (Braz, 2021; Ehin et al., 2022). Outside of Europe, municipal initiatives in Canada and local experiences in Australia, the United States, Indonesia, India, Pakistan, and Sri Lanka have been carried out (De Silva et al., 2021; Ehin et al., 2022; Goodman et al., 2018; Muhammad and Ahmad, 2021). Studies have focused on proposing technological alternatives for future projects and discussing, based on documented experience, how to conduct electronic electoral processes, considering the necessary conditions and aspects. However, specific e-voting proposals for people with disabilities are scarce, except for the blind, for whom mechanisms that include audio in the process have been suggested (De Silva et al., 2021). Despite this, various authors agree that non-presential electronic voting would especially benefit people with disabilities (Chigona et al., 2009; Chima, 2022; Fahri and Hardianto, 2022; Hassan et al., 2022; Parihar et al., 2021; Okediran, 2019; Sreekanth et al., 2022; Thangavel et al., 2022).

The advanced technologies implemented so far in *e-voting* processes focus mainly on *blockchain*, recommending not to include the voter's public key to preserve the secrecy of the vote (Giraldo et al., 2021). Processes of validation and identification have been proposed using facial recognition with artificial intelligence, deep learning, and convolutional neural networks (CNN) (Sreekanth et al., 2022), as well as fingerprint recognition (Arshad et al., 2021; Hassan et al., 2022; Okediran, 2019). In India, two-phase authentication based on the Aadhar number and OTP codes sent to mobile

phones is suggested, which must match to allow voting over the internet (Sreekanth et al., 2022; Rathore, 2022). The use of *IoT* in each stage of the electoral process has also been explored (Udhaya et al., 2019), promoting an architecture that assesses the performance of a multifaceted electronic vote (Okediran, 2019). Pethig and Kroenung (2019) emphasize the importance of integrating accessible functionalities from the system design, ensuring its usability for all and promoting true inclusion, thus avoiding the stigmatization of certain voter groups.

Among the identified limitations and gaps, Goodman et al. (2018) noted that the absence of paper ballots favors voters with greater technological knowledge. This finding coincides with that of Chigona et al. (2009), that the use of mobile internet is low among the most socially excluded sectors, widening the digital divide. Although both in-person voting and *e-voting* are constitutional (Fahri and Hardianto, 2022), both face constant threats, highlighting the need to invest in advanced technology, train participants in the electoral process, and establish robust security mechanisms (Toapanta et al., 2022). The practice of electronic government has simplified government administration, improving efficiency, transparency, and accountability, as demonstrated by the case of Estonia, which has promoted the development of *e-voting* in a highly digitized society (Ehin et al., 2022). The implementation of *e-voting* could reduce electoral fraud and citizen dissatisfaction, although it does not necessarily increase electoral participation, as observed in the Estonian elections (Germann and Serdu"lt, 2017; Braz, 2021; Ehin et al., 2022).

IMPLEMENTATION PROPOSAL

Building on the mentioned background, we propose a model of non-presential electronic voting initially focused on specific segments that face mobility difficulties during electoral processes and would therefore significantly benefit from this system, encouraging them to participate more actively. These segments include individuals with motor disabilities and the elderly. In various countries, the registry of these groups may not be entirely accurate, so it is suggested to complement the information with data from formal entities such as health ministries, social security institutions, and foreign affairs ministries, or their equivalents, depending on the reality of each country.

It is recommended that online electronic voting system trials begin with small groups. From the planning and design stage, it is crucial to focus on the development of accessible functionalities, including user interface testing and other specific requirements for people with disabilities, so that the system can eventually be scaled up to a national level.

The proposal, detailed in Figure 3, suggests the use of a web interface that incorporates identity validation mechanisms through facial recognition. This would include access to the national identity registry, recording information on a private *blockchain*, components for generating block identity for each vote, chain nesting components, and replicas for auditing, scrutiny, and results presentation.

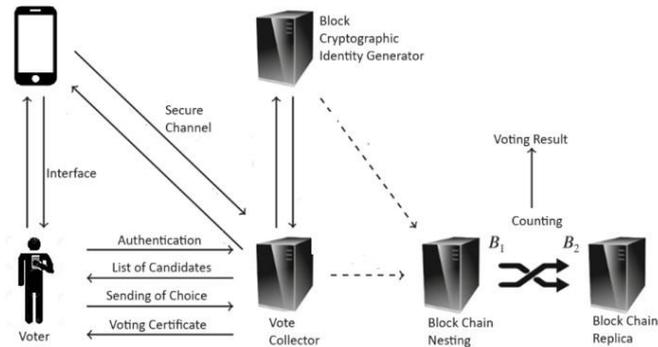


Figure 3: Pilot architecture proposal for non-presential election

The initial implementation phase of this model would target a sample ranging from 1000 to 5000 citizens with motor disabilities, who have sufficient ability to handle mobile devices, are duly accredited, and reside in major cities with adequate mobile communication services. The process is detailed as follows:

Before voting:

- *Registration:* Voters sign up using their identity document, disability certificate, and demonstrate their capacity to respond to online identity validation questions.
- *Registration confirmation:* Voters receive confirmation by email, an access PIN, and the link to the voting webpage.
- *Communicating the process to the voter:* A link to a digital-format voting tutorial is sent, along with recommendations on the conscious exercise of the right to vote, to be conducted on pre-established dates.

During voting:

- Voters access the web on voting day, within the established hours.
- They identify themselves on the platform using their username and security PIN.
- Facial biometric validation is performed, including a proof-of-life test, by comparing image sequences.
- The system presents the available list of candidates. Voters select their candidates and confirm their choice by re-entering their security PIN.
- A vote receipt is sent to the voter.

After voting:

- *Scrutiny:* The integrity of the cast votes is verified and counting proceeds.
- *Process review:* Agents and observers record any challenges.

This project assumes the development and widespread adoption of digital identity among citizens, promoting use cases that enhance interaction with both the public and private sectors, positioning it as a central pillar in the provision of institutional services. The results obtained would allow for the consideration of including new population segments or expanding the number of participants.

Limitations: This study is based exclusively on a systematic review of published literature and does not include empirical testing or field validation of the proposed *e-voting* solutions. While this approach allows for a comprehensive synthesis of existing knowledge, it limits the ability to assess real-world usability, institutional constraints, and user perceptions. Future empirical studies, including controlled pilots and user-centered evaluations, are necessary to validate the feasibility and inclusiveness of the identified technological approaches.

CONCLUSION AND FUTURE RESEARCH

Electronic voting has the potential to transform electoral accessibility for people with disabilities, particularly in developing countries where physical voting infrastructure may be inadequate. However, existing e-voting solutions are not designed with accessibility as a primary consideration, leaving people with disabilities excluded from digital electoral advancements.

The findings of this study highlight blockchain-based e-voting as a secure and transparent option, but its implementation faces key challenges, including technological accessibility, digital literacy, and legal adoption barriers. The lack of tailored solutions for individuals with disabilities further widens the gap in electoral participation.

To ensure a truly inclusive voting process, it is critical to:

1. Develop and test inclusive e-voting prototypes that integrate biometric authentication, assistive technologies, and voice-based interfaces.
2. Conduct pilot programs in developing countries to evaluate the feasibility of remote voting for individuals with disabilities.
3. Encourage legislative changes that promote the adoption of inclusive voting technologies.

Future research should prioritize empirical pilot studies in developing countries, involving people with disabilities as active participants in the design and evaluation of e-voting systems. Additionally, interdisciplinary collaboration between technologists, policymakers, and disability advocacy organizations is essential to translate technological innovation into inclusive public electoral policies.

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