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# Analysis of research on the implementation of Blockchain technologies in regional electoral processes

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**ABSTRACT**

Implementation of Blockchain technologies in online voting system is becoming increasingly popular in modern society and has significantly efficiency in governance. This article explores how Blockchain technologies can boost government operations, making them more transparent and effective. It focuses on an in-depth analysis of current research and methods on Blockchain-based electronic voting systems. The aim of this study is investigated and analysis the potential contributions of Blockchain technology to e-voting by drawing insights from global best practices. According to literature review and case studies of Blockchain implementation in government are conducted to identify existing systems and methods of e-voting, identifying their strengths and weaknesses by analyzing European countries and preparing the ground for future alternatives. Additionally, it examined the role of public education in fostering trust and understanding of Blockchain technology and analyzed the legislative landscape in neighboring jurisdictions to solidify Blockchain's role in decision-making processes. The results of the study provide a comprehensive perspective, and the findings emphasize the relevance of the study, its contribution to understanding the problems and prospects of introducing Blockchain into electoral processes at the regional level.



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## 1. INTRODUCTION

The implementation of Blockchain technologies in online voting systems represents a transformative leap in modern governance, fostering efficiency and transparency. As societies evolve, the adoption of Blockchain in electoral processes gains traction due to its potential to revolutionize government operations. This article delves into a comprehensive analysis of the current state of research and methodologies surrounding Blockchain-based electronic voting systems, also highlights the principle of Blockchain operation in voting systems, illustrates a Blockchain-based voting system architecture that promotes secure and transparent elections. As methodology article provides analysis of the procedure for the implementation of e-elections in European countries, demonstrated statistics of using Blockchain technologies in e-voting in the Worlds practices and experience an experiment done in a certain country. The objective is to investigate and scrutinize the potential contributions of Blockchain technology to e-voting, drawing insights from global best practices.

However, traditional electoral systems often face challenges related to transparency, security, and efficiency. Instances of fraud and manipulation have raised concerns about the integrity of the electoral process. The need for a secure and transparent voting mechanism is paramount to address these challenges and enhance the credibility of democratic practices at the regional level. As for today, the global adoption of Blockchain technology in e-voting remains nascent. While the potential benefits of enhanced security, transparency, and efficiency are widely acknowledged, widespread implementation faces various challenges [1]. Precisely quantifying the percentage of countries using Blockchain in e-voting is difficult due to:

- Limited adoption: Only a handful of countries and regions have implemented pilot programs or small-scale deployments. These include Estonia, Sierra Leone, Dubai, and the Indian state of West Bengal.
- Varying degrees of integration: Blockchain can play different roles in e-voting systems. Some use it for voter registration, while others leverage it for vote casting and counting.
- Data limitations: Reliable and comprehensive data on global e-voting practices, including Blockchain integration, is not readily available.

A review of the literature reveals significant advancements in the exploration of Blockchain technologies in Blockchain electoral domain. Notable contributors have engaged in studies to understand the application of Blockchain in government operations. The focus has been on identifying existing systems and methods of e-voting, emphasizing strengths and weaknesses. European countries have been examined to provide insights into diverse approaches, forming the foundation for future alternatives.

In a recent study of using Blockchain technology in e-voting, Baudier *et al.* [2] argued that, while Blockchain offers potential for secure e-voting, human factors and trust in the technology are critical for success, concerns include technological complexity that may discourage adoption and create vulnerabilities. Also centralized control, especially replacing centralized authority with might not address trust issues. In addition, lack of user education can lead to voting mistakes and misunderstandings. As a result, e-voting with Blockchain can contribute to peace by increasing trust and transparency, but only if human trust, education, and responsible implementation are addressed. At the same time Blockchain can foster collective decision-making, increase transparency in resource allocation, and empower local communities through secure data storage and sharing. Literature review and case study analysis of two Blockchain projects in rural Brazil and Cambodia. Merrell *et al.* [3] interviewed stakeholders and analyzed project documents to understand how Blockchain can support decentralized governance and development. However, challenges like user education, digital divide, and limited internet access need to be addressed. In other case, according to Schulz *et al.* [4] in terms of exploring the governance and implementation of sustainable development initiatives through Blockchain technology, the study demonstrates the potential of Blockchain to improve monitoring, resource tracking, and stakeholder engagement in sustainable development projects. As results research highlights the broader applications of Blockchain beyond e-voting, showcasing its potential to contribute to positive societal and environmental impact through increased transparency and trust in responsible initiatives.

In view of these urgent research gaps, we argue that the need for a secure and transparent voting mechanism is paramount to address these challenges and enhance the credibility of democratic practices at the regional level. To achieve these goals, this article analyzes current landscape in the world, by examining specific countries, and highlighting some advantages and relevance of using Blockchain technology. As mentioned earlier, several countries have conducted pilot programs or deployed Blockchain-based e-voting systems in limited settings. These initiatives provide valuable insights and pave the way for future expansion.

This study seeks to address existing gaps by conducting a holistic examination of the role of public education in fostering trust and understanding of Blockchain technology. In particular, we aim to contribute to the literature by analyzing the legislative landscape in neighboring jurisdictions, solidifying Blockchain's role in decision-making processes at the regional level. This dual approach distinguishes our work, providing a nuanced perspective on the challenges and prospects of introducing Blockchain into electoral processes.

The subsequent sections of this article will delve into a thorough examination of global best practices and case studies, offering insights into the strengths and weaknesses of existing systems. The study will then transition to an exploration of public education initiatives and the legislative context, providing a comprehensive understanding of the factors influencing the successful implementation of Blockchain in regional electoral processes. Finally, the results and discussion section will present findings and compare them with previous research, emphasizing the significance of this study in advancing our understanding of Blockchain's role in enhancing electoral systems at the regional level.

## 2. LITERATURE REVIEW

The implementation of Blockchain technologies in electoral processes has gained increasing attention for its potential to enhance transparency, security, and trust in democratic systems. This literature review explored the applications of Blockchain in e-voting systems, highlighting key studies that delve into the applications, challenges, and opportunities of integrating Blockchain in e-voting systems. However, challenges such as scalability, privacy concerns, and the need for voter education have been identified as significant barriers to widespread adoption. Despite these challenges, researchers emphasize the opportunities presented by Blockchain, including enhanced voter accessibility, increased voter turnout, and improved auditability of election results.

Nigmatov *et al.* [5] delve into the intricacies of a groundbreaking Blockchain-based e-voting system, outlining its architecture and functionality. The focus is on its potential to reshape electoral landscapes, citing enhanced security and transparency as key advantages. They conscientiously acknowledge potential challenges, paving the way for a balanced exploration. Barghuthi *et al.* [6] contribute by proposing adjustments to Blockchain technology, aligning it with the unique needs of electronic voting systems. Their study delves into modifications necessary for building trust in the electoral process, providing valuable insights into adapting Blockchain for this purpose.

Alvi *et al.* [7] systematic review adds depth, categorizing challenges and opportunities associated with Blockchain in e-voting. Their meticulous approach sheds light on the multifaceted nature of Blockchain’s application in the electoral domain, offering insights into potential hurdles and areas for improvement. Gupta *et al*. [8] critically examine Blockchain’s role in electronic voting systems. Their review scrutinizes both merits and open research challenges, emphasizing Blockchain’s role in upholding voting process integrity. The study serves as a compass, guiding understanding of current landscapes and future directions in Blockchain-based e-voting.

Tripathi *et al.* [9] exploration focuses on emerging trends in Blockchain-based electronic voting systems. Their analysis spans evolving technologies, potential advancements, and the transformative impact of Blockchain on the electoral landscape. It stands as a forward-looking resource, anticipating the dynamic nature of Blockchain applications in e-voting. In response to these challenges, the literature presents a paradigm shift towards Blockchain technology as a potential panacea. Blockchain, renowned for its decentralized and tamper-resistant nature, emerges as a transformative force in the electoral landscape. However, as literature scrutinizes this technological leap, concerns regarding security, scalability, and public trust come to the forefront. The literature, therefore, paints a nuanced picture of the promises and pitfalls associated with the integration of Blockchain in electoral processes.

The existing flaws within electronic voting systems underscore the pressing need for an innovative and secure alternative. Vulnerabilities identified in current systems, coupled with the escalating sophistication of cyber threats, pose a significant threat to the integrity of democratic practices. As technology advances, so do the tactics of those seeking to undermine the electoral process. In this case, the problem statement encapsulates the urgency to address the deficiencies in contemporary voting systems and seeks a robust solution. The literature, in echoing this sentiment, advocates for a comprehensive understanding of Blockchain’s implications in electoral contexts, emphasizing its potential to instill confidence, transparency, and security in the democratic process.

Collectively, these studies underline the growing significance of Blockchain in shaping the future of electoral processes. While recognizing the advantages, researchers emphasize the need to address challenges for seamless integration. These insights pave the way for further research, optimizing Blockchain’s use in creating secure, transparent, and efficient electoral systems.

## 3. THE AIM AND OBJECTIVES OF THE STUDY

The primary aim of this study is to conduct an in-depth analysis and evaluation of modern research on Blockchain-based electronic voting systems. By doing so, the study aspires to contribute invaluable insights into the application and challenges associated with Blockchain technology in the electoral domain. Additionally, the study endeavors to shed light on the various obstacles and limitations that need to be addressed for the widespread adoption of Blockchain-based voting systems, thereby informing future research in this critical area.

a. Objectives:

- Examine existing electronic voting systems: delve into the intricacies of current electronic voting systems to discern their strengths and weaknesses, setting the stage for alternative solutions.
- Explore the concept of Blockchain: provide a comprehensive overview of Blockchain technology, unraveling its fundamental principles and investigating its potential application in the realm of electronic voting.

- Identify defects in current systems: systematically document and analyze the defects and vulnerabilities inherent in existing electronic voting systems that necessitate a paradigm shift.
- Assess Blockchain's potential in e-voting: evaluate the potential benefits and challenges associated with integrating Blockchain technology in electronic voting systems, focusing on security, transparency, and efficiency.
- Examine literature on Blockchain in electoral processes: synthesize existing literature on the utilization of Blockchain technology in the electoral processes of developed countries, highlighting both positive and negative aspects.
- Propose solutions to identified problems: based on findings, propose practical and feasible solutions to address the problems identified in current electronic voting systems, harnessing the potential of Blockchain technology.

## 4. MATERIALS AND METHOD

Blockchain technology is a sign of development not only in the information technology industry but also in the financial sector. Financial officials believe that Blockchain technology has a great future, and they do not hide it. So how does this technology work and how is it organized?

What is a Blockchain gene? A "block" is a Blockchain, a "chain" is a chain, and a "Blockchain" is a "Blockchain". There are two types of chains:

- Official Blockchain is an open, complementary database. Each participant can write and read the information.
- An informal, or personal, Blockchain sets known limits on writing and reading information. There may be nodes that have priority. The unofficial surplus of Blockchain is that it is an exclusive Blockchain. In such a chain, certain people engaged in translations are clearly established.

Blocks are information about the intended transactions, transactions and contracts in cryptographic form within the system, all blocks are stacked in a chain and interconnected, actions are performed directly between entities and are carried out by all participants connected to one Blockchain network, which is considered one of the main advantages of Blockchain [10].

Work graphics: the basis of the work is the integration of certain information and digital records into the block. Each successive block is combined with the previous block through a chronological chain based on cryptographic encryption. Another main parts of Blockchain technologies are blocks. The blocks are firmly connected at the end of the chain. Encryption is provided by large-scale devices that are simultaneously integrated into the same network. Accordingly, the decentralized nature of blockchain networks involves large-scale devices working together within the same network to provide encryption and validate transactions. These devices form a solid chain based on complex mathematical calculations. If they get the same result as a result, then the block will not be able to change the number. Because of this, you cannot create a specific block, you can only add new notes [11]. The principle of operation is that the blocks are invariably linked and cryptographically secured, as indicated in Figure 1. When new information is added, it is distributed throughout the network and confirmed by miners. This ensures transparency, reliability, and no tampering with data. Blockchain is widely used in finance, procurement, and other industries for security and decentralization.

A Blockchain-based e-voting system where critical tasks like voter list preparation, candidate selection, and ballot design occur before the election in Figure 1. Utilizing a permissioned Blockchain structure, interconnected nodes, and an independent control node, this system ensures a secure environment. Nodes, representing neutral third-party organizations, use consensus mechanisms to mine transactions and add blocks to the voting ledger. After voter registration, a voting token facilitates secure vote transactions. The administrator manages election details, voter lists, and candidate information. The registration process, either at offices or online, involves issuing voting accounts through SMS, email, or envelopes. Blockchain's efficiency lies in securely storing election results as transactions, synchronized through smart contracts for transparency and reliability.

The term first appeared as the name of a completely duplicate common database that was introduced into Bitcoin, often referred to as transactions in different cryptocurrencies, but Blockchain technology can be extended to some interconnected blocks of information. Blockchain exceptions:

- Trustworthiness: Blockchain is reliable because it uses a peer-to-peer network so that anyone can access the transaction history and know the details of the transaction and with whom the transaction will be made. It includes a hash function that is very secure and cannot be changed by anyone using an algorithm.
- Distributed: Blockchain is a distributed system, not every node has a supervisory authority that can get information about the transaction. Wherever the centralized system is located, only a central authority can

carry out the transaction. If nodes fail in a distributed system, other nodes are not affected, and other nodes are added.
- Hashing technology: The hash function is an important Blockchain technology, a feature that makes Blockchain technology very secure because each block has a hash of the front block, and if there are any changes in the block, it is not the same as the hash of the next block [12]. In this way, you can reduce the risk of bullying here.
- Secure: Blockchain is very secure and cannot be easily hacked. Blocks will be added to the vat, and if someone tries to break any block, they will have to close the block next to that block and will not be able to withstand the speed of the blocks.
- Transaction fees: In a centralized system, banks charge a fee for a specific transaction when a transaction is made, but in Blockchain technology, this is out of the question.

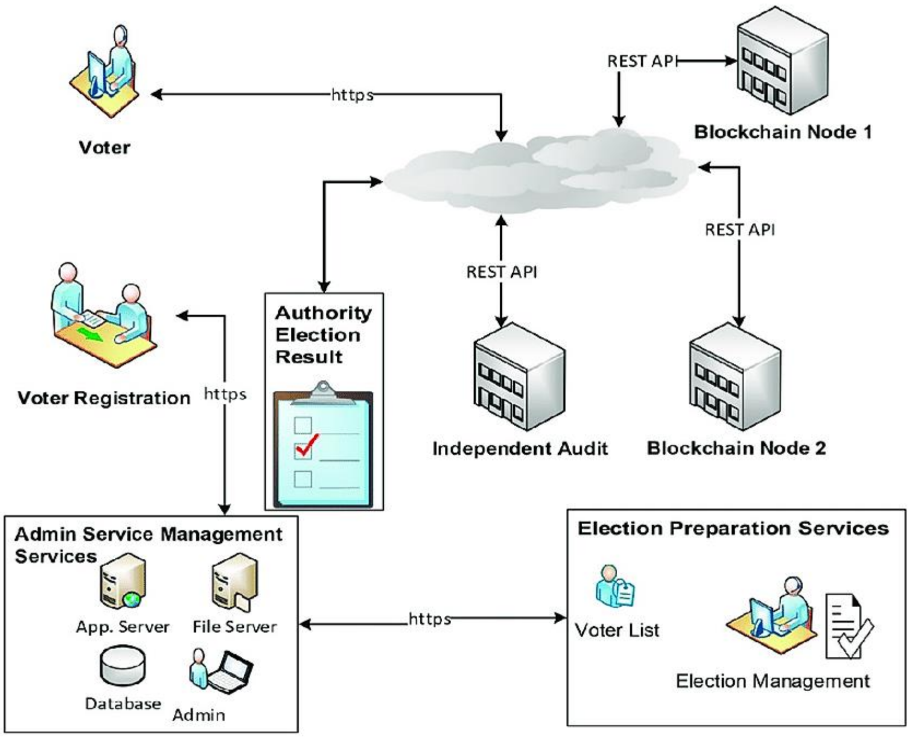


Figure 1. The principle of Blockchain operation in voting systems

According to experts: "At that time, a revolutionary idea appeared on the internet. Some believed, some did not. Blockchain technology is also entering our lives. Thanks to this system, we will be able to achieve financial transparency in society, save time and money, and restore public trust [13].

You cannot break it for a distributed database description. To do this, the Blockchain must have access to all devices on the chain. If a block is reached and a change is made, then any action will be stopped when the integrity of the entire chain is compromised. A block that receives a new entry does not correspond to the overall system.

Various methods of scientific cognition have been used in the research of Blockchain technology. With the help of the method of component analysis of the definition, a scientific justification for the term "Blockchain" was given. Using a comparative approach, the author of the study compared "exclusive" (closed) and "inclusive" (i.e., open) Blockchain technologies, identifying the positive and negative aspects of each of the proposed platforms. The advantages of inclusive Blockchain technology include the ability to process and conduct many transactions at the same time, as well as the use of long keys to access the Blockchain. Since the technology has not yet become widespread, there is a lot of research and testing that can be found in the most important areas of human life, but now Blockchain is actively used in banking systems, which protects not only the bank's financial instruments, but also its depositors, and the use of this technology will reduce operating costs for any organization.

Advantages and disadvantages of Blockchain technology: Blockchain technology is already considered innovative and promising. It provides a safe and secure exchange of data and saves the entire fund from the possibility of disconnection due to a centralized database. Anyone who wants to carry out an attack can break the integrity of the block by gaining access to only one block. You cannot change the contents of the block after the Blockchain technology is updated, you can only add a new record.

Despite the above advantages, there are also some disadvantages. First of all, this is due to the fact that the system is not fully developed. The use of technology in cases involving the law is ineffective. Similar problems can arise in business. Despite these drawbacks, large and reliable companies are increasingly confidently and actively using Blockchain technology in their institutions.

Based on such advantages of technology, it is possible to organize the exchange of any kind of information. In addition to large banking systems, the distributed database system is used in micropayments, logistics, law enforcement, and medicine. Blockchain technology is becoming an indispensable tool that is widely used at the state level.

As Blockchain technology continues to unfold, it emerges as a catalyst for innovation and transformation. Its applications, yet to be fully realized, offer a plethora of opportunities on the horizon. Particularly in electronic voting systems, the global landscape showcases increasing interest, as seen in Germany, Norway, and Switzerland. The comparison of Blockchain nodes to electoral components underscores its decentralized, secure nature. Challenges such as integration hurdles and public skepticism persist, requiring ongoing research and adaptation. However, the evolving synergy between optimism and caution shapes a future where Blockchain's transformative capacity reshapes societal structures. Stakeholders are urged to navigate this dynamic journey with a judicious balance, recognizing both the potential and challenges inherent in the promising realm of Blockchain technology.

Figure 2 illustrates a Blockchain-based voting system architecture that promotes secure and transparent elections. Voters register and authenticate, cast encrypted votes, and view tallied results on the Blockchain network. Disputes are resolved using the immutable voting record. The Blockchain ensures data integrity, resistance to tampering, and auditability in Figure 2.

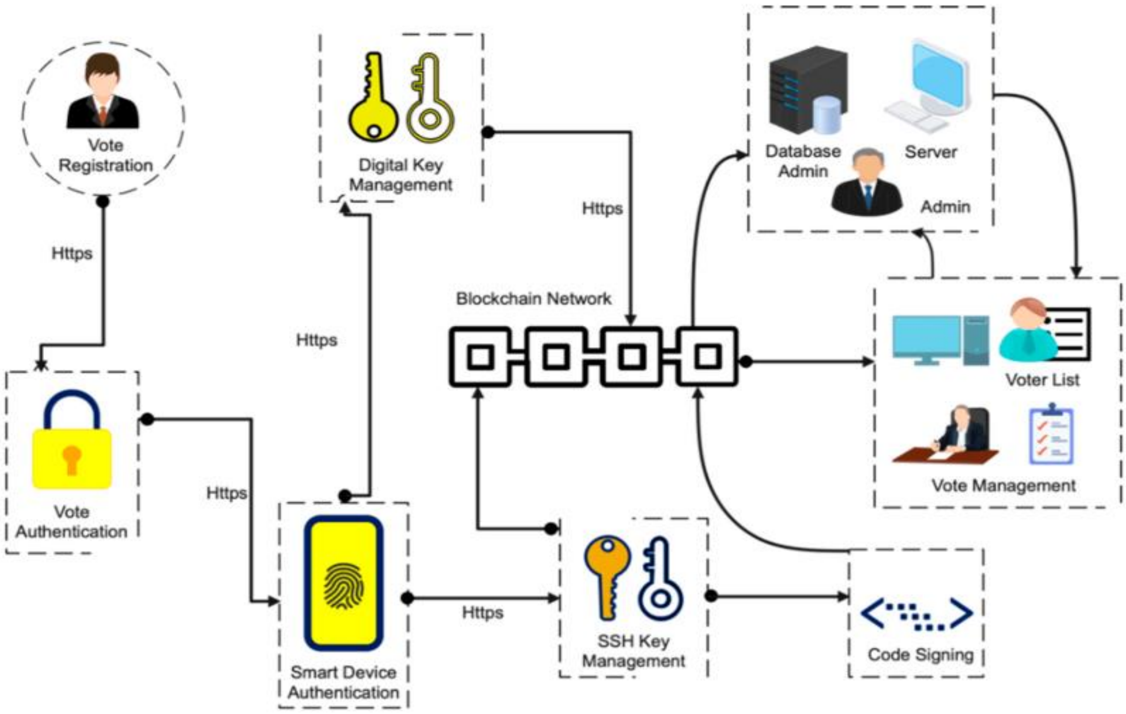


Figure 2. Blockchain technology chain

This network operates on a consensus mechanism, like proof-of-work. This mechanism ensures agreement among all participants about the state of the Blockchain. It is computationally expensive to alter past transactions, making the system secure and tamper resistant. The ledger is decentralized, stored across all computers in the network. This transparency allows anyone to verify transactions. The immutability of the

Blockchain makes it reliable, as altering one block would require changing all subsequent blocks, practically impossible. Some Blockchains, like Ethereum, go beyond transactions. They support smart contracts-self-executing contracts with terms written in code. These contracts automatically execute when predefined conditions are met [14].

In the realm of electoral voting systems, one can draw intriguing parallels with the diverse nodes in a Blockchain network as shown in Figure 3. Imagine voter records as the full nodes, akin to Blockchain 's comprehensive ledger. These contain exhaustive details about registered voters, reminiscent of a full node storing the complete Blockchain. Election validators play a role analogous to mining nodes, ensuring the validity and accuracy of votes, much like their Blockchain counterparts validating transactions.

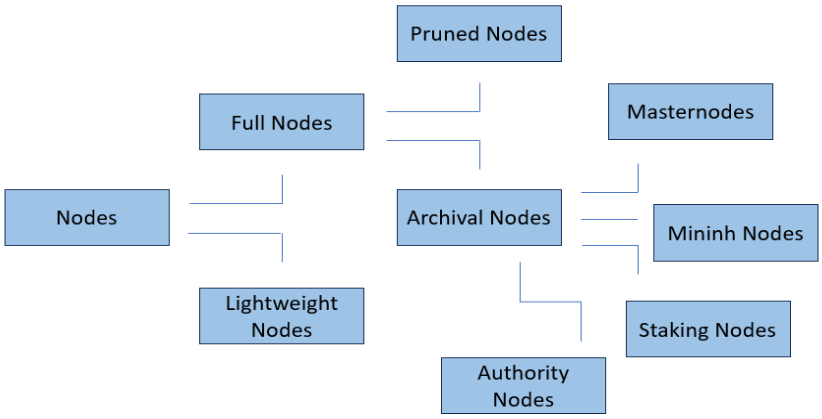


Figure 3. Types of Blockchain nodes

Consider master nodes in Blockchain networks; they perform specific functions. Similarly, election facilitators oversee tasks like managing instant voting and ensuring accessibility. Voter booths, like light nodes, do not store all records but depend on centralized systems for verification, much like light nodes rely on full nodes. Archival nodes, storing the Blockchain's complete history, find an equivalent in election archives, maintaining comprehensive records for auditing past elections.

Validator nodes in Blockchain, participating in the consensus process, aligning with poll workers in elections, validating voter identities and overseeing the voting process. Non-validating nodes relay information in Blockchains, mirroring observers in elections who share information about the process without actively participating in validation. These parallels illustrate how the decentralized, secure nature of Blockchain nodes finds resonance in the various components and participants shaping the dynamics of an electoral voting system [15].

a. Blockchain technology in the electoral process:

– Transparency and immutability of records: Blockchain is a distributed ledger that records transactions in a secure and transparent form. When applied to the electoral process, Blockchain can create an immutable and transparent record of votes. Each vote can be recorded as a transaction, and once added to the Blockchain, it is difficult to change or tamper with. Voter Authentication: Blockchain can be used to securely authenticate voters. Each voter can be given a unique digital ID stored on the Blockchain. This would help prevent identity fraud and ensure that only authorized voters cast their votes.
– Decentralization and security: traditional election systems often rely on centralized databases, making them vulnerable to hacking or tampering. Blockchain, being a decentralized technology, distributes data across a network of nodes, reducing the risk of a single point of failure and increasing the overall security of the system.
– Real-time results: using Blockchain can potentially enable real-time vote counting. Once a vote is cast, it can be recorded on the Blockchain, allowing for faster and more accurate reporting of election results.
– Reduce Fraud: the transparency and immutability of Blockchain can help reduce the risk of fraud in the election process. Any attempts to manipulate the results will be easily detected.

Blockchain technologies are also used in the electoral process, and if a voting platform is created on the basis of Blockchain, then everyone will be able to register and cast their vote, where no one will be able to change the vote, no one will vote twice, and the state will not be able to interfere, that is, starting from the process of registration in the voting system, voting for a specific candidate, the calculation of the results of which is automatically carried out without the human factor. It enhances electoral systems by ensuring transparent, secure, and tamper-resistant voting processes. Each vote is recorded as a block in the chain, linked through cryptographic hashes, preventing manipulation. This decentralized approach minimizes the risk of fraud and provides a verifiable, immutable record of election results. Voters gain confidence in the integrity of the system, as they can independently verify their contributions. Additionally, Blockchain simplifies cross-border voting, making electoral systems more inclusive and efficient. Countries exploring this technology aim to revolutionize elections by fostering trust, reducing intermediaries, and ultimately strengthening democratic principles.

Electronic voting provides a high level of security during the procedure. The table represents the diverse practices of electronic voting implementation across several countries as shown in Table 1. An electronic direct access system is often controlled by a computerized interface equipped with a touch screen or buttons that captures the voter's choice and records it directly into electronic memory. These systems are often self-contained devices that are not connected to an external network during the voting process to provide a degree of security against unauthorized access. The recorded data is then securely transferred to a central database to create tables and obtain results.

These statistics illustrate the integration of Blockchain-based e-voting and provide estimates of usability across different countries over the specified years, reflecting trends in worldwide practice. This overview underscores a growing trend towards technological innovation in electoral systems, signaling a shift towards more secure and transparent voting practices worldwide as shown in Figure 4.

Table 1. Analysis of the procedure for the implementation of e-elections in European countries

| State | Practice of electronic voting implementation |
|---|---|
| Estonia | The system that made it possible to conduct electronic voting in 2005 is working, and today it is increasingly using the method of choice. |
| Lithuania | The proposal was rejected due to the short deadline, given the possibility of using electronic voting in the parliamentary elections in 2020. Security options are being explored, threats are being identified, and preparations are underway for the introduction of electronic voting in the future. |
| Germany | 1998-2005 Testing with positive feedback was suspended due to insufficient security of voting machines. The need for reintroduction lies in the transparency of the electoral mechanism. |
| Norway | In 2011, e-voting tests were carried out for the population testing group in the municipal elections, and in 2013, before the parliamentary elections, another stage of testing was carried out for a selected group of residents. Citizens welcomed the opportunity, but turnout did not increase. In 2014, it was decided to temporarily suspend electronic elections. |
| Austria | The concept of electronic voting was tested in student councils in 2009, as a result, there were very few people willing to take advantage of this opportunity, one of the main reasons being the need to have an electronic card necessary for authentication. The election was later declared invalid. |
| Switzerland | In 2004, a certain group of citizens was allowed to use e-voting services in the electoral cantons of Switzerland, but in the same year this possibility was abolished, and the security of these elections had to be improved before they could be resumed. |

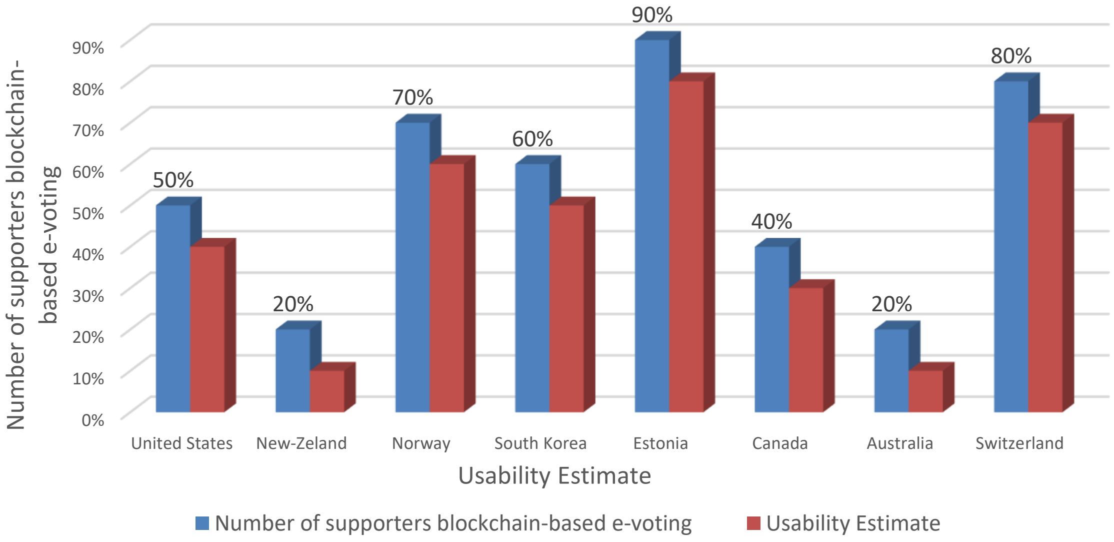


Figure 4. Statistics of using Blockchain technologies in e-voting in the worlds practices

There are many advanced technologies in the world, the most advanced of which is Blockchain technology. This technology allows you to digitize any information. It is a data storage system that is not tied to a single center. For example, any organization has a database, if there is a party-about voters and party members, if there is an anti-corruption service-employees, data, investigation data, and others. All information is sent to a centralized database. Accordingly, when hackers attack, they delete all information from a single source. And the Blockchain chain does not allow you to spread information.

The information is divided into several blocks and moved randomly. That is, the hacker has to crack entire blocks individually in order to hack the database. This is a very complex farm. According to him, it will take a lot of effort to demolish one unit itself and the broken block will be blocked, while the rest of the parts will continue to function normally. For example, imagine a new book that has gone out of print. You cannot change anywhere in the book. If you've torn one page, it is obvious. If important pages are lost, the meaning of the book will change. And even if you add your own thoughts to its pages, it is almost as clear as pencil writing. It is the same with Blockchain. The same information will not change or be deleted. This will require the consent of more than one organization to change the same information. That is, one person cannot come and change the data the way he wants. This means that the human factor can be reduced.

Nowadays, Blockchain technology is used everywhere. Its main task is to digitize any information. For example, in the field of healthcare, the patient does not go to any hospital, repeatedly enters data about himself, but allows him to withdraw it from the ready-made system. "As for the banking system, of course, Blockchain does not accelerate trans nationalization and does not prevent corruption. Because anyone who opens a digital wallet goes through a digital identification (ID) procedure. Here you can enter all the details once. Any bank manager will ask you for permission to use data about you. That is, all information about you is digitized and stored in a database, and no one can change it.

At the same time, Blockchain technology can be effectively used in the fight against corruption and the shadow economy. "For example, state inspectors who monitor road safety have a video camera that records violations. However, there may be human error, and some inspectors may not be able to turn on the camera when needed. Or the experts sitting in the control system can turn off the video. In Blockchain technology, nothing is disabled. If there is a violation of the rules, a message about the fine is immediately sent from the camera to the digital wallet. Even if you are held under the influence of alcohol and detained by the police, this video will be saved without deletion. In other words, corruption and the human factor are very closely related. If the human factor decreases, corruption will decrease [16]. Blockchain technology will undoubtedly be of great help in elections.

Blockchain technologies should be used in elections. If you create a voting platform in the Blockchain database, everyone will be able to register and cast their vote. Even here, no one can change the vote, and one person will not vote twice. The state will not be able to intervene. That is, starting with the process of registration in the voting system, voting for a specific candidate, the calculation of the results of which is automatically carried out without the human factor." To do this, it is necessary to minimize the human factor and massively introduce new technologies. Citizens should not leave their homes and receive any public services. Yes, the implementation of Blockchain technology and the creation of infrastructure is a very expensive project, but it is a necessary step to build your own cybersecurity, prevent data theft and create favorable conditions for the population [17].

Blockchain networks can have different nodes. These include full knots, light knots, super knots, and zippers. Blockchain technology is considered the newest iteration of application software from a business perspective. Blockchain and other collaborative technologies promise to improve organizational processes between businesses, organizations, and individuals, significantly lowering the "cost of trust." All voters and neutral observers can see voting records stored in the Blockchain system. On the other hand, researchers have found that most publications on Blockchain-based electronic voting reveal similar problems [18].

The investigation into Blockchain-based electronic voting systems illuminates a landscape where promise converges with pragmatic challenges. Diverse global implementations provide nuanced insights, with notable instances including Germany's testing hiatus due to security concerns and Switzerland's experimentation with e-voting services. These cases underscore the delicate balance required when integrating Blockchain into electoral processes, navigating the intersection of technological innovation and public acceptance. Critical components of Blockchain technology, such as decentralization, cryptographic security, and a transparent ledger, emerge as transformative elements in reshaping the electoral process. The portrayal of a Blockchain-based e-voting system in Figure 1 accentuates the potential for enhanced transparency, heightened security, and real-time reporting of election results [19].

The discourse surrounding Blockchain technology in electoral processes oscillates between optimism and caution. Inherent features like transparency and immutability offer a promising antidote to vulnerabilities present in centralized systems. The decentralized nature of Blockchain mitigates risks linked to single points of failure, as evidenced by Germany's cautious approach stemming from security concerns.

Acknowledging the multifaceted applications of Blockchain technology, particularly in voter authentication, decentralized security, and real-time result reporting, the discussion delves into the intricacies of its implementation. However, challenges persist, encompassing integration hurdles, public apprehension, and the necessity for legislative adjustments. The findings underscore the imperative of continuous research and adaptation to harness the full potential of Blockchain in fortifying electoral foundations. The combined results and discussion advocate for a nuanced approach to Blockchain integration, recognizing its transformative capacity while addressing challenges with resilience. As technology propels forward, the study urges stakeholders to tread the path of innovation with prudence and a steadfast commitment to democratic integrity, drawing valuable lessons from both successes and challenges across diverse global implementations [20].

## 5. RESULTS AND DISCUSSION

E-voting is a project of many experts, not one authority. The experience of European countries shows that e-voting is a complex process based on the cooperation of several experts. Therefore, in order for e-elections to be developed, the cooperation of several groups of people is necessary: i) programmers creating an election app and a vote counting program, ii) security analysts providing security, voter separation and vote verification, iii) political scientists who prepare the basic skeleton of the e-elections process, including in terms of official acts and overseeing compliance with the democratic principles of elections, iv) lawyers adjusting legislation based on the outputs of political scientists and programmers, v) marketers working on the app's user-friendliness and marketing campaign, and vi) PR experts preparing the communication campaign.

Each area specifies the requirements that e-voting must meet and therefore it is necessary to construct e-voting as a common project. Moreover, the development of e-elections should be a public process to ensure transparency and voter confidence. Ideally, therefore, voters should be given the opportunity to participate in the development from the beginning and the finished project should be made available to the public for testing [21].

Who are Czech voters and how to test e-voting with them? One of the key prerequisites for e-voting is internet access and computer literacy. In the case of Switzerland, Estonia and Norway, the number of households with an internet connection exceeded 80%, with Norwegian households reaching 90%. The highest possible number of households with internet access is not the most important prerequisite but remote I-voting can only take place in a country whose voters are computer literate and have access to the internet.

According to Eurostat data, only 4% of Czech households had internet access in 2004 and 5% a year later. By 2006, the number had climbed to 17% and, with an annual increase of around 10%, the number rose to 54% in 2010. Growth slowed slightly in the following years, but by 2015, 76% of households had an internet connection. By comparison, Estonian households were ahead by 11 percentage points and Swiss households by 10 percentage points in 2015. In 2015, the internet was primarily a platform for information and communication for Czechs 93% of internet users use it for email communication, half of people use social networks, and 2/3 consume news portals. Czechs also frequently use the internet to search for information about goods and services and to make purchases [22].

According to current proposals, I-voting should be a complement to traditional voting, so there is no justification for demanding 100% household internet connectivity. The age distribution of internet users is also related to this. In 2015, 6 million and 900 000 Czechs used the internet. The groups of citizens aged 12 to 25, 26 to 35 and 36 to 45 represent 22%, 20% and 23% of internet users respectively. Citizens aged 46 to 55 account for a 16% share and people aged 56 to 65 account for a 13% share. Only 5% are 66 to 75 years old. Thus, the share of users is relatively evenly distributed, and no age group is excluded from the right to vote electronically. Among voters living in the Czech Republic, e-voting could target people who cannot make it to the polling station, for example, because of their workload or travel. A notable group are disabled people, for whom I-voting could mean less dependence on the help of another person. There are currently more than one million Czechs with some form of disability, with an increase in the under-29 and over-75 age groups, according to a 2013 survey [23].

Remote I-voting could also be used by citizens living or residing abroad. Currently, almost 370,000 Czechs live abroad. They mostly go to Slovakia, Germany, and Austria. Another group of Czechs abroad is made up of soldiers on missions, the number of which is variable, in the spring of 2016 it was around a thousand soldiers. It is clear that the ideal is to allow citizens living at home and abroad to vote via the internet. The appropriate solution seems to be to launch e-voting in its simplest version first: for a limited number of voters living in the Czech Republic who will vote both electronically and conventionally. Such e-elections will not be indicative of the impact on voter turnout, but the election results will be easily verifiable by a recount of paper ballots and there will be no need to repeat the election in case of problems. Such an election would be an ideal pilot test where all age groups would have the opportunity to vote [24].

However, the Czech Interior Ministry's 2012 e-voting proposal envisaged a pilot test for students at five universities. Such a pilot test would have been fine if the target group had been university students. It is appropriate to hold interim tests, for which academia may be an ideal setting, but the final pilot test of the project should involve representatives of all constituencies. In Switzerland, for example, we are witnessing the gradual spread of e-voting not only within the country but also within each canton. Similarly, Estonia first piloted in the capital. Therefore, we consider it appropriate to run a pilot test in a limited number of municipalities and only for voters residing in the Czech Republic, get feedback, implement changes, and gradually expand e-voting to other municipalities.

To discern the shortcomings, it is useful to observe how a real voter performs when making a choice. It is important to ensure a clear user interface of the I-election application. Testing can include A/B testing, which is used in marketing to increase conversions through more effective advertising strategies. The principle consists in a binary test of two variants of a web page and banner. The advantage is that the testing takes place in live operation. Half of the users are presented with variant A, the other half with variant B. This testing can be used in a series of continuous tests as well as in a pilot test that would run in parallel with the classic election. A/B testing is a tool of the marketing branch of User Experience (UX), which deals with designing user interfaces or improving them in such a way that they provide maximum user experience. Utilizing UX practices and expertise can be very beneficial for designing the most appropriate user interface.

Elections must be technically and procedurally perfect. Let's return to the 2012 Interior Ministry document, which is the most elaborate Czech proposal for e-voting to date. In addition to the advantages, disadvantages and risks of e-elections, the authors also set out the principles of Czech e-elections. The e-voting system must guarantee the secrecy of the vote and the separation of the vote from the voter, and no one can be counted more than once. Arbitrary repetition of the election is supposed to solve the problem of family voting. The system must ensure high security when the voter logs in and provide information on e-voting security. The voter's vote must not be altered by anyone and the possibility of recounting and checking votes must be ensured. The document also sets out specific points to be addressed in the amendment to the Electoral Act [25].

In the second part, the document proposes an e-voting architecture. It should be based on the existing data boxes supplemented by a special version of the ballot boxes with a special superstructure in the form of the eVollection system containing a user interface for voters. Another component should be the already existing registers and information systems of public administration. Voting electronically would be possible in the term before the traditional elections, and the voter's e-voting would be informed by the electoral data box to the electoral commission, which could record the way a particular person voted.

So, let us work with the assumption of remote I-elections complementing classical paper elections. Voters will need a login and password to the online voting application or a certificate with a digital signature. In the first case, it would be advisable to complement the system with authentication via SMS as in the case of internet banking or by entering data such as birth number or OP number. In the second case, a digital signature carrier, probably an electronic ID card, carrying a public and private key, and a card reader connected to or embedded in the computer would be needed. E-citizen cards with digital signatures already exist in the Czech Republic, but there is not much interest in them among citizens, mainly due to the lack of benefits. At the same time, it remains to be examined whether existing e-citizenship cards are suitable for I-voting or whether they would need to be designed differently. The data boxes proposed in the ministry's document do not have to be used, but they have the same weight as e-signatures, so they should be considered further.

In both cases, it would be possible to ensure the separation of the voter from the vote and equality of voting. A possibility is to use two different systems, one to log and record the user, the other to store the vote. Separation of voter identification from the vote can be ensured through identity fingerprinting using a hashing function. This means that a voter logs into one system under their name and their vote is counted under a randomly assigned number, with the last vote hiding under that number always counted. In this case, it is not a problem to organize an I-election even during a regular election and ensure that no two votes are counted. A voter could also vote more than once over the internet, with the last i-vote or vote cast in the ballot box at the polling station being valid. It would be possible to identify how many times an anonymous person has voted through the number assigned. In other words, when a voter logged into the system online or at the polling station, the same number would be generated each time and associated with the vote, but without the possibility of identifying the voter from the number. Separating the voter from his or her vote would be possible, for example, through a virtual private network, or VPN, which, in addition to anonymizing users, has the advantage of creating a secure network that protects against unauthorized persons penetrating network communications [26]. Voters can also use the hash function to verify their vote. When logging into the voting app, it is possible to check, as in Estonia, whether the vote has been counted and that the voter has voted for the candidate of his/her choice, has not mistakenly chosen another candidate.

## 6. CONCLUSION

In conclusion, this article underscores the growing significance of implementing Blockchain technologies in online voting systems as a transformative leap in modern governance. The exploration of global best practices and case studies reveals the potential contributions of Blockchain to e-voting, emphasizing its role in addressing challenges related to transparency, security, and efficiency. The study highlights the limited but promising adoption of Blockchain in select countries and regions, showcasing the diverse roles it plays in e-voting systems. However, challenges such as technological complexity, centralized control, and the importance of user education are recognized as critical factors that must be addressed for the successful integration of Blockchain in electoral processes. The literature review and case studies illustrate the broader applications of Blockchain, extending beyond e-voting to contribute positively to societal and environmental impact through increased transparency and trust in responsible initiatives. The article argues for the paramount importance of a secure and transparent voting mechanism to enhance the credibility of democratic practices. It emphasizes the need for public education initiatives and a detailed analysis of the legislative landscape to foster trust and understanding of Blockchain technology, solidifying its role in decision-making processes at the regional level. The dual approach of examining both global best practices and legislative contexts provides a nuanced perspective on the challenges and prospects of introducing Blockchain into electoral processes.

In conclusion, this article effectively accomplishes its objective by thoroughly analyzing research on the implementation of Blockchain technologies in regional electoral processes. As the subsequent sections delve into a thorough examination of strengths and weaknesses in existing systems, public education initiatives, and legislative contexts, the study contributes to bridging research gaps. The findings presented in the results and discussion section emphasize the relevance of this research, providing valuable insights for advancing our understanding of Blockchain's role in enhancing electoral systems at the regional level. Ultimately, the article advocates for continued research, collaboration, and responsible implementation to fully unlock the potential benefits of Blockchain technology in revolutionizing the democratic electoral landscape.

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