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UNVEILING ROADBLOCKS AND MAPPING SOLUTIONS FOR BLOCKCHAIN ADOPTION BY GOVERNMENTS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Aim/Purpose	Blockchain technology (BCT) has emerged as a potential catalyst for transforming government institutions and services, yet the adoption of blockchain in governments faces various challenges, for which previous studies have yet to provide practical solutions.
Background	This study aims to identify and analyse barriers, potential solutions, and their relations in implementing BC for governments through a systematic literature review (SLR). The authors grouped the challenges based on the Technology-Organisation-Environment (TOE) framework while exercising a thematic grouping for the solutions, followed by a comprehensive mapping to unveil the relationship between challenges and solutions.
Methodology	This study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 methodology, combined with the tollgate method, to improve the quality of selected articles. The authors further administer a three-level approach (open coding, axial coding, and selective coding) to analyse the challenges and solutions from the articles.
Contribution	The authors argue that this study enriches the existing literature on BC adoption, particularly in the government context, by providing a comprehensive framework to analyse and address the unique challenges and solutions, thus contributing to the development of new theories and models for future research in BC adoption in government settings and fostering deeper exploration in the field.

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Findings	The authors have unveiled 40 adoption challenges categorised using the TOE framework. The most prevalent technological challenges include security concerns and integration & interoperability, while cultural resistance, lack of support and involvement, and employees' capability hinder adoption at the organisational level. Notably, the environmental dimension lacks legal and standard frameworks. The study further unveils 28 potential solutions, encompassing legal frameworks, security and privacy measures, collaboration and governance, technological readiness and infrastructure, and strategic planning and adoption. The authors of the study have further mapped the solutions to the identified challenges, revealing that the establishment of legal frameworks stands out as the most comprehensive solution.
Recommendations for Practitioners	Our findings provide a big picture regarding BC adoption for governments around the globe. This study charts the problems commonly encountered by government agencies and presents proven solutions in their wake. The authors endeavour practitioners, particularly those in governments, to embrace our findings as the cornerstone of BC/BCT adoption. These insights can aid practitioners in identifying existing or potential obstacles in adopting BC, pinpointing success factors, and formulating strategies tailored to their organisations.
Recommendations for Researchers	Researchers could extend this study by making an in-depth analysis of challenges or solutions in specific types of countries, such as developed and developing countries, as the authors believe this approach would yield more insights. Researchers could also test, validate, and verify the mapping in this study to improve the quality of the study further and thus can be a great aid for governments to adopt BC/BCT fully.
Impact on Society	This study provides a comprehensive exploration of BC adoption in the government context, offering detailed explanations and valuable insights that hold significant value for government policymakers and decision-makers, serving as a bedrock for successful implementation by addressing roadblocks and emphasising the importance of establishing a supportive culture and structure, engaging stakeholders, and addressing security and privacy concerns, ultimately enhancing the efficiency and effectiveness of BC adoption in government institutions and services.
Future Research	Future research should address the limitations identified in this study by expanding the scope of the literature search to include previously inaccessible sources and exploring alternative frameworks to capture dynamic changes and contextual factors in BC adoption. Additionally, rigorous scrutiny, review, and testing are essential to establish the practical and theoretical validity of the identified solutions, while in-depth analyses of country-specific and regional challenges will provide valuable insights into the unique considerations faced by different governments.

Keywords	blockchain, distributed ledger, blockchain technology, government, challenge, problem, solution, systematic literature review, SLR, PRISMA, tollgate, TOE

INTRODUCTION

Blockchain (remains widely acknowledged as a groundbreaking technology with the potential to transform society and the economy in significant ways (Cagigas et al., 2021). BC stands as a form of Distributed Ledger Technology (DLT) that utilises cryptography to store information among a group of users in a transparent and distributed system without the control of a central entity (Lykidis et al., 2021). This process ensures data integrity and reduces the risk of manipulation or system failure

while allowing for the sharing of information by all members (Hou, 2017; Ølnes et al., 2017; Verma & Sheel, 2022). Blockchain technology (BCT) is particularly well-suited for situations that involve ownership changes, such as government decisions, licenses, certificates, and legislation (Batubara et al., 2022; Ganguly, 2022; Ølnes et al., 2017). Additionally, BC can promote transparency, prevent fraud, establish trust, and create new opportunities for organisations to engage in peer-to-peer processes (Alexopoulos et al., 2019).

Since its emergence, the advent of BCT has held the promise of fundamentally transforming governmental institutions and public services (Gov.UK, 2022; Hou, 2017; Ølnes & Jansen, 2017; Verma & Sheel, 2022). Recent studies indicate that BCT is expected to significantly disrupt contract management, with 70% of government executives anticipating this disruption (Alexopoulos et al., 2019). Additionally, 14% of government entities plan to implement BCT, and 90% intend to invest in BCT for various purposes, including financial transaction management, asset management, contract management, and regulatory compliance (Alexopoulos et al., 2019; Verma & Sheel, 2022). As such, governments worldwide have adopted BCT to catalyse their operations: land registers in Georgia, Ghana, and Honduras; property transactions in Sweden; e-government in China; e-Health in Estonia; departmental services in the UK; and personal health data exchange in the US (Alexopoulos et al., 2019; Allessie et al., 2019; Hou, 2017; Jun, 2018; Lykidis et al., 2021).

BCT offers a wealth of practical advantages that can revolutionise how governments operate (Allessie et al., 2019). By leveraging distributed ledgers and smart contracts, BCT can simplify information exchange, reduce bureaucracy and corruption, and automate governmental registries – increasing transparency and trust (Allessie et al., 2019; Cagigas et al., 2021; Reddick et al., 2020; Verma & Sheel, 2022). Owing to the decentralised ledger of transactions, BCT can also help exert a transparent and tamper-proof system that ensures aid and services reach their intended recipients while minimising the risk of fraud and corruption (Cagigas et al., 2021; Reddick et al., 2020; Xu, 2021). Additionally, as per the findings of Ølnes et al. (2017), BCT offers the potential to facilitate government transformation by transitioning from a conventional hierarchical framework to a networked governance paradigm. This approach involves multiple entities sharing responsibility for transactions and governance, allowing direct engagement between citizens without undue intervention from government bodies (Ølnes et al., 2017).

However, though presented with "a gold mine", governments face significant roadblocks in its adoption. Lindman et al. (2020) point out that governments worldwide are hindered by myths surrounding technology, leading to perceptions that BCT possesses a disruptive, preposterous, deviant, and redundant nature. Researchers have also identified factors impeding the adoption, such as neglect of data protection policies/regulations, service and cultural disruptions, limited scalability, legal uncertainty, lack of expertise, BCT immaturity, and security concerns (Alexopoulos et al., 2019; Batubara et al., 2018, 2022; Cagigas et al., 2021; Ølnes et al., 2017). To map out the challenges in various industries, Batubara et al. (2018), Ganguly (2022), and Malik et al. (2021) have successfully employed the Technology-Organisation-Environment (TOE) framework, highlighting the barriers in its wake.

Notwithstanding numerous studies highlight the difficulties and obstacles in the use of BCT in government settings, there remains a scarcity of practical, proven solutions to address these issues (Batubara et al., 2018; Cagigas et al., 2021; Lykidis et al., 2021; Ølnes & Jansen, 2017). Researchers have yet to present a comprehensive framework of possible solutions to tackle the problems that arise from implementing blockchain in governments. This study therefore aims to identify and analyse barriers, potential solutions, and their relations in implementing BC for governments through a systematic literature review (SLR). By mapping out these problems and solutions, this study can provide government officials with a detailed reference guide for implementing BCT in the future. Finally, this study postulates the following research questions:

RQ1: What are the existing challenges of BC adoption in government settings?

RQ2: What are the potential solutions to address the challenges in BC adoption for governments?

RQ3: How are the challenges and solutions of BC adoption related to one another?

The authors thus organise this study as follows: The next section delves into the theoretical background that underpins the research; the following section elucidates the research methodology employed in the study. The research findings are then presented, along with their respective implications and limitations. Finally, the last section concludes the study and provides a suggestion for future research.

LITERATURE REVIEW

The adoption of BCT has become a highly-discussed topic among both academic and industry circles, and for good reason – it has made a significant impact on this research field in recent years (Lindman et al., 2020; Ølnes et al., 2017; Tan et al., 2022). While some governments have taken bold steps to embrace this innovative technology, others remain reluctant, highlighting the complexities and challenges associated with governmental blockchain initiatives (Allessie et al., 2019; Cagigas et al., 2021; Jun, 2018; Lykidis et al., 2021; Reddick et al., 2020; Verma & Sheel, 2022). This issue has captured the attention of numerous researchers, who have utilised a variety of frameworks in an effort to shed light on the matter. The TOE framework thus stands out as a robust and effective method for gaining a deeper understanding of the issues surrounding BC adoption, as previous studies have adeptly elucidated the hurdles in BC adoption, further affirming the framework's efficacy (Batubara et al., 2018; Ganguly, 2022; Malik et al., 2021; Taherdoost, 2022). For instance, Ganguly (2022) administers TOE to gain a deeper understanding of the challenges associated with BC adoption within the logistics sector. Simultaneously, Malik et al. (2021) effectively utilise the TOE framework to elucidate factors related to organisational adoption within the Australian context. Moreover, Wibowo et al. (2023) and Batubara et al. (2018) have also achieved success in the application of the TOE framework to comprehend the challenges for the Indonesian government regarding the adoption of Open Government Data and BC/BCT. Consequently, the TOE framework presents significant potential for unveiling the obstacles associated with blockchain adoption within governmental contexts.

BLOCKCHAIN IN GOVERNMENTS

In 2008, the advent of Bitcoin signalled the birth of BCT, a decentralised network that facilitates secure transactions between nodes without a central authority (Cagigas et al., 2021; Nakamoto, 2008; Ølnes & Jansen, 2017). The consensus mechanism – such as Proof-of-Work (PoW) or Proof-of-Stake (PoS) (Lykidis et al., 2021) – verifies each transaction before adding it to the ledger and is updated throughout the network (Allessie et al., 2019). Governments are turning towards electronic forms and recognising the potential of BCT to transform public service delivery in response to the increasing demand for online services (Alexopoulos et al., 2019; Lykidis et al., 2021).

Governments increasingly embrace BCT as an innovative tool for policy-making and service delivery (Allessie et al., 2019; Ølnes et al., 2017). By integrating it into their strategies, governments have gained a significant advantage in a rapidly evolving ecosystem (Alexopoulos et al., 2019; Allessie et al., 2019; Cagigas et al., 2021; Reddick et al., 2020; Verma & Sheel, 2022). While BCT has been widely used in the private sector, it also holds great potential in government services (Ølnes et al., 2017). As such, BCT is being heralded as an essential asset for governments to revolutionise public service production and delivery (Allessie et al., 2019; Lykidis et al., 2021; Ølnes et al., 2017).

BCT presents a revolutionary opportunity for governments to transform their operations and interactions with citizens, although its implementation requires a rethinking of governance strategies (Alexopoulos et al., 2019; Lykidis et al., 2021; Ølnes et al., 2017). BC has been successfully imple-

mented in many government organisations worldwide, with seven prominent case studies highlighting its effectiveness: Exonum land title registry in Georgia; Blockcerts academic credentials in Malta; Chromaway property transactions in Sweden; uPort decentralised identity in Switzerland; Infrachain governance framework in Luxembourg; Pension infrastructure and Stadjerspas smart vouchers in the Netherlands (Alexopoulos et al., 2019; Allessie et al., 2019; Reddick et al., 2020). Through these case studies, both quantitative and qualitative benefits of utilising BCT in government have been identified.

Governments have experienced a myriad of advantages in BC adoption, ranging from reduced costs and complexity to greater transparency, accountability, and reduced corruption (Alexopoulos et al., 2019; Cagigas et al., 2021; Lykidis et al., 2021). BC enhances data stewardship, simplifies processes, promotes information sharing, safeguards privacy, and reduces transaction costs. By facilitating direct interactions between public institutions, citizens, and economic agents, BC serves as an information infrastructure for exchanging data between public administrations (Alexopoulos et al., 2019; Allessie et al., 2019; Lykidis et al., 2021). Meanwhile, services that utilise smart contract automation or notarisation, such as personal certificates or land title issuance, have yielded economic benefits and efficiency gains for citizens (Reddick et al., 2020). Standardisation and flexibility are also essential factors to consider when employing BCT in the public sector (Alexopoulos et al., 2019).

The implementation of BC in the vein of government operations, however, presents several obstacles, including higher administrative costs, slow data movements, lack of standardisation and shareability of operational information, infrastructure limitations, complexity and compatibility issues with BCT, perceived risks, resource and stakeholder management, government regulation, geographic limitations, security and scalability issues, BC immaturity, and lack of audit (Batubara et al., 2018, 2022; Carter & Ubacht, 2018; Ganguly, 2022; Lindman et al., 2020; Tan et al., 2022). Nonetheless, previous studies have highlighted the successful adoption of BC technology in various industries by focusing on a clear value proposition, appropriate technology, stakeholder management, user focus, experimentation, legal support, and other factors (Batubara et al., 2022; Hou, 2017; Lindman et al., 2020; Xu, 2021).

Technology-Organisation-Environment (TOE) Framework

In previous studies, the TOE framework is presented as a theory that describes three distinct elements that impact decisions on adopting new technologies at the organisational level: technological, organisational, and environmental dimensions (Dwivedi et al., 2012; Wibowo et al., 2023). The flexibility of this framework in identifying various research factors, such as in SLRs on BC adoption (Lykidis et al., 2021; Reddick et al., 2020; Verma & Sheel, 2022), makes it highly versatile and widely employed (Cagigas et al., 2021; Ganguly, 2022; Malik et al., 2021; Ølnes et al., 2017). As a result, researchers have effectively administered this framework to chart the obstacles in BC adoption (Batubara et al., 2018; Ganguly, 2022; Malik et al., 2021; Taherdoost, 2022).

Technological dimension

This dimension encompasses internal and external factors relevant to the organisation, such as instruments and processes (Dwivedi et al., 2012; Wibowo et al., 2023). Numerous studies have pinpointed a multitude of factors that need to be taken into account when implementing BCT. These factors include infrastructure, compatibility (integrating the technology with existing software and human resources), complexity (the shared ecosystem, decentralised and distributed database system, implementation, and level of maturity), risk (immutability, cybersecurity, transaction transparency, and verifiability), negative perception, accessibility, cost-effectiveness, computation efficiency, storage size, design variables, scalability, and interoperability (Batubara et al., 2018; Ganguly, 2022; Malik et al., 2021; Taherdoost, 2022).

Organisational dimension

On the other hand, this dimension refers to the organisation's characteristics and resources: size, approach, communication processes, and more (Dwivedi et al., 2012; Wibowo et al., 2023). The organisational dimension encompasses several crucial factors that can impact the adoption of innovation within an organisation. These factors include the company's innovativeness level, adoption strategy, top management support, digital culture, financial resources, and cost-saving measures. Internal stakeholder factors such as the organisation's structure, knowledge management, and employee motivation also play a role, along with the organisation's size, the team's expertise, and their ability to learn and adapt to new technologies. Additional considerations include internal policies, organisational readiness, acceptability, implications, and trust (Batubara et al., 2018; Ganguly, 2022; Malik et al., 2021; Taherdoost, 2022).

Environmental dimension

The environmental dimension encompasses various aspects, such as the industry structure, the current state of technology service providers, and the regulatory landscape (Dwivedi et al., 2012; Wibowo et al., 2023). Previous studies point to multiple examples in BC adoption: industry adoption and demands, geographical location (such as the availability of support structures, industry strategies, and social and cultural beliefs), government regulations (including jurisdictional issues and legislative support), and uncertainty around standards (Batubara et al., 2018; Ganguly, 2022; Malik et al., 2021; Taherdoost, 2022).

RESEARCH METHODOLOGY

SLR guarantees a comprehensive and transparent approach that provides an overview of the state-of-the-art in a particular field, by examining and interpreting previous studies (Castillo & Grbovic, 2022; Rethlefsen et al., 2021). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach was developed in 1999 to facilitate efficient and accurate SLRs and has undergone several improvements since then (Moher et al., 2000; Page, McKenzie, et al., 2021; Shamseer et al., 2015). The PRISMA 2020 approach provides researchers with essential tools for conducting SLRs – a 27-item checklist, a 12-item abstract checklist, and a flow diagram, improving the quality of SLRs. By following these guidelines, researchers can conduct thorough and up-to-date reviews, ensuring transparency and adherence to best practices (Castillo & Grbovic, 2022; Rethlefsen et al., 2021). PRISMA 2020 provides three sequential mechanisms: Identification, Screening, and Inclusion (Page, Moher, et al., 2021; Wibowo et al., 2023). The PRISMA 2020 methodology thus is deemed highly efficient, reliable, and comprehensive, making it an indispensable instrument for performing meticulous and transparent SLRs across multiple research domains (Wibowo et al., 2023).

IDENTIFICATION PHASE

In order to conduct a thorough analysis of relevant literature, the authors of this study have devised a comprehensive strategy that outlines their approach to selecting appropriate sources. This strategy includes identifying relevant databases, selecting appropriate keywords, and establishing clear search criteria for determining which sources will be included or excluded from the analysis. By carefully considering these crucial factors, the authors aim to ensure that their study is grounded in a robust and diverse selection of high-quality literature, enabling them to draw meaningful conclusions and contribute to the ongoing discourse in their field.

Data sources

After conducting extensive research and taking into account the recommendations of Chen et al. (2010), the authors select a total of five digital repositories for use in this study. The repositories were selected based on their relevance and reliability in the particular research field. The following sources were included after careful consideration:

- IEEE Xplore
- ACM Digital Library
- ScienceDirect
- Emerald
- Scopus

By utilising these reputable digital repositories, the authors aim to access a diverse range of high-quality literature, enabling a comprehensive analysis to generate insights for this study.

Keywords

To retrieve relevant literature from the selected data sources, the authors then employ a rigorous search string, based on the RQs. The initial set of keywords aims to uncover issues, hindrances, and solutions associated with BC and is defined as: ("CHALLENGE" OR "BARRIER" OR "PROBLEM" OR "OBSTACLE" OR "ISSUE" OR "SUCCESS" OR "SOLUTION"). The second set of keywords focuses specifically on BC, formulated as: ("BLOCKCHAIN" OR "BLOCK CHAIN" OR "DISTRIBUTED LEDGER"). The final set of keywords locks the search area in governments and public sectors, thus resulting in the following string: ("GOVERNMENT" OR "PUBLIC SECTORS"). Combining the three sets resulted in the final query: ("CHALLENGE" OR "BARRIER" OR "PROBLEM" OR "OBSTACLE" OR "ISSUE" OR "SUCCESS" OR "SOLUTION") AND ("BLOCKCHAIN" OR "BLOCK CHAIN" OR "DISTRIBUTED LEDGER") AND ("GOVERNMENT" OR "PUBLIC SECTOR"). By using this robust search string, this study aims to retrieve a comprehensive selection of literature that would facilitate a thorough analysis.

Search criteria

To define the expected results of SLR, the authors adhere to inclusion and exclusion criteria, as shown in Table 1. IN1–IN5 further postulates the inclusion of articles, while EX1–EX5 posits the exclusion criteria for the selection of articles.

After selecting the final publications (see Appendix A), the authors simultaneously conducted data extraction and quality assessment (QA). To ensure objectivity and subjectivity in assessing primary studies, the authors employ a checklist, shown in Table 2. The authors then scored each article based on how well the articles answer the seven questions (QA1–QA7) in the QA checklist. Each primary study in the research was evaluated based on its response to the checklist questions. A comprehensive answer was assigned a score of 1, a partial answer received a score of 0.5, and a lack of coverage of the question resulted in a score of 0. Appendix B depicts the complete score for the selected studies. The quality assessment of the studies considered their credibility, integrity, and relevance in addressing the research questions.

In order to maintain objectivity, the authors have established criteria for both QA4 and QA5. Regarding QA4, the authors stipulate that each study should meet the following requirements: (i) a clear and comprehensive explanation of the chosen methodology, be it qualitative or quantitative; (ii) the presence of consistency in the arguments presented; (iii) the use of logical and precise arguments; (iv) avoidance of excessive use of specialised terminology (jargon) or any ambiguities in terminology; (v) the correct presentation of visual elements, including units, labels, and graphics; and (vi) the expression of ideas in clear and intelligible sentences. If a selected study meets at least four criteria, it qualifies for the highest score. As for QA5 – the interpretation and discussion of the results – the authors define the following criteria. Each study must: (i) provide a comprehensive explanation of the presented data and information; (ii) substantiated by references to prior studies or other justifications; (iii) if statistical analyses are employed, appropriately applied statistical techniques in discussing its findings; (iv) acknowledge any limitations or constraints that may affect the validity of its results; and (v) provide implications, whether practical or theoretical, stemming from its findings. If a study fulfils at least four criteria, it earns a full score.

Table 1. Search criteria

ID	DESCRIPTION	TYPE
IN1	Related to BC adoption in governments/public sectors.	Inclusion
IN2	Published between 2019 and 2023.	
IN3	Provide at least one problem or solution	
IN4	Peer-reviewed in conferences and journals.	
IN5	Written in English	
EX1	Focused on other than challenges/solutions of BC adoption	Exclusion
EX2	Unavailable full-text access	
EX3	Working papers, presentation, SLR	
EX4	Duplicate papers	
EX5	Do not describe practical/real life problems/challenges or solutions	

Table 2. Study quality assessment criteria

ID	CHECKLIST	%
QA1	Are the research objectives clearly stated?	10
QA2	Does the study explore challenges and solutions in BC adoption?	25
QA3	Does the article examine real-world problems and their corresponding solutions?	20
QA4	Are the presented results clear and unambiguous?	15
QA5	Are the results adequately interpreted and discussed?	15
QA6	Does the conclusion address the research questions?	10
QA7	Does the article propose future research directions?	5

SCREENING PHASE

Previous studies encourage the use of the tollgate method (Afzal et al., 2009) in refining the research articles obtained during the primary study (Grida et al., 2022; Shoaib et al., 2020). This study therefore employs the tollgate method, resulting in the following phases:

- **Phase 1 (P1):** Employing search strings to retrieve relevant articles.
- **Phase 2 (P2):** Applying selection criteria based on titles and abstracts.
- **Phase 3 (P3):** Applying selection criteria based on the introduction and conclusion sections.
- **Phase 4 (P4):** Applying selection criteria through a thorough reading of the full-text articles.
- **Phase 5 (P5):** Evaluating the quality of the studies based on predefined assessment criteria.

Table 3 depicts the five-phase selection for this study. The initial phase yielded a total of 2,237 articles. Subsequently, the application of selection criteria during Phases 2 to 4 resulted in a reduction of articles to 52. The final phase (Phase 5) further narrowed down the selection to 50 qualified articles, which were ultimately used to inform the findings of this study (see Appendix A).

Table 3. Study quality assessment criteria

SOURCE	P1	P2	P3	P4	P5
IEEE Xplore	496	30	25	7	7
ACM Digital Library	27	6	5	3	3
ScienceDirect	135	14	12	11	10
Emerald	201	7	7	5	5
Scopus	1378	44	33	26	25
Total	**2237**	**101**	**82**	**52**	**50**

INCLUDED PHASE

The authors set a threshold score of 70% to select articles, resulting in 50 articles meeting the criteria with an impressive average weighted score of 91% (see Appendix B). The authors then administer a thorough three-level approach for the analysis, commencing with open coding to classify themes based on the TOE framework. Subsequently, the authors employ axial coding to establish connections between themes and conduct a more extensive analysis, followed by selective coding for in-depth examination and cross-case analysis (Saunders et al., 2019).

Furthermore, the authors conscientiously follow the PRISMA 2020 checklist to enhance the clarity of this study. For instance, in the Introduction section, the authors unequivocally address the components of Rationale (describe the rationale for the review in the context of existing knowledge). In the Results section, the authors also ensure that this study ticks the "Risk of bias in studies" criterion from the PRISMA 2020. After ensuring all criteria are met, the authors hereby declare that this study has fully incorporated the PRISMA 2020 methodology.

RESULT AND DISCUSSION

From the 50 selected articles, the authors provide a visual representation of the selected articles in Figure 1, Table 4, and Table 5, which shed light on the state of BC adoption in government contexts. Figure 1 illustrates the government-based BC research trend, revealing a significant increase in articles on BC adoption from 4 in 2019 to 17 in 2021, followed by a decline to 8 articles in 2023. Table 4 offers a fresh perspective on the case study locations in BC adoption for governments. It reveals that ten articles discuss multiple locations, while India is the focus of study in seven articles. Furthermore, Table 5 highlights the critical issues discussed in the articles. It indicates that BC adoption across the entire government is the most prevalent topic, with 12 articles exploring this aspect, followed by 8 articles examining the application of blockchain in the Land Registry.

Table 4 further illustrates the study's findings on the distribution of case studies, revealing an equal representation of 8 location-based study cases for lower-middle-income and high-income countries. Table 5 further strengthens the notion that governments worldwide share a common aspiration to revolutionise their essential operations by adopting BCT. This compelling evidence highlights the growing demand for BC adoption among governments, transcending income levels, and diverse contexts.

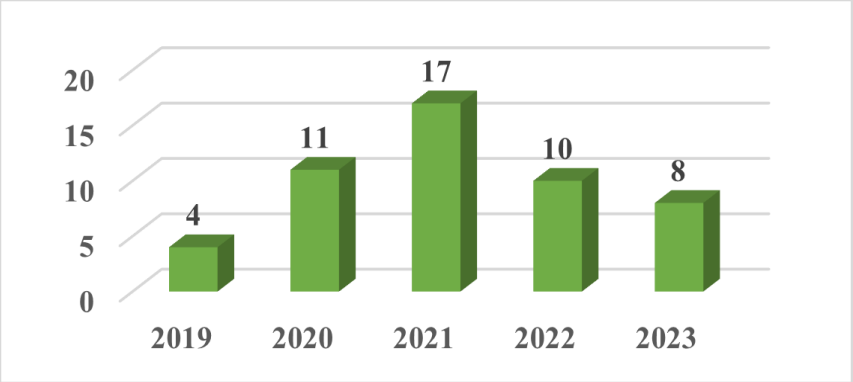

Figure 1. Year-wise distribution of articles published

Table 4. Country-wise articles distribution with status (The World Bank, 2023)

Country	Status	N	Country	Status	N
Various	-	10	Thailand	UMI	1
India	LMI	7	Canada	HI	1
Indonesia	LMI	4	Germany	HI	1
Bangladesh	LMI	3	Malaysia	UMI	1
Brazil	UMI	3	United Arab Emirates	HI	1
China	UMI	3	Sweden	HI	1
Ghana	LMI	2	Estonia	HI	1
Russia	UMI	2	Ukraine	LMI	1
United Kingdom	HI	2	Netherland	HI	1
Sri Lanka	LMI	1	Korea	HI	1
Pakistan	LMI	1	South Africa	UMI	1
Nigeria	LMI	1			

Note: LMI: Lower middle income; UMI: Upper middle income; HI: High Income

Table 5. Sector/area-wise articles distribution

Sector/area	N	Sector/area	N
Government Settings	12	Migration and Refugees	1
Land Registry	8	Environmental Services	1
Voting	4	Asset Management	1
e-Government Services	4	Port Management	1
Healthcare	4	Supply Chain	1
Procurement	3	Company Register	1
Identity Management	3	Customs	1
Education	2	Document Management	1
Court System	1	Waste Management	1

Classification of Challenges (Address RQ1)

This section provides insights into roadblocks in BC adoption, serving as a valuable resource for governments to address these barriers in their future endeavours proactively. Through SLR, the authors have compiled a comprehensive list of 40 barriers. In the subsequent subsections, we delve into a detailed discussion of these identified challenges, including their frequencies and implications. By understanding and addressing these risks, software development government organisations can understand the common issues encountered by government agencies worldwide.

Technological dimension

Table 6 highlights sixteen challenges that hinder government BC adoption, with security and interoperability/integration being the most prevalent obstacles, as indicated by 13 articles each. Data privacy, quality, and integrity are significant concerns, discussed in 9 articles each. Public or open-source blockchain platforms are susceptible to tampering and security breaches, while the decentralised nature of the system exposes them to a similar threat – unauthorised data manipulation (S. Alam et al., 2021; Alsaed et al., 2021; Clavin et al., 2020; Majumdar et al., 2020; Mintah et al., 2021; Nath et al., 2021; Thakur et al., 2020) The Norwegian government's decision to discontinue e-voting platforms reflects concerns about potential cyberattacks (Vladucu et al., 2023), clarifying the lack of trust in BC from government agencies (Hiwale et al., 2023; Khan et al., 2022; Luthra et al., 2022; Schwarzman et al., 2020; Sung & Park, 2021). The complexity and immutability of BCT add to the security concerns faced by governments, which in turn creates hesitancy towards adopting or transitioning to blockchain for their operations.

Table 6. Technological barriers to BC adoption

ID	Challenges	N
CT1	Security Concerns	13
CT2	Integration and interoperability	13
CT3	Privacy of data	9
CT4	Ensuring data quality and integrity	9
CT5	Perceived scalability of the system	7
CT6	Cost implications	7
CT7	The immutability of BCT	6
CT8	Lack of trust in the technology	5
CT9	Complexity of the technology	5
CT10	Maturity of the system or BCT	4
CT11	Transparency of operations	3
CT12	Decentralisation of control	2
CT13	Compatibility with existing systems	2
CT14	Perceived speed of transactions	1
CT15	Ensuring inclusiveness	1
CT16	Maintaining data confidentiality	1

Furthermore, establishing a data-sharing mechanism and integrating blockchain with legacy systems present additional obstacles, including mapping and ensuring data quality (Rana et al., 2022; Song et al., 2022). Addressing these challenges requires overcoming issues related to integrating with established systems and achieving interoperability among different blockchain platforms (Khan et al.,

2022). As such, the European Commission has underscored these technical and legal challenges, emphasising the importance of further research and funding to facilitate their resolution and promote the development of BCT in government applications (Clavin et al., 2020).

While BC can address trust issues, ensuring the accuracy and prevention of incorrect or manipulated data input pose ongoing difficulties, particularly in sectors like waste management and land registration (Majumdar et al., 2020; Song et al., 2022). Furthermore, blockchain's inability to safeguard against data from untrustworthy sources and its potential to store low-quality or inaccurate data have significant implications, particularly in government contexts where transparent data remain paramount (Clavin et al., 2020; Murphy et al., 2021). Additional barriers involve ensuring the accuracy of data provided by businesses and protecting user privacy, as intentional misinformation and vulnerability to privacy breaches are pressing concerns in the implementation of BCT (S. Alam et al., 2021; Alsaed et al., 2021; Shahaab et al., 2023).

The scalability challenges encountered by public blockchain platforms, characterised by the growing size of blocks and limited transaction throughput, hinder the efficiency of transaction processing (Clavin et al., 2020; Farnaghi & Mansourian, 2020; Rana et al., 2022). The substantial costs involved in implementation and maintenance, encompassing storage capacity and network infrastructure, also pose financial obstacles for government adoption as transaction costs are notably higher in permissionless (public) blockchains compared to centralised solutions, exacerbating the cost concerns (Alsaed et al., 2021; Baharmand et al., 2021; Clavin et al., 2020; Luthra et al., 2022; Prux et al., 2021; Schwarzman et al., 2020; Thakur et al., 2020).

Organisational dimension

Table 7 presents the key findings of this study on the organisation-related challenges associated with BC adoption. This study unveils 14 factors that hinder organisational progress, with the organisational culture of resistance, limited support and participation from top management, and inadequate human resource capability emerging as the most prevalent issues, each mentioned in seven articles.

Table 7. Organisational barriers to BC adoption

ID	Challenges	N
CO1	Resistance to change within the organisation	7
CO2	Lack top management support or involvement	7
CO3	Insufficient capability of human resources	7
CO4	Inadequate organisational infrastructure	5
CO5	Financial constraints or lack of budget	4
CO6	Issues related to IT governance	4
CO7	Limited organisational knowledge or understanding	3
CO8	Organisational capacity and capabilities	3
CO9	Availability of training facilities	2
CO10	Perceived risks associated with the implementation	1
CO11	Structural aspects of the organisation	1
CO12	Lack of organisational innovativeness	1
CO13	Allocation of substantial resources	1
CO14	Ethical concerns or considerations	1

Resistance to change and inadequate top management support pose significant obstacles to BC adoption in government. Public officials in Nigeria, the UK, Brazil, and Dubai display hesitance towards embracing new technologies and processes – with cultural barriers, job security concerns, and fear of losing control impeding the implementation of BC systems (Baharmand et al., 2021; Danwar et al., 2022; Farooque et al., 2020; Luthra et al., 2022; Prux et al., 2021; Rana et al., 2022; Shahaab et al., 2023). Insufficient stakeholder engagement, weak leadership, and scepticism towards BCT further hinder progress (Alnafrah & Mouselli, 2021; Farooque et al., 2020; Jattan et al., 2020; Khan et al., 2022; Murphy et al., 2021). The commitment and support of decision-makers remain essential in reshaping institutional structures and operational mechanisms as political will and influence also play a role, as observed in South Africa's government organisations (Ramazhamba & Venter, 2023).

The adoption of BCT in government settings is also hindered by a lack of technical skills and an insufficient number of trained civil servants/expertise, observed in countries like India, Brazil, the UK, Indonesia, and Dubai (Baharmand et al., 2021; Hafizon et al., 2019; Khan et al., 2022; Luthra et al., 2022; Rana et al., 2022; Thakur et al., 2020). These skill shortages encompass various aspects of blockchain development, including front-end and back-end programming, chain coding, integration, protocol development, and consensus mechanisms (Baharmand et al., 2021; Hafizon et al., 2019; Khan et al., 2022; Prux et al., 2021). Previous research indicates that the lack of organisational knowledge, understanding, and capability become additional factors that contribute to this challenge (Akaba et al., 2020; Farooque et al., 2020; Luthra et al., 2022; Prux et al., 2021; Rana et al., 2022; Sung & Park, 2021). Specifically, the absence of updated policies concerning the adoption of BCT exacerbates the situation (Farooque et al., 2020).

Insufficient infrastructure and resources pose significant obstacles to government adoption of BCT. Challenges such as operational bottlenecks, weak IT infrastructure, and inadequate funding impede the implementation of blockchain solutions in countries including the UK, Canada, Brazil, Syria, and Sudan (Akaba et al., 2020; Alnafrah & Mouselli, 2021; Baharmand et al., 2021; Luthra et al., 2022; Prux et al., 2021; Rana et al., 2022; Shahaab et al., 2023). Furthermore, the limited availability of training and facilities exacerbates governments' difficulties in addressing these issues (Baharmand et al., 2021; Prux et al., 2021).

Additional challenges identified in the literature also hinder the adoption of BCT. These include the complexities associated with governing organisational IT systems following blockchain implementation, existing organisational structures that may not align with blockchain requirements, limited innovativeness within organisations, ethical concerns, and perceived risks (Baharmand et al., 2021; Khan et al., 2022; Luthra et al., 2022; Prux et al., 2021; Rana et al., 2022; Song et al., 2022).

Environmental dimension

Table 8 presents ten environmental challenges associated with the government's adoption of BCT. The major obstacle governments encounter worldwide is the uncertainty surrounding legal and standard support (mentioned in 17 articles), followed by challenges such as limited external participation and inadequate support from jurisdictional and external government entities.

The absence of comprehensive laws and standards related to BCT presents significant obstacles to its integration within government entities (Semenzin et al., 2022). Brazil lacked specific legislation addressing blockchain, while China's regulations primarily focus on token control, lacking the necessary frameworks and standards for broader blockchain implementation (Silva, 2020; Song et al., 2022). This issue extends to India, Indonesia, and the UK, where legal complexities and the absence of standards governing transactions and smart contracts impede BC adoption (Alsaed et al., 2021; Baharmand et al., 2021; Farooque et al., 2020; Luthra et al., 2022; Rana et al., 2022; Shahaab et al., 2023).

Furthermore, limited access to vital datasets, the absence of a consensus on blockchain design, and the lack of guidelines for key management and cross-jurisdictional application also impede the progress (Murphy et al., 2021). In India, the lack of transaction writing regulations and standardised attributes for private blockchains further compound the challenges (Thakur et al., 2020). Weak regulations governing the storage and processing of personal data in Korea also hamper the development of innovative identity solutions (Sung & Park, 2021).

Table 8. Environmental barriers to BC adoption

ID	Challenges	N
CE1	Uncertainty/lack of legal and standard frameworks	17
CE2	Limited participation	6
CE3	Government/jurisdiction policies or support	5
CE4	Insufficient national and geographical infrastructure	4
CE5	Lack of expertise from vendors or private entities	4
CE6	External pressures	4
CE7	Trust issues based on institutional factors	3
CE8	Technological advancements in the industry	2
CE9	Inter-organisational communication/coordination	2
CE10	Competitive pressures	1

This issue relates to the low support from the government/jurisdiction area as it poses significant obstacles to the widespread adoption of BCT in countries like Nigeria, India, Indonesia, and China (Akaba et al., 2020; Farooque et al., 2020; Hafizon et al., 2019; Rana et al., 2022). The lack of political will, essential technology policies, and coordination among relevant institutions handicap the successful implementation of blockchain, underscoring the absence of a government/jurisdiction approach to push the adoption (Akaba et al., 2020; Kassen, 2022; Rana et al., 2022).

The human-related challenges – limited participation, lack of external expertise, and external pressure – also postpone the adoption of blockchain in government because of low digital illiteracy in Bangladesh (K. M. Alam et al., 2022), unfamiliarity in Canada (Murphy et al., 2021), lack of expertise in China's hazardous waste transfer (HWT) system (Song et al., 2022), limited skilled professionals in blockchain development, insufficient stakeholder involvement in China (Thakur et al., 2020), and citizen concerns about traceability (Rukanova et al., 2021).

Possible Solutions (Address RQ2)

Over the past half-decade, there has been an increasing emphasis on success factors and best practices for BC adoptions in governments. This section aims to provide a comprehensive overview of BC adoption practices, enabling governments to proactively implement BC in their operations. To address the second research question (RQ2), the authors have curated the list in Table 9, followed by five thematic subsections to elaborate on the solutions.

Table 9. Possible solutions for government-based BC adoption

ID	Solutions/Best Practices	N	ID	Solutions/Best Practices	N
S1	Prioritise security and privacy considerations.	24	**S15**	Assess organisational suitability	7
S2	Develop a robust framework or model.	21	**S16**	Establish industry standards and guidelines.	7

ID	Solutions/Best Practices	N	ID	Solutions/Best Practices	N
S3	Establish supportive legal frameworks.	19	**S17**	Create a supportive technological environment.	6
S4	Safeguard data integrity and validity.	17	**S18**	Enhance human resources capabilities through training.	6
S5	Foster collaboration for a BC environment.	14	**S19**	Develop a clear adoption strategy.	5
S6	Promote transparency and traceability.	13	**S20**	Educate and engage stakeholders to address concerns.	5
S7	Implement inclusive and decentralised governance structures.	11	**S21**	Foster trust in technology.	4
S8	Enhance scalability and transaction speed.	9	**S22**	Secure top management support and involvement.	3
S9	Cultivate external trust and gain support from citizens and governments.	9	**S23**	Plan for long-term system maturity and evolution.	1
S10	Ensure the availability of tools and infrastructure for BCT.	8	**S24**	Allocate resources effectively.	1
S11	Formulate national policies and investments to support blockchain infrastructure.	8	**S25**	Foster a supportive organisational culture and structure.	1
S12	Foster consensus and support among organisations.	8	**S26**	Ensure sufficient financial and cost resources.	1
S13	Ensure seamless integration of blockchain systems.	7	**S27**	Form a dedicated team.	1
S14	Conduct research and pilot testing.	7	**S28**	Implement effective change management practices.	1

Regulatory and legal frameworks

Establishing supportive legal frameworks serves as a cornerstone for adopting BCT, as legal obligations bind governments. Bangladesh, for instance, enforces transactions on the public ledger through government officials, enforced by the laws (K. M. Alam et al., 2022). In Brazil, incorporating BC terminology into Law No. 12.965 of April 23, 2014 (Establishment of Principles, Guarantees, Rights and Obligations for the Use of the Internet in Brazil) bridges architectural and terminological gaps (Silva, 2020). Thailand places significant emphasis on government policy support to align with the country's digital economy objectives (Thoppae & Praneetpolgrang, 2021). Conversely, China advocates for revising laws and policies to provide legal backing in HWT management (Song et al., 2022). In the United States, regulatory changes such as the 21st Cures Act and privacy laws serve as guiding principles for designers in the blockchain space (Clavin et al., 2020). Meanwhile, Ukraine and Russia aim to implement blockchain in their property rights systems through legal measures and the legalisation of smart contracts (Bachynskyy & Radeiko, 2019; Schwarzman et al., 2020).

Accordingly, governments establish supporting infrastructure for BC adoption through policies and investments. In China, establishing a comprehensive four-level blockchain management system and deploying government public critical infrastructure become paramount to enhance supervision in BC adoption (Song et al., 2022). Meanwhile, preparing legal instruments and physical infrastructure in Indonesia is recommended to ensure a seamless transition and successful BC adoption (Hafizon et

al., 2019). Also, the social integration of BCT relies on a consensus mechanism that actively encourages stakeholder participation – underscoring the significance of accessible ICT connectivity (Rizal Batubara et al., 2019). For Russian public procurement, the development of digital technologies emerges as a pivotal determinant in shaping the strategic potential of BC (Schwarzman et al., 2020).

Finally, governments must assist in establishing industry standards and guidelines, collaborating with multiple parties. The Brazilian government establishes a common language and terminology for effective BC implementation for defining interoperability (Silva, 2020). Clavin et al. (2020) posit that policy assessments and standard development could address governance, privacy, security, and standards for BC adoption. In Russia, the standardisation of goods & services, improved electronic language, and increased competence of civil services and suppliers have facilitated BC integration (Shahaab et al., 2023). Similarly, in Indonesia, Rizal Batubara et al. (2019) argue that standard protocols for interoperability among blockchain systems become paramount.

Security and Privacy for Data Integrity and Validity

Security & Privacy and Data Integrity & Validity remain the top solutions for BC adoption in governments, with 24 and 17 articles highlighting the issues, respectively. As such, governments worldwide have recognised the importance of security and privacy in BC adoption. Efforts include combating data fraud and manipulation in Brazil (Silva, 2020); managing private keys for transaction security in China (Song et al., 2022); ensuring confidentiality, integrity, and availability in India (Khairwal & Shah, 2022); addressing data security through division of work and personalised privacy in Bangladesh and the UK (Majumdar et al., 2020; Shahaab et al., 2023); using asymmetric key cryptography and selective disclosure for data protection (Habib et al., 2023); and implementing mechanisms such as encrypted transactions and digital IDs for sensitive information safeguarding (Gao et al., 2021; Rizal Batubara et al., 2019).

Moreover, many governments have also administered robust measures to ensure the integrity and validity of information, such as validation methods for detecting alterations in election results and intervention mechanisms for rectifying erroneous data input in alliance chains (Song et al., 2022; Vatsaraj et al., 2021). The implementation of data validation mechanisms also safeguards the authenticity and precision of judicial data, while the consolidation of data at a central hierarchy enhances the integrity of land records and cadastral mapping (Khairwal & Shah, 2022; Thakur et al., 2020). Governments also facilitate data verification within consortia (Shahaab et al., 2023), guarantee the immutability and dependability of data in customs processes (Rukanova et al., 2021), and employ certificate validation features to authenticate land certificates (Kusuma et al., 2022).

These collective endeavours underscore the importance of prioritising security and privacy while upholding data integrity and validity in successful BC adoption.

Collaboration and governance

The implementation of blockchain necessitates the involvement of multiple parties, prompting governments to engage in collaborative efforts with private and public entities to foster a BC environment and consensus mechanism (Corrêa Tavares et al., 2021; Luthra et al., 2022). Sierra Leone made history by using Agora, a private BC, for transparent digital voting during the 2018 presidential election (Vladucu et al., 2023). Adopting the ShareTendPro network in South Africa promotes a collaborative and transparent environment among stakeholders in tendering projects (Ramazhamba & Venter, 2023). Also, carefully considering requirements becomes crucial in selecting an appropriate consensus mechanism (Rizal Batubara et al., 2019). This implementation entails off-chain and on-chain document storage and a proof-of-authority consensus mechanism within a private permissioned blockchain network (Rukanova et al., 2021). Bangladesh addresses land registry challenges with a Delegated Proof of Stake consensus (Majumdar et al., 2020).

The collaboration continues further as many articles endeavour to cultivate external trust and support. China highlights the significance of direct support from government departments in driving the deployment of blockchain in HWT management (Song et al., 2022). Estonia's early utilisation of BCT showcases the country's pioneering role, with participants acknowledging its adoption even before the emergence of Bitcoin – attributing to Estonia's strong tradition in cryptography and innovative contributions (Semenzin et al., 2022).

In governance areas, decentralisation plays a crucial role in the adoption of BCT by governments. Notable examples include the Thai FDA's decentralised system (Thoppae & Praneetpolgrang, 2021), the proposed complete decentralisation of the Indian court system (Khairwal & Shah, 2022), and the decentralised design of the Malaysian blockchain for higher education institutions (Junejo et al., 2022). Estonia and Norway have also utilised decentralisation to foster citizen trust by employing e-voting and partially decentralised software (Semenzin et al., 2022; Vladucu et al., 2023). Further research remains paramount to determine the ideal level of centralisation or decentralisation in sharing business-government information (Rukanova et al., 2021).

Technological readiness and infrastructure

Albeit BC mandates no cutting-edge infrastructure, it requires specific requirements and conditions for any organisation to satisfy.

First, organisations should develop a framework and establish supportive internal environments. Sri Lanka is exploring a JavaScript-based voting system (Wattegama et al., 2021), while Pakistan focuses on reliable e-voting solutions (Danwar et al., 2022). Akaba et al. (2020) propose a framework for blockchain-based procurement in Nigeria, and Khairwal and Shah (2022) introduce the Blockbend model for the Indian court system. Estonia's digital infrastructure relies on "e-ID," "X-Road," and "KSI Blockchain" (Semenzin et al., 2022), while Russia adopts Waves' blockchain e-voting system (Vladucu et al., 2023). Alnafrah and Mouselli (2021) stress the need for a clear governance framework, and Ghana integrates blockchain for secure land administration (Mintah et al., 2021). Performance evaluation tools like Caliper are used for e-government applications (Gao et al., 2021). Vladucu et al. (2023) list successful BC frameworks: Bitcoin; Ethereum; Exorum; Hyperledger Fabric; Permissioned; Quantum; and Proprietary. Therefore, it is crucial to establish an appropriate infrastructure that aligns with the chosen framework, encompassing both physical and technical aspects (K. M. Alam et al., 2022; S. Alam et al., 2021; Hafizon et al., 2019; Rukanova et al., 2021; Vatsaraj et al., 2021).

Second, integration and seamless operation remain vital for BC adoption in governments, requiring the establishment of standards and protocols for interoperability (Rizal Batubara et al., 2019; Silva, 2020). Custom block structures have been designed to integrate blockchain with existing systems on an uninterrupted communication approach (Alsaed et al., 2021), as seen in Bangladesh's land registry (Majumdar et al., 2020). Transitioning from legacy systems to blockchain-based models also involves linking the old and new systems, mapping data, and performing quality checks (Khan et al., 2022). As such, organisations must follow up with enhancing their employees through training. In Nigeria, consensus exists on the importance of educating procurement staff and stakeholders about blockchain's intricacies and functionalities (Akaba et al., 2020). Similarly, the UAE's "Dubai blockchain centre" provides certification courses on various blockchain protocols and use cases (Khan et al., 2022).

Third, in maintaining the availability and optimisation of organisational infrastructure, a robust infrastructure – backed by advanced tools like FSolidM, KEVM, Securify, MAIAN, or Mythril – ensures seamless blockchain transactions and protects smart contracts against potential attacks (Alsaed et al., 2021). In Russia, the use of blockchain for electronic interaction between the government and healthcare organisations enhances reliability, highlighting the need for a strong infrastructure (Przhedetskiy et al., 2019). Then, organisations need to maintain the scalability and performance of

the infrastructure, as seen in many examples like in polling system (Wattegama et al., 2021), court system (Khairwal & Shah, 2022), land registry (Majumdar et al., 2020; Thakur et al., 2020), and many more (Alsaed et al., 2021; Gao et al., 2021; Ramazhamba & Venter, 2023; Shahaab et al., 2023).

Strategic planning and adoption

In government agendas, it is imperative to establish a strategic plan to execute BC transformation within the agreed time. Organisations could follow the solutions in the preparatory phase, strategy development and stakeholder engagement, implementation, and management.

In the preparatory phase, successful BC adoption in the government attributes to research and pilot testing before fully taking on the implementation. Estonia's e-health program ensured data security (Kassen, 2022), while Japan, Georgia, Ghana, South Burlington, Australia, Ukraine, and Korea conducted successful pilot projects in land records, property disputes, real estate transactions, e-voting, and identity management services (Bachynskyy & Radeiko, 2019; Shuaib et al., 2020; Sung & Park, 2021; Vladucu et al., 2023). These pilot studies highlight the importance of testing blockchain solutions for effective implementation (Baharmand et al., 2021). Employee-centred systems are crucial in ensuring organisational readiness for BC adoption in governments (Akaba et al., 2020). Ongoing efforts in e-government applications aim to identify practical and generic solutions (Clavin et al., 2020).

Then, developing strategies and engaging with relevant stakeholders must be attended. Governments worldwide are formulating adoption strategies for blockchain solutions based on their experience with cryptocurrencies, aiming to reduce transaction costs (Clavin et al., 2020). This approach becomes evident in Indonesia's blockchain-based sea toll research, emphasising the need for comprehensive analysis and a clear adoption strategy (Hafizon et al., 2019). Similarly, decision-makers in the Middle East are encouraged to define their role and allocate infrastructure investment to implement and operate blockchain projects, successfully (Alnafrah & Mouselli, 2021). Thus, organisations can foster trust in the adoption of BCT for government entities (Jattan et al., 2020; Khan et al., 2022; Semenzin et al., 2022).

To ensure the successful implementation and management of BC adoption, organisations must secure the support and involvement of top management (Alnafrah & Mouselli, 2021; Junejo et al., 2022; Rizal Batubara et al., 2019). This enables them to allocate necessary resources (Clavin et al., 2020), establish dedicated teams to oversee the adoption process (Alnafrah & Mouselli, 2021), and implement effective change management approaches (Shahaab et al., 2023).

Mapping Solutions to Challenges (Address RQ3)

Employing NVIVO 12, this study engages in the systematic mapping of solutions to identified challenges. The authors undertake this mapping by drawing upon recommendations and success factors documented in prior research, substantiating their conclusions with robust arguments and empirical evidence. For instance, when addressing security concerns (CT1), the authors meticulously delve into the studies that articulate this concern, subsequently unearthing legal frameworks (S3) as one of the viable solutions from suggestions and success factors. From the array of potential remedies, the authors ensure their selection aligns closely with the evidence presented in the literature, thereby minimising subjectivity.

To address technological challenges in BC adoption, national policies, and investments in infrastructure (S11) remain crucial. Additionally, promoting transparency and traceability within blockchain systems (S6) is essential for technological barriers, along with ensuring the seamless integration of these systems (S13). For organisational challenges, establishing a supportive culture and structure within organisations becomes vital (S25), followed by promulgating legal frameworks (S3). In the environmental dimension, educating and engaging stakeholders (S20) stands as the top leading solution.

However, should governments look for a comprehensive solution, supportive legal frameworks (S3) become the go-to solution (see Figure 2), followed by fostering a supportive organisational culture

and structure (S25) and promoting education and engagement for stakeholders to address concerns (S20) are essential remedies for blockchain adoption in governments worldwide.

The following subsections expound on the specific solutions for each identified challenge, ranging from technological to environmental aspects.

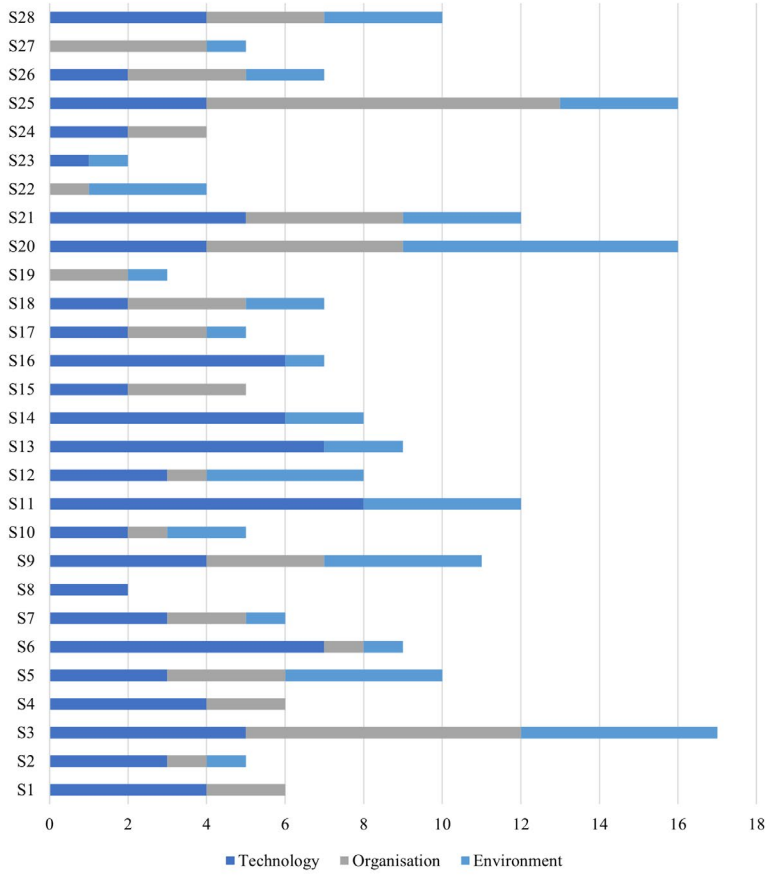

Figure 2. Summary of mapped solutions

The following subsections expound on the specific solutions for each identified challenge, ranging from technological to environmental aspects.

Solutions to the technological dimension

Table 10 highlights possible solutions for the technological barriers for governments worldwide. In this area, security concerns (CT1) become the most common issue; thus, the authors argue that S1–S4, S6, and S21 would solve the problem. Vatsaraj et al. (2021) emphasise the need for a secure asset management mechanism in India's blockchain implementation. In Brazil, legal measures have been enacted to ensure privacy and security (Silva, 2020). Additionally, the Chinese HWT promotes a private key management mechanism to enhance transaction security (Song et al., 2022). Khairwal and Shah (2022) evaluate their framework/model using the Confidentiality-Integrity-Availability (CIA) criteria to ensure adoption security. Bangladesh addresses identity management challenges through the adoption of Hyperledger Fabric Channel, a private subnetwork that ensures authentication and confidential transactions (Habib et al., 2023). Similarly, a framework is introduced in Ghana for securing the integrity, confidentiality, and security of data related to skin lands (northern region) (Mintah et al., 2020).

Table 10. Mapped solutions for technological barriers

ID	Solutions/Best Practices
CT1	S1, S2, S3, S4, S6, S21
CT2	S3, S9, S11, S13, S14, S16, S17, S25, S28
CT3	S1, S3, S6, S16, S21, S25
CT4	S4, S6, S13, S14, S16, S25, S26
CT5	S8, S10, S11, S13, S14, S24, S25
CT6	S11, S24, S26, S28
CT7	S2, S4, S6, S7, S11, S12
CT8	S1, S5, S6, S9, S20, S21
CT9	S2, S5, S13, S14, S18, S20
CT10	S11, S14, S15, S23
CT11	S6, S11, S16, S20, S21, S28
CT12	S3, S7, S11, S12, S13, S16
CT13	S9, S13, S15, S16, S17
CT14	S8, S11, S13, S14, S18, S28
CT15	S5, S7, S9, S10, S12, S20
CT16	S1, S3, S4, S6, S21

In this domain, governments should focus on formulating national policies and making strategic investments in blockchain infrastructure (S11) to address key challenges such as integration and interoperability (CT2), scalability (CT5), cost (CT6), immutability (CT7), maturity (CT10), transparency (CT11), decentralisation (CT12), and transaction speed (CT14) (K. M. Alam et al., 2022; Clavin et al., 2020; Hafizon et al., 2019; Hiwale et al., 2023; Song et al., 2022; Vladucu et al., 2023). By prioritising the solution (S11), governments can pave the way for successful blockchain adoption and harness the full potential of this transformative technology.

Solutions to the organisational dimension

Table 11 illustrates the identified solutions for organisational challenges in BC adoption. Within this dimension, the study highlights three key remedies for addressing resistance culture (CO1) and emphasises the significance of fostering a supportive culture and structure (S25) as a comprehensive solution to tackle various obstacles.

To solve the common problem from the literature, resistance culture (CO1), the authors propose three possible remedies: education and engagement (S20), supportive culture and structure (S25), and change management (S28). In a Nigerian case study, it is evident that educating and involving procurement staff and stakeholders remain crucial for fostering acceptance and comprehension of blockchain technology (Akaba et al., 2020). Furthermore, establishing a communication channel among actors remains essential for facilitating efficient information exchange (Alnafrah & Mouselli, 2021). Similarly, in the context of German migration and refugee initiatives, promoting a supportive culture characterised by selective transparency, adaptability, and reliable information sharing proves effective in mitigating resistance (Roth et al., 2023). Lastly, the successful implementation of blockchain requires effective change management strategies, employee buy-in, and the support of senior management (Shahaab et al., 2023).

Table 11. Mapped solutions for organisational barriers

ID	Solutions/Best Practices
CO1	S20, S25, S28
CO2	S3, S22
CO3	S9, S18, S19, S25
CO4	S10, S17, S25
CO5	S3, S24, S26
CO6	S3, S5, S7, S12, S15, S17, S25, S27, S28
CO7	S5, S18, S20, S21, S25
CO8	S3, S15, S25, S27
CO9	S3, S9, S18, S26
CO10	S1, S4, S5, S9, S20, S21
CO11	S3, S7, S15, S25, S27
CO12	S19, S20, S21, S25, S28
CO13	S24, S26, S27
CO14	S1, S3, S4, S6, S2, S20, S21, S25

The solution to tackle a range of organisational challenges lies in fostering a supportive culture and structure (S25). By doing so, resistance culture (CO1), employees' capability (CO3), infrastructure (CO4), IT governance (CO6), organisational understanding (CO7), organisational capacity and capabilities (CO8), perceived risk (CO11), lack of innovativeness (CO12), and ethical concerns (CO14) can be effectively addressed. Governments thus could opt for this solution (S25) to overcome a wide array of organisational barriers in blockchain implementation.

Solutions to the environmental dimension

Table 12 presents a comprehensive map of solutions for addressing the environmental dimension of BC adoption. The authors highlight that the lack/uncertainty of legal and standard frameworks (CE1) can be effectively tackled through four proposed solutions. Notably, S20 – stakeholders' education and engagement – emerges as the most relevant and applicable solution for addressing a wide range of challenges in this dimension.

Table 12. Mapped solutions for environmental barriers

ID	Solutions/Best Practices
CE1	S3, S11, S16, S20
CE2	S3, S5, S12, S20
CE3	S3, S9, S10, S11, S20, S28
CE4	S3, S9, S10, S11, S25, S26
CE5	S14, S17, S18, S20, S25, S26, S27, S28
CE6	S5, S9, S12, S20, S21, S22, S25
CE7	S6, S9, S20, S21, S22
CE8	S2, S14, S18, S21
CE9	S3, S5, S7, S12, S13,
CE10	S5, S11, S12, S13, S19, S20, S22, S23, S28

Solving the most common problem, lack of legal and standards (CE1), requires four possible solutions: supportive laws (S3); national policies and investments for infrastructure (S11); industry standards and guidelines (S16); and education and engagement (S20). Many countries have implemented (successfully or in the process) supportive laws and standards to address the emergence of BC, such as Bangladesh's Land Registry (K. M. Alam et al., 2022), the Brazilian and Thailand governments (Silva, 2020; Thoppae & Praneetpolgrang, 2021), and many more (Kassen, 2022; Khan et al., 2022; Song et al., 2022). The problem can further be addressed through policies and investments in national infrastructure like in Russia and Indonesia (Rizal Batubara et al., 2019; Schwarzman et al., 2020). Policymakers must allocate sufficient time to assess the technology, explore the need for developing standards, and gain practical experience (Clavin et al., 2020; Song et al., 2022), followed by education and engagement for involved parties (Corrêa Tavares et al., 2021; Khan et al., 2022).

In the context of addressing environmental challenges in blockchain adoption, the most critical solution identified is educating and engaging stakeholders (S20). This solution has the potential to address various issues, including the lack of legal frameworks (CE1), limited participation (CE2), lack of government/jurisdictional support (CE3), inadequate expertise (CE5), external pressure (CE6), trust issues (CE7), and competitive pressure (CE10). By prioritising this solution, governments can effectively tackle environmental barriers and facilitate BCT adoption.

Transitioning to Practical Realities

Deriving from the mapping, the authors strongly encourage practitioners and researchers to delve into the intricacies of their respective organisations or governments in light of the insights from this study. For instance, following the insights of Ward and Peppard (2016), previous studies (Lestari et al., 2019; Waspodo & Rakhmawati, 2021) argue that organisations should harmonise their strategic objectives and business needs, all while carefully considering both the internal and external business environment, as well as the Information System (IS)/Information Technology (IT), resulting in various BC-adoption strategies: Business IS, IS/IT Management, and IT. Consequently, governments can methodically prioritise solutions, aligning them with the mapping in accordance with their specific issues and challenges. Subsequently, a systematic, phased approach can be formulated to break down complex strategies into manageable tasks. Then, governments could initiate resource allocation (Clavin et al., 2020), develop change management strategies (Shahaab et al., 2023), and establish rigorous monitoring and evaluation processes.

This study also pinpoints some practical solutions to put into practice. For instance, our findings encourage government agencies to conduct small-scale pilot projects (S14). Success stories were seen in the Estonian e-Health Foundation in 2016 (Kassen, 2022) and the Estonian government in 2008, even before the term "Blockchain" was coined (Semenzin et al., 2022). Other countries have also followed this approach, such as Japan, the Republic of Georgia, Sweden, Ghana, India, the United States, Australia, Ukraine, and South Korea (Bachynskyy & Radeiko, 2019; Baharmand et al., 2021; Shuaib et al., 2020; Sung & Park, 2021; Vladucu et al., 2023). Another practical solution is the establishment of legal frameworks (S3), mentioned in 19 different articles. Governments in Brazil, Thailand, India, China, the United States, and some European countries have incorporated BC/BCT and DLT-related issues into their respective laws which strengthen and accelerate BC adoption (Alnafrah & Mouselli, 2021; Bachynskyy & Radeiko, 2019; Clavin et al., 2020; Kassen, 2022; Schwarzman et al., 2020; Shahaab et al., 2023; Shuaib et al., 2020; Silva, 2020; Song et al., 2022; Thakur et al., 2020; Thoppae & Praneetpolgrang, 2021). All these practical solutions are available and have proven effective in assisting BC adoption for governments; thus, practitioners and decision-makers could prioritise these practical solutions (and mapping) accordingly to their respective organisations' needs, resources, and environments.

IMPLICATIONS

From a practical perspective, this study offers a comprehensive exploration of BC adoption in the government context, providing detailed explanations and insights. The findings from this study hold significant value for government policymakers and decision-makers considering implementing blockchain technology. By identifying and addressing roadblocks, this study provides a solid foundation for the successful adoption of blockchain in government settings – a bedrock for BC adoption in governments. This study emphasises establishing a supportive culture and structure, engaging stakeholders through education and involvement, and addressing security and privacy concerns. These practical implications hold the potential to shape government initiatives, enhancing the efficiency and effectiveness of blockchain adoption in government institutions and services.

On a theoretical level, the authors believe that this study adds richness to the current literature on BC adoption, especially in the government context. This study enhances the understanding of the unique challenges and solutions within the government domain and presents a comprehensive framework for analysing and addressing these challenges. The theoretical implications of this research extend to developing new theories and models that can be utilised in future studies and facilitate further exploration of blockchain adoption. By expanding the theoretical knowledge base, this study opens avenues for more profound research and advances our understanding of blockchain adoption in government settings.

This research holds practical implications that can directly influence decision-making and policy development in real-world contexts. The identified practical implications can guide governments in adopting effective strategies and policies for blockchain adoption, ultimately enhancing the efficiency and effectiveness of utilising this technology in government operations. Furthermore, the study's theoretical implications contribute to advancing knowledge and understanding in the academic sphere. By bridging the gap between theory and practice, this research has the potential to catalyse positive transformations in how governments embrace and leverage blockchain technology for their benefit.

LIMITATIONS

While this study could offer significant contributions, it is essential to acknowledge its limitations. During the screening phase (especially in phase 1), specific literature on blockchain adoption was inaccessible (6 articles), which may have impacted this study. Additionally, construct validity concerns could be related to article selection, including potential bias from digital libraries and authors. The authors thus encourage readers to assess the extracted data independently. While the framework has also provided insights into factors affecting BC adoption, its limited flexibility hinders capturing dynamic changes and a deeper understanding of contextual factors. Another limitation occurs in the depth of analysis, as some literature lacked sufficient detail for a comprehensive examination. Furthermore, this study did not analyse country-specific or regional challenges. Lastly, the mapped solutions provided in this study should be further scrutinised, reviewed, and tested for practical and theoretical validity in future research.

CONCLUSION

The above discussion has provided a concise overview of blockchain adoption in governments, encompassing the identification of challenges, solutions, and their interconnection. Blockchain technology continues to disrupt various industries, offering transformative potential for society and the economy. Its decentralised and transparent nature facilitates secure information exchange, simplifies bureaucratic processes, combats fraud, and fosters trust. Governments worldwide increasingly embrace blockchain across land registration, e-government, and healthcare sectors. However, the widespread implementation of blockchain in government encounters barriers, including misconceptions, regulatory complexities, scalability limitations, and security concerns. It is imperative to address these

challenges to effectively integrate blockchain into government operations and unleash its full capabilities.

The authors propose a systematic literature review to address the issue, employing the PRISMA 2020 and tollgate methods to refine the article selection. This rigorously comprehensive process identifies 50 articles from five reputable digital sources. The authors then categorise the identified challenges into the TOE framework, resulting in 40 distinct challenges. In the technological dimension, security concerns and issues related to integration and interoperability emerge as significant roadblocks, impeding government adoption of blockchain technology. From an organisational perspective, challenges such as a culture of resistance, lack of top management support, and inadequate employee capabilities hinder the adoption process. Additionally, in the environmental dimension, the lack of legal and standard frameworks and the accompanying uncertainty deter government entities from embracing blockchain technology.

Finally, this study reveals 28 potential solutions, categorised into five thematic areas: regulatory and legal frameworks; security and privacy for data integrity and validity; collaboration and governance; technological readiness and infrastructure; strategic planning and adoption. The authors then align these 28 remedies with each respective challenge. Overcoming technological challenges in blockchain adoption requires implementing national policies and investments in blockchain infrastructure. Promoting transparency, traceability, and seamless integration within blockchain systems is crucial. Addressing organisational challenges entails fostering a supportive culture and structure within organisations and implementing appropriate legal frameworks. In the environmental dimension, educating and engaging stakeholders emerges as the primary solution to facilitate the adoption of blockchain technology.

In short, this study highlights the shared challenges governments worldwide face in adopting BCT. The findings of this research offer practical solutions to address these challenges. The authors believe this study can significantly assist governments in their blockchain adoption endeavours despite the limitations. By demonstrating how solutions can be applied to overcome each challenge, this research represents a significant step towards advancing government practices in the future – *a leap of faith*.

Future Work

Future research should address the limitations identified in this study to advance our understanding of BC adoption in governments. Firstly, there is a need to expand the literature search to include previously inaccessible sources, ensuring a more comprehensive analysis. Addressing construct validity concerns requires employing a broader range of article selection methods and mitigating potential bias from digital libraries and authors. Furthermore, future studies can explore alternative frameworks that offer greater flexibility in capturing dynamic changes and contextual factors to understand blockchain adoption better. Conducting in-depth analyses of country-specific and regional challenges will provide valuable insights into the unique considerations faced by different governments. Lastly, it is essential to subject the mapped solutions to rigorous scrutiny, review, and testing in order to establish their practical and theoretical validity.

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APPENDIX A: SELECTED STUDIES

Authors	Title	Year	Journal/Proceedings	ID
(Wattegama et al., 2021)	"iSAY": Blockchain-based Intelligent Polling System for Legislative Assistance	2021	International Journal of Advanced Computer Science and Applications	A-1
(K. M. Alam et al., 2022)	A Blockchain-based Land Title Management System for Bangladesh	2022	Journal of King Saud University - Computer and Information Sciences	A-2
(Danwar et al., 2022)	A Framework for e-Voting System Based on Blockchain and Distributed Ledger Technologies	2022	Computers, Materials and Continua	A-3
(Akaba et al., 2020)	A Framework for the Adoption of Blockchain-Based e-Procurement Systems in the Public Sector: A Case Study of Nigeria	2020	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	A-4
(Nath et al., 2021)	A Heuristic Approach using Block Chain to Fight Novel COVID-19 During an Election	2021	2021 6th International Conference on Innovative Technology in Intelligent Systems and Industrial Applications (CITISIA)	A-5
(Silva, 2020)	A Legal Framework for Blockchain Technology in Brazil	2020	Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance	A-6

Authors	Title	Year	Journal/Proceedings	ID
(Elisa et al., 2023)	A Secure and Privacy-Preserving E-Government Framework Using Blockchain and Artificial Immunity	2023	IEEE Access	A-7
(Thoppae & Praneetpolgrang, 2021)	An Analysis of a Blockchain-Enabled E-Government Document Interchange Architecture (DIA) in Thailand	2021	TEM Journal	A-8
(Song et al., 2022)	An implementation framework of blockchain-based hazardous waste transfer management system	2022	Environmental Science and Pollution Research	A-9
(Fathiyana et al., 2020)	An Integration of National Identity towards Single Identity Number with Blockchain	2020	Proceedings of the 7th Mathematics, Science, and Computer Science Education International Seminar, MSCEIS 2019	A-10
(Rana et al., 2022)	Analysis of challenges for blockchain adoption within the Indian public sector: an interpretive structural modelling approach	2022	Information Technology and People	A-11
(Murphy et al., 2021)	Assessing the potential use of blockchain technology to improve the sharing of public health data in a western Canadian province	2021	Health and Technology	A-12
(Khairwal & Shah, 2022)	BlockBlend: An Interoperable Decentralized Framework for Court Excellence	2022	2022 5th International Conference on Advances in Science and Technology (ICAST)	A-13
(Kassen, 2022)	Blockchain and e-government innovation: Automation of public information processes	2022	Information Systems	A-14
(Roth et al., 2023)	Blockchain as a driving force for federalism: A theory of cross-organisational task-technology fit	2023	International Journal of Information Management	A-15
(Junejo et al., 2022)	Blockchain based Framework for Efficient Student Performance Tracking (BloSPer)	2022	International Journal of Advanced Computer Science and Applications	A-16
(Majumdar et al., 2020)	Blockchain based Land Registry with Delegated Proof of Stake (DPoS) Consensus in Bangladesh	2020	2020 IEEE Region 10 Symposium, TENSYMP 2020	A-17
(Habib et al., 2023)	Blockchain Based Secured Refugee Identity Management by Using the Assistance Smart Contract	2023	2023 3rd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)	A-18
(Khan et al., 2022)	Blockchain for Governments: The Case of the Dubai Government	2022	Sustainability (Switzerland)	A-19
(Corrêa Tavares et al., 2021)	Blockchain in the Amazon: creating public value and promoting sustainability	2021	Information Technology for Development	A-20
(Mintah et al., 2021)	Blockchain on stool land acquisition: Lessons from Ghana for strengthening land tenure security other than titling	2021	Land Use Policy	A-21

Authors	Title	Year	Journal/Proceedings	ID
(Przhedetskiy et al., 2019)	Blockchain technologies in healthcare institutions: Focus on security and effective cooperation with the government	2019	International Journal of Economics and Business Administration	A-22
(Farnaghi & Mansourian, 2020)	Blockchain, an enabling technology for transparent and accountable decentralized public participatory GIS	2020	Cities	A-23
(Semenzin et al., 2022)	Blockchain-based application at a governmental level: Disruption or illusion? The case of Estonia	2022	Policy and Society	A-24
(Shuaib et al., 2020)	Blockchain-based framework for secure and reliable land registry system	2020	Telkomnika (Telecommunication Computing Electronics and Control)	A-25
(S. Alam et al., 2021)	Blockchain-based Initiatives: Current state and challenges	2021	Computer Networks	A-26
(Clavin et al., 2020)	Blockchains for government: Use cases and challenges	2020	Digital Government: Research and Practice	A-27
(Luthra et al., 2022)	Categorizing and relating implementation challenges for realizing blockchain applications in government	2023	Information Technology & People	A-28
(Vatsaraj et al., 2021)	Decentralized Document Holder Using Blockchain	2021	2021 12th International Conference on Computing Communication and Networking Technologies (ICCCNT)	A-29
(Hafizon et al., 2019)	E-Toll Laut: Blockchain Port as the Key for Realizing Indonesia's Maritime Fulcrum	2019	Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance	A-30
(Vladucu et al., 2023)	E-Voting Meets Blockchain: A Survey	2023	IEEE Access	A-31
(Baharmand et al., 2021)	Exploring the application of blockchain to humanitarian supply chains: insights from Humanitarian Supply Blockchain pilot project	2021	International Journal of Operations & Production Management	A-32
(Farooque et al., 2020)	Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China	2020	Computers and Industrial Engineering	A-33
(Thakur et al., 2020)	Land records on Blockchain for implementation of Land Titling in India	2020	International Journal of Information Management	A-34
(Bachynskyy & Radeiko, 2019)	Legal regulations of blockchain and cryptocurrency in Ukraine	2019	Hungarian Journal of Legal Studies	A-35
(Hiwale et al., 2023)	NikshayChain: A Blockchain-Based Proposal for Tuberculosis Data Management in India	2023	Technologies	A-36
(Prux et al., 2021)	Opportunities and challenges of using blockchain technology in government accounting in brazil	2021	BAR - Brazilian Administration Review	A-37

Authors	Title	Year	Journal/Proceedings	ID
(Piao et al., 2021)	Privacy preserving in blockchain-based government data sharing: A Service-On-Chain (SOC) approach	2021	Information Processing & Management	A-38
(Schwarzman et al., 2020)	Prospects for Distributed Ledger Technology Use in Public Procurement System of the Russian Federation	2021	Proceedings of the International Scientific Conference - Digital Transformation on Manufacturing, Infrastructure and Service	A-39
(Shahaab et al., 2023)	Public service operational efficiency and blockchain – A case study of Companies House, UK	2023	Government Information Quarterly	A-40
(Rukanova et al., 2021)	Realizing value from voluntary business-government information sharing through blockchain-enabled infrastructures: The case of importing tires to the Netherlands using TradeLens	2021	ACM International Conference Proceeding Series	A-41
(Alnafrah & Mouselli, 2021)	Revitalizing blockchain technology potentials for smooth academic records management and verification in low-income countries	2021	International Journal of Educational Development	A-42
(Alsaed et al., 2021)	Role of blockchain technology in combating COVID-19 crisis	2021	Applied Sciences (Switzerland)	A-43
(Kusuma et al., 2022)	Security System for Digital Land Certificate Based on Blockchain and QR Code Validation in Indonesia	2022	2022 International Conference on Advanced Creative Networks and Intelligent Systems (ICACNIS)	A-44
(Mintah et al., 2020)	Skin lands in Ghana and application of blockchain technology for acquisition and title registration	2020	Journal of Property, Planning and Environmental Law	A-45
(Jattan et al., 2020)	Smart Complaint Redressal System Using Ethereum Blockchain	2020	2020 IEEE International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER)	A-46
(Gao et al., 2021)	The Notarial Office in E-government: A Blockchain-Based Solution	2021	IEEE Access	A-47
(Sung & Park, 2021)	Understanding of blockchain-based identity management system adoption in the public sector	2021	Journal of Enterprise Information Management	A-48
(Rizal Batubara et al., 2019)	Unraveling transparency and accountability in blockchain	2019	ACM International Conference Proceeding Series	A-49
(Ramazhamba & Venter, 2023)	Using distributed ledger technology for digital forensic investigation purposes on tendering projects	2023	International Journal of Information Technology (Singapore)	A-50

APPENDIX B: QUALITY ASSESSMENT SCORE

ID	QA1 (10%)	QA2 (25%)	QA3 (20%)	QA4 (15%)	QA5 (15%)	QA6 (10%)	QA7 (5%)	Score
A-1	0.5	1	1	1	1	0.5	0.5	88%
A-2	1	1	1	1	1	1	1	100%
A-3	0.5	1	1	1	1	0.5	0	85%
A-4	1	1	1	1	1	1	1	100%
A-5	0.5	1	1	1	1	0.5	0	85%
A-6	1	1	1	1	1	1	1	100%
A-7	0.5	1	0	1	1	0.5	1	70%
A-8	0.5	1	1	1	1	0.5	1	90%
A-9	1	1	1	1	1	1	0.5	98%
A-10	0.5	1	1	1	1	0.5	0.5	88%
A-11	1	1	0	1	1	1	1	80%
A-12	1	1	1	1	1	1	0.5	98%
A-13	1	1	1	1	1	1	0.5	98%
A-14	0.5	1	1	1	1	0.5	1	90%
A-15	1	1	1	1	1	1	1	100%
A-16	1	1	1	1	0.5	1	0.5	90%
A-17	0.5	1	1	1	1	0.5	0	85%
A-18	0.5	1	1	1	1	0.5	0	85%
A-19	1	1	1	1	1	1	1	100%
A-20	0.5	1	1	1	1	1	1	95%
A-21	0	1	1	1	1	0	1	80%
A-22	0.5	1	1	1	1	0.5	0.5	88%
A-23	0	1	1	0.5	0.5	1	1	75%
A-24	0.5	1	1	1	1	0.5	1	90%
A-25	0.5	1	0.5	1	1	1	0	80%
A-26	0.5	1	1	1	1	0.5	0.5	88%
A-27	1	1	1	1	1	1	1	100%
A-28	1	1	0	1	1	1	0.5	78%
A-29	0.5	1	1	1	1	0.5	0.5	88%
A-30	0.5	1	1	1	1	0.5	1	90%
A-31	1	1	1	1	1	1	1	100%
A-32	1	1	1	1	1	1	1	100%
A-33	1	1	1	1	1	1	1	100%
A-34	1	1	1	1	1	1	1	100%
A-35	0	1	1	1	1	0	1	80%
A-36	0.5	1	1	1	1	1	0.5	93%
A-37	1	1	1	1	1	1	1	100%

ID	QA1 (10%)	QA2 (25%)	QA3 (20%)	QA4 (15%)	QA5 (15%)	QA6 (10%)	QA7 (5%)	Score
A-38	0.5	1	0	1	1	1	0.5	73%
A-39	0.5	1	1	1	1	1	0.5	93%
A-40	1	1	1	1	1	1	1	100%
A-41	0.5	1	1	1	1	0.5	0	85%
A-42	1	1	1	1	1	1	1	100%
A-43	1	1	1	1	1	1	1	100%
A-44	0.5	1	1	1	1	0.5	0.5	88%
A-45	0.5	1	1	1	1	1	1	95%
A-46	0.5	1	1	1	1	0.5	0	85%
A-47	0.5	1	1	1	1	0.5	0	85%
A-48	0.5	1	1	1	1	0.5	1	90%
A-49	0.5	1	1	1	1	0.5	0.5	88%
A-50	1	1	1	1	1	1	1	100%

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