Assessing application of Blockchain, Artificial Intelligence, and Cloud-Computing in e-Governance

Mohsin Shaikh*, Abdul Aziz Memon, Khalil Rauf, Ashfaq Ahmed, Shah Nawaz Khuhro

Chronicle	Abstract

Mohsin Shaikh* & Ashfaq Ahmed are currently affiliated with the Department of Computer Science the University of Larkano Pakistan.
Email: drmohsinshaikh@uolrk.edu.pk
Email: ishfaque7878@gmail.com

Abdul Aziz Memon is currently affiliated with the Department of Electrical Engineering IBA Sukkur University Sukkur, Pakistan.
Email: aziz.memon@iba-suk.edu.pk

Khalil Rauf is currently affiliated with the Department of Artificial Intelligence Mehran University of Engineering and Technology Sindh, Pakistan.
Email: khalilraufs@gmail.com

Shah Nawaz Khuhro is currently affiliated with the Department of Entomology Faculty of Agriculture Sciences the University of Larkano, Pakistan.
Email: snkhuhro@uolrk.edu.pk

Administrative setups in developing countries face hurdles due to traditional manual processing of daily government affairs. Further, lack of transparency, delayed service and irregularities aggravate these challenges despite partial computerization. Conventional, data storages are subject to unauthorized modification, inefficient data registers and lack of coordination among administrative agencies. Establishment of decentralized, transparent, fraud-resilient and digitized e- governance infrastructure becomes inevitable to address these challenges. In this study, we outline e-governance model that particularly allows workflow automation of administrative affairs leveraging blockchain-based immutability, AI powered data analytics and cloud-computing services. The proposed architecture is further expanded to determine its efficacy in healthcare, electoral process and supply chain management. We conducted an analytical study to formulate modular architecture of these critical e-governance service. We also carried out experimental evaluation using blockchain based implementation for tamper-resistant, secure and anonymized public record registration. Results of this study shall help towards development scalable, interoperable and digitized e-governance model.

Corresponding Author*

INTRODUCTION

In today's technologically advanced and digitized world, information and communication occupy a significant aspect of governance. There has been a paradigm shift in administrative functionalities and structures of government with integration of information digitized information [1]. Evidently, digital infrastructures in governance have automated administrative tasks, improved the ability to make appropriate decision and improved service delivery to public [2]. Moreover, the pro-cess of computerization, digitization and automation is driven by growing need for appropriate response to citizen-centric facilitations. The concept of digital transformation is aimed at reforming government institutions to provide effective service, facilitate interactions and ensure transparency in the management of public affairs [3]. E-governance has emerged as vital com- ponent of the technological paradigm shift that objectively computerize the bureaucratic tasks, automate the workflows and enhances the administrative structural mechanism [4]. Recently, there has been emphasis of integrating data analytics, cloud-based data management and transparency of data through rigorous technologies [5], [6]. Thus, AI-powered,

blockchain-based, and cloud computing services have become essential for e-governance for minimizing human error and cost-effectiveness in all operations. E-governance is now to be powered with modern AI analytics to detect the fraudulent practices in public records, integrated with blockchain services for decentralized, transparent, and duplication-free data management, and aided with the computational capacity of big data using cloud technologies [7]. The economic growth, national productivity and development index are significantly linked with various dimension of e-governance.

The evolution of e-governance strategies has been taking place since two decades mainly focusing on the transition from a manual tradition system to digitized, computerized and data-driven information center. Countries around the world are increasingly adopting this novel concept to enhance public sector development and facilitated by United Nation Organization [8]. However, this process of e-governance has been gradual for developing countries and quite rapid for developed economies like South Korea and Estonia. In order to formalize the e-governance, UN has devised four stages of its maturity model described below:

1.   **Emerging stage**—Basic delivery of public services through digital tools

2.   **Enhanced stage**- Computer based interactive services through different digital platforms

3.   **Transactional stage**—Automation of advanced financial services through online payments and secure transactions

4.   **Connected stage**—Integration of all the administrative affairs utilizing AI, Blockchain and Big-data analytics

Although the development of e-governance infrastructure is challenging due to socio-politico-economic aspects in any country, the significance of digital technology in public administration is inevitable to achieve following essential objectives.

-      Developing online portals and mobile applications to improve service delivery

-      Incorporate blockchain services with public data for transparency, fraud resilience, and persistence

-      Automation of routine tasks to minimizing the human errors and adhere to administrative efficiency

Having acknowledged the potential of e-governance's potential to uphold the socio-economic stability, developing countries often face disparity in implementation and maintenance of digitized infrastructure. Developing countries can achieve development goals with effective utilization of information and communication technologies in their administrative workflows. Pakistan has been strengthening measures to invest in e- governance infrastructure and implementation to provide effective services and facilities to public. It was COVID-19 pan- demic duration, government officials insisted on the adoption of digital platforms to accomplish day-to-day workings [9]. Government of Pakistan later on enforced the promulgation of policies for the digitization of state affairs, realizing as e- governance as the sole solution to coup with the challenges of misgovernance, mismanagement and adverse functioning. Despite all these conducive efforts, Pakistan has not fully integrated information management using digitized platforms. E-governance is

recognized as key to the human development index; it incurs challenges if not implemented with suitable technical compliance. There has been often delayed, expensive, paper-based and manual operations in government management leading to Inefficient and unreliable service delivery. In addition, traditional system of governance restrict citizen participation due to bureaucratic hassle and centralization in decision-making. Moreover, this conventional mismanagement does not allow to real-time determination of policies and processes. This is further worsened weak and corrupt institutional frameworks in developing countries. Therefore, an immediate transformation of such systems with transparent, temper-proof and proficient management of public records is required.

This is possible through technological solutions presented by the e-governance model that enables improved regulations of administrative functions through digital platforms, data-driven services, and big-data analytics. In order to eradicate inappropriate paper- based systems through secure transactions, enable decision-making in real time and allow data-driven operations, there comes in effect, concepts of blockchain, artificial intelligence, and Cloud Computing [10]–[12]. However, this infrastructure entails certain challenges of cyber security, lack of digital literacy and lack of awareness for technological adoption.

This study undertakes review of key challenges of e- governance implementation process. We also present a re- formed framework of e-governance that embeds state-of-the- art technologies like blockchain services, AI-powered data analytics, and cloud-computing-based data modeling. Further sections are devised resolve in the context of e-governance implementation. Section 2 explains the problem statement we aim to resolve, and Section 3 illustrates the overall proposed framework of e-governance. Section 5 provides an analytical implementation model of e-governance in 3 key area, i.e., Land Record Management Patient Record Management and Elec- toral System Management. Section 5 elaborates limitations of this study followed by conclusion in Section 6.

LITERATURE REVIEW

Although process of digitization has existed for a long time, their mode has been relative to requirement of digitization, prevalent technology and infrastructural availability. Notably, societal, political and economic domains have often realized unique trends and practices in varying generations. E-governance concept stems from the incorporation of in- formation and communication technologies for effective operations [13] . E-governance implementation requires range of tools, devices, methods, and infrastructural resources in terms of hardware and software [14]. Administrative fields of government operating on information and communication technologies can reduce corruption and fraudulent practices in developing countries like Pakistan. However, it is eminent to investigate the factors and requirement that can pave the digitization process in countries like Pakistan. Ahmed et al explained how government initiatives in Pakistan, like Citizen Portal and e-Procurement have been productive [15]. This study provided comprehensive assessment of impact of e- governance to be significant utility towards public service. On the other hand, several other investigations were made to study challenges of digitization process in Pakistan. Nishat explored that inter-departmental and inter-provincial coordination can be established through digitization process, thereby making entire system centralized and accessible [16]. Atiq et al studied comparative analysis of e-governance implementation in Pakistan and China [17]. Atiq suggested the Chinese model can be a benchmark in coping with challenges in devising policy

level framework for e-governance.

E-GOVERNANCE IN PAKISTAN

The e-governance framework in Pakistan requires architectural integration of various digitized segments, notably, public administration, registration of citizens into the national database, health, education, and justice. We have presented a Visual sketch of e-governance model for Pakistan, as show in figure 1

Digital identification through NADRA devices provides core authentication with the proposed e-governance system and composite interface for utilizing services[18][19]. After the successful authentication process, the user can subscribe to shared technology services. The provincial and federal administrating centers facilitate the data sharing through the integration layer. Further, the data of all subscribers requires scalability, inter- operability, and cost-effective storage through infrastructure founded by cloud computing services. This unified approach enhances the operational capacity of the government's administrative structure.

Model incorporates blockchain-based decentralization to ensure transparent verification and auditable records in various domains of administration, i.e, land ownership, civil registration, health records, and financial transactions[20][21]. Blockchain basically deploys smart contracts for automation of records with persistence, minimum human intervention, and encrypted storage. Blockchain has emerged as vital component of e- governance infrastructure, bearing a range of applications from supply chain and welfare disbursement to employment verification and law enforcement. The artificial intelligence layer compliments this integrated structure of the e-governance model with real-time data mining, predictive analytics, and automated decision support. This can benefit intelligent diagnostic and e-treatment methodologies in healthcare, enabling education through adaptive learning and early forecast for human resources management trends[22][23].

In general, cloud computing, blockchain and artificial intelligence guarantee efficiency and rapid response across the ad- ministrative sectors for proficient public service. This transformation of traditional governance into a secure, transparent and digitized interconnected sphere promotes accountability and accessibility of records and information. However, these technological shifts always entail adverse effects caused by lacking digital literacy, prevalent legacy systems and insecurities of data breach within public and administrative units of any government. This comprehensive approach of e-governance promises institutional strength, infrastructure development and social-economic progress in Pakistan[24][25].

BLOCKCHAIN AND AI ENABLED MANAGEMENT

In this section, we present technological architecture of healthcare, e-voting and supply-chain management systems. These models specifically provide implementation framework utilizing services of AI, blockchain, and cloud-enabled e-governance in critical domains pertaining to public service. We aim to evaluate and illustrate adherence of operational flow within these domains to transparency, trust and efficiency.

E-HEALTHCARE SYSTEM

In digitized national database and technological infrastructure, interoperability and data-centered connectivity is established among public hospitals, laboratories,

clinics, and pharmaceutical units. This develops e-health information ecosystems for effective health record management for national database, insightful health diagnostics and public health policies. In the context of Pakistan, we propose following visual representation of model as shown in Figure 2. This visual architecture comprises of five components. The first phase provides an interface to citizens to utilize e-health services. The authentication process is the second phase of this model that verifies identity of the patient, and records are stored in database. Further cloud-based health platforms presents required services to patients. In the service layer, AI models analyze electronic health records to ensure predictive information related to disease outbreaks, risks alerts for pa- tients, and efficient treatment recommendations. Blockchain cryptographic storage system is another component of ser- vice layer that encrypts records to ensure authorized data, persistence of records and modification-free records. In the last phase, health diagnostics and reports are further processed in evaluation chain of administrative spheres of e-governance. This model is designed to avoid record tampering, help making clinical decisions timely, and secure the data in e-health database.

E-Voting System

Biometric verification, blockchain-based vote registration and AI-assisted fraud detection devise corner stone of tech- enabled electoral processes. We have devised the e-voting model that is aimed at preserving voter privacy, election integrity and transparency. Figure 3 depicts sketch of its major components The proposed e-voting model shown in Figure 3 outlines workflow of casting the vote several components. The citizen interface and biometric verification components allow initial registration of voter into the system through secure authentication and biometric verification. The e-voting system allows a voter to cast his/her vote using appropriate UI/UX facilitation. Recorded and registered votes acquire tamper-proof, immutable and auditable states using blockchain service. AI services implemented in service layer applies algorithmic and predictive methodology for monitoring patterns in votes casted. AI layer should be capable of detecting anomalies and fraudulent practices, like, duplicate voting, illegal attempts of voting and unprecedented voter turnout. Furthermore, system can maintain verifiability of voter with zero-knowledge proof techniques, thereby preserving anonymity. Implementation of e-voting system is expected to increase public trust in smooth electoral process.

E-Supply Chain Management System

Supply chain management of essential goods such as pharmaceuticals, agricultural ingredients, IT equipment, heavy machinery parts and food commodities bears immense regulatory significance for governmental offices.
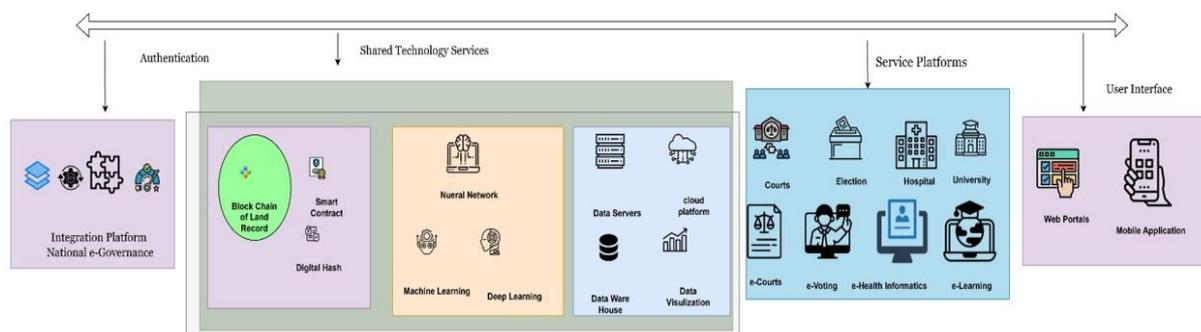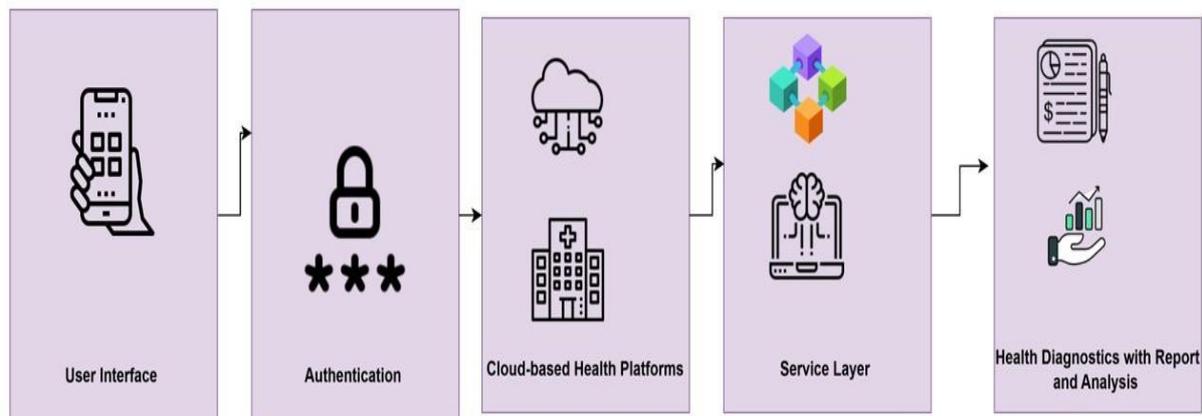

Figure 1.

Proposed e-Governance Model.

Figure 2.
Proposed e-Health Model.
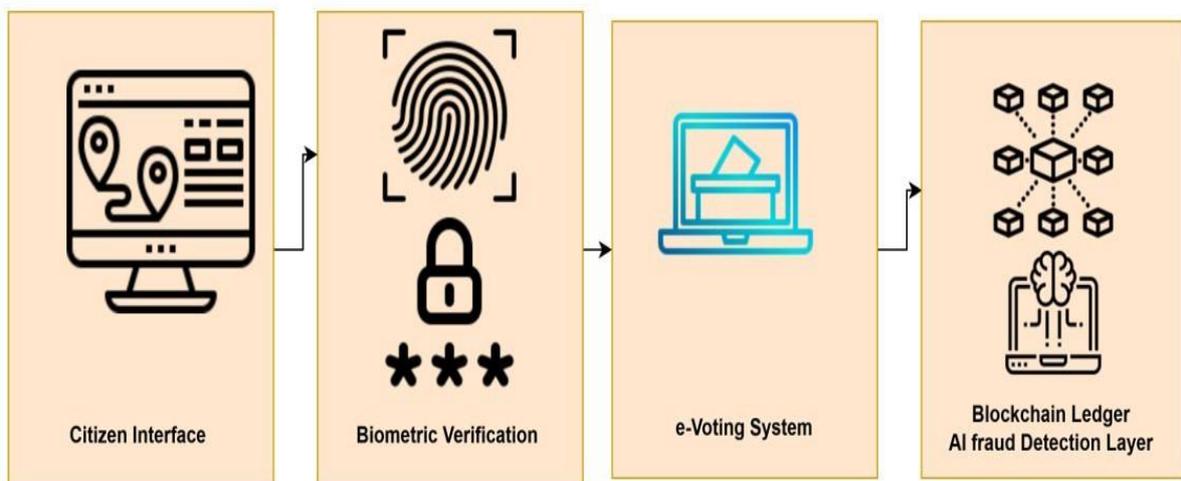

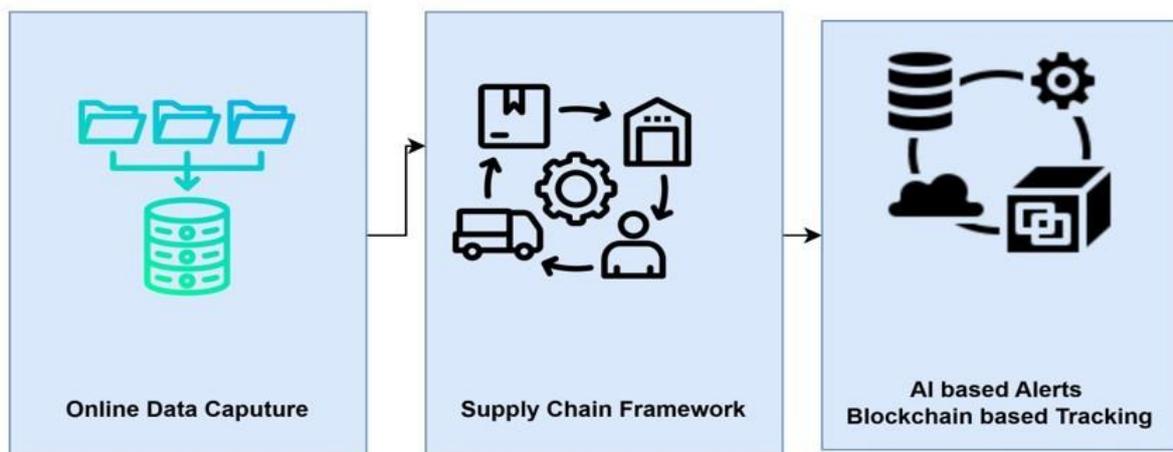
Figure 3.
Proposed e-Voting Model.

Figure 4.
Proposed e-Supply Chain Management Model .
In the context of e- governance, supply chain management system with reliance and effective tracking throughout its process can be developed using blockchain and AI-

based services, as shown in Figure4. This process of supply chain requires initial data capturing and processing it in related data centers and storage. Further, the blockchain framework manages tracking, monitoring, and regulation of all the commodities along with shipment records, certificates of quality assurances, and logistics details. AI predictors implemented in the model should be capable of evaluating demand and supply requirements, detecting goods with defects and anomalies, and keep logs of possible disruptions in supply processes. The supply model in the context of e- governance is expected to strengthen the logistic efficiency and enhance regulatory oversight. These models of e-governance pave the architectural path for blockchain-oriented trust and immutability services, AI-enabled automation and intelligence, and scalable and interoperable computing through cloud-based services. E-governance is capable of building a digitized ecosystem to tackle the challenges of mismanagement and inefficient service delivery in Pakistan.

IMPLEMENTATION

This section illustrates blockchain implementation of de- vised e-governance models, i.e,, e-Health, e-Voting and e- Supply Chain Management. We have presented a smart contract approach to imitate e-governance operations. This blockchain implementation can be easily deployed over a local blockchain for testing using Remix IDE as proof-of-concept suited in academic research. We aim to develop a prototype that shows a single, generalized blockchain-based model for transparent, immutable and tamper-proof storage. Algorithm 1 demonstrates the rationale of the e-governance design module using unified government registry contract. It consists of three main events: *EHealth*, *Evoting* and *ESupplyChain*. All these events are representations of services of specific module. Each service accepts cryptographic hash to e registered over smart contract. After successful event logs, immutability, traceability, and auditability in each of module is verified. It initializes transaction holder with global record counter in the code *recordCounter* and defines the record structure with *service, issues datahash and timestamp* variables.

Algorithm 1 shows interoperable blockchain logging of various services. Once the contract is deployed, global record counter is initialized. This record counter is incremented for each service request and logging event separately, i.e., health, vote and supply chain. Each event registers record counter, service type, issuer address an data hash in particular timestamp, allowing auditable and verifiable records.

The execution logs shown in Listing **1** represent the complete lifecycle of the proposed e-governance smart contract, from deployment to service-specific transaction execution. The first log entry corresponds to the deployment of the **GovEgovernanceRegistry** contract, where the constructor is executed on the Ethereum Virtual Machine (EVM). The absence of emitted logs during deployment indicates that no service records are created at this stage, which is expected behavior. The presence of a unique transaction hash confirms that the contract has been successfully deployed on the blockchain. Subsequent log entries demonstrate the invocation of the e-Voting service through the **castEVote** function. Each transaction shows the caller's address, the target function signature, and the emission of exactly one event log, confirming that a vote hash has been immutably recorded. The repeated invocation of the voting function, followed by a read-only call to **recordCounter**, validates that the global counter is incremented correctly and that stored records persist.

Algorithm 1: Unified Blockchain-Based e-Governance Registry

Input: Service request
$$S \in \{EHealth, EVoting, ESupplyChain\},$$
Data hash H, Issuer address A

Output: Immutable blockchain record and audit log

Define service types
$$\{EHealth, EVoting, ESupplyChain\};$$

Define record structure
$$(service, issuer, dataHash, timestamp);$$

Initialize global record counter $recordCounter \leftarrow 0$;

Initialize mapping $records[recordId] \rightarrow Record$;

if *service request received* **then**

    $recordCounter \leftarrow recordCounter + 1$;

    $records[recordCounter] \leftarrow$
    $(S, A, H, currentTimestamp)$;

    if $S = EHealth$ **then**

        | Emit EHealthRecordLogged event;

    else

        if $S = EVoting$ **then**

            | Emit EVoteCast event;

        else

            Emit SupplyChainEventLogged
            event;

return $recordCounter$;

Listing 1.

Test Algorithm for Blockchain Validation

```
Transaction Logs}, label={lst:remix_logs}]
[vm] from: 0x5B3...eddC4
to: GovEgovernanceRegistry.(constructor)
value: 0 wei
data: 0x608...e0033
logs: 0
hash: 0x127...152eb

transact to GovEgovernanceRegistry.castEVote pending ...

[vm] from: 0x5B3...eddC4
to: GovEgovernanceRegistry.castEVote(string)
value: 0 wei
data: 0xdb2...00000
logs: 1
hash: 0xe26...3b970

call to GovEgovernanceRegistry.recordCounter
[call] from: 0x5B38...eddC4
to: GovEgovernanceRegistry.recordCounter()

transact to GovEgovernanceRegistry.castEVote pending ...

[vm] from: 0x5B3...eddC4
to: GovEgovernanceRegistry.castEVote(string)
value: 0 wei
data: 0xdb2...00000
logs: 1
hash: 0xd5e...eee1c

transact to GovEgovernanceRegistry.logEHealthRecord pending ...

[vm] from: 0x5B3...eddC4
to: GovEgovernanceRegistry.logEHealthRecord(string)
value: 0 wei
data: 0x048...00000
logs: 1
hash: 0xbb5...26f4b

transact to GovEgovernanceRegistry.logSupplyChainEvent pending ...

[vm] from: 0x5B3...eddC4
to: GovEgovernanceRegistry.logSupplyChainEvent(string)
value: 0 wei
data: 0x941...00000
logs: 1
hash: 0xe63...531f
```

across transactions. These logs collectively confirm the correct execution flow and state update of the voting component. The final set of logs corresponds to the e-Health and e- Supply Chain services, executed via **logEHealthRecord** and **logSupplyChainEvent**, respectively. Each transaction produces a single event, indicating successful registration of hashed medical records and shipment information. The uniform structure of the logs across all services demonstrates the effectiveness of the unified registry design, where multiple governance services share a common blockchain infrastructure while maintaining service-specific audit trails. Overall, these logs provide verifiable evidence of transparency, immutability, and correct functional behavior of the proposed blockchain- enabled e-governance system.

CONCLUSION

This study presented a conceptual, analytical, and simulation-based e-governance model for Pakistan that integrates technical architecture of cloud computing, artificial intelligence and blockchain technologies. We emphasized e- governance as comprehensive solution to alleviate the challenges such as data fragmentation, manual process and institutional opacity. We also devised architectural design of selected domains based on operational requirements and functional constraints. Our focus of implementation details imitates interoperability among various services, privacy preservation of identities, immutability of records, and the federated structure of administrative units within Pakistan. In order to determine the practical feasibility of the proposed approach, detailed case studies were conducted using blockchain-based solidity prototypes for e-health, e-voting, and e-supply chain management. This pilot-level deployment provides verifiable audit trails for crucial e-governance components. We also presented lightweight experimental logs, which reveal successful execution and transparent record generation across e-health, e-voting and e-supply chain management. Consequently, experimental work validates the effectiveness and reliable data storage mechanism of blockchain.

In summary, digital transformation of manual and conventional governmental operations requires an incremental, scalable and interoperable path. As a part of future work, we intend to incorporate more authentication and verifiable access control and voting mechanisms utilizing cryptographic techniques and determine the feasibility of real-world data centers of Pakistan, like NADRA and the Election Commission of Pakistan.

DECLARATIONS

Availability of data and material: In the approach, the data sources for the variables are stated.
Authors' contributions: Each author participated equally in the creation of this work.
Conflicts of Interest: The authors declare no conflict of interest.
Consent to Participate: Yes
Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

REFERENCES

A. Carvin, J. Hill, and S. Smothers, *E-government for all: Ensuring equitable access to online government services*. EDC Center for Media & Community, 2004.

A. Nazuk, A. U. N. Erkin, M. Noor, and R. Zahid, "Exploring the potential and challenges of e-governance in pakistan," *Sustainable Futures*, vol. 10, p. 101472, 2025.

A. Ullah, C. Pinglu, S. Ullah, H. S. M. Abbas, and S. Khan, "The role of e-governance in combating covid-19 and promoting sustainable development: a comparative study of china and pakistan," *Chinese Political Science Review*, vol. 6, no. 1, pp. 86–118, 2021.

A. Z. Shaikh, U. L. Shah, and C. Wijekuruppu, "Public service delivery and e-governance: The case of pakistan," *International Journal for infonomics*, vol. 9, no. 2, pp. 1161–1170, 2016.

K. Rehman, A. A. Shah, and K. Ahmed, "E-government identification to accomplish sustainable development goals (un 2030 agenda) a case study of pakistan," in *2018 IEEE Global Humanitarian Technology Conference (GHTC)*. IEEE, 2018, pp. 1–6.

M. A. Alqudah and L. Muradkhanli, "E-government in jordan and studying the extent of the e-government development index according to the united nations report," *International Journal of Multidisciplinary: Applied Business and Education Research*, vol. 2, no. 4, pp. 365–375, 2021.

M. I. Sarwar, Q. Abbas, T. Alyas, A. Alzahrani, T. Alghamdi, and

P. Petkova and B. Jekov, "Blockchain in e-governance," in *Selected and Extended Papers from X-th International Scientific Conference 'E- Governance and e-Communication*, 2018, p. 149.

Q. Abbas, T. Alyas, T. Alghamdi, A. B. Alkhodre, S. Albouq, M. Niazi, and N. Tabassum, "Redefining governance: a critical analysis of sustain- ability transformation in e-governance," *Frontiers in big Data*, vol. 7, p. 1349116, 2024.

S. Alshomrani and S. Qamar, "Cloud based e-government: benefits and challenges," *International Journal of Multidisciplinary Sciences and Engineering*, vol. 4, no. 6, pp. 1–7, 2013.

S. Dash and S. K. Pani, "E-governance paradigm using cloud infrastruc- ture: Benefits and challenges," *Procedia Computer Science*, vol. 85, pp. 843–855, 2016.

S. N. A. Kazmi, "Factors influencing e-governance implementation: Is- sues and challenges in pakistan," in *2010 Fifth International Conference on Digital Information Management (ICDIM)*. IEEE, 2010, pp. 326– 331.

S. O. Adams and C. Paul, "E-government development indices and the attainment of united nations sustainable development goals in africa: A cross-sectional data analysis," *European Journal of Sustainable Development Research*, vol. 7, no. 4, pp. 1– 11, 2023.

T. ALGHAMDI and Y. ALSAAWY, "Digital transformation of public sector governance with it service management—a pilot study."

T. Almarabeh, Y. K. Majdalawi, and H. Mohammad, "Cloud computing of e-government," 2016.

This work is funded through project (Ref:AD(ACAD- 1)/SRSP/IT and CS-3/288/2024-2025) of Sindh Resaearch Support Program funded by Sindh Higher Education Com- mission of Pakistan.

Y. Alsaawy, "Digital transformation of public sector governance with it service management– a pilot study," *IEEE Access*, vol. 11, pp. 6490– 6512, 2023.

Shaikh, M.; Vayani, A.H.; Akram, S.; Qamar, N. Open-source electronic health record systems: A systematic review of most recent advances. Health Inform. J. **2022**, 28, 14604582221099828. [CrossRef] [PubMed]

Shaikh, M.; Tunio, I.A.; Shah, S.M.S.; Sohu, F.K.; Aziz, A.; Ali, A. Distributed Incremental Approximate Frequent Itemset Mining Using MapReduce. Int. J. Comput. Sci. Netw. Secur. IJCSNS **2023**, 23, 207–211.

Serban, C.; Shaikh, M. Software reliability prediction using package level modularization

metrics. Procedia Comput. Sci. **2020**, 176, 908–917.

Shaikh, M.; Tunio, I.; Khan, J.; Jung, Y. Effort-Aware Fault-Proneness Prediction Using Non-API-Based Package-Modularization Metrics. Mathematics **2024**, 12, 2201.

Shaikh, M.; Jalbani, A.H.; Ansari, A.; Ahmed, A.; Memon, K. Evaluating dependency based package-level metrics for multiobjective maintenance tasks. Int. J. Adv. Comput. Sci. Appl. **2017**, 8, 345–354.

Shaikh, M.; Lee, C.G. Aspect Oriented Re-engineering of Legacy Software Using Cross-Cutting Concern

Characterization and Significant Code Smells Detection. Int. J. Softw. Eng. Knowl. Eng. **2016**, 26, 513–536.

M. Shaikh, D. Ibarhimov, and B. Zardari, "Assessing architectural sustainability during software evolution using package-modularization metrics," *International Journal of Advanced Computer Science and Applications*, vol. 10, no. 12, 2019.

M. Shaikh, K.-S. Lee, and C.-G. Lee, "Assessing the bug-prediction with re-usability-based package organization for object-oriented software systems," *IEICE TRANSACTIONS on Information and Systems*, vol. 100, no. 1, pp. 107–117, 2017.