

Article

A Comprehensive Survey on Blockchain Technology Applications in Different Sectors of Pakistan to Develop Smart Cities

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ABSTRACT: A smart city is an amalgamation of various task-oriented systems and technologies that strive to evolve and adapt according to the needs of the city and its infrastructure. These systems aim to provide citizens with efficient services, tackle urban challenges through data-driven analytical means, and minimize the need for human intervention. One technology that can assist in achieving these goals is Blockchain. Blockchain's decentralization of assets can simplify costly and time-consuming processes, minimize expenses, and enhance transparency, security, and data integration. However, being a relatively new technology, Blockchain faces regulatory hurdles which can be attributed to incomplete knowledge of infrastructure by governing organizations. This lack of understanding often leads to confusion while comprehending different infrastructure elements, hindering problem-solving efforts. In this paper, we analyze different sectors of smart cities and their challenges in Pakistan. We also examine the existing parameters to establish the smart city and their way of upgrading infrastructure technology.

Keywords: blockchain, smart city, decentralization, data-driven analysis

Introduction:

In a Smart City (SC), multiple systems are integrated to address urban challenges and provide services to citizens through data-driven technologies that adapt to the city's evolving needs and climate. Blockchain technology offers characteristics such as authorization, interdependence, cost efficiency, and accuracy that can enhance the development of SC infrastructure. Blockchain aims to achieve infrastructure implementation by eliminating intermediaries, which aligns with sustainability objectives. This study aims to explore how Blockchain integration can shape the future of SC infrastructure and operations while addressing challenges related to privacy and resource alignment for infrastructure sustainability [1]. The authors state that the first authorized application of the blockchain technique was Bitcoin, which operates as a decentralized system for data storage and transactions. Since the term was coined in 2008, there has been a growing interest in Blockchain technology due to its unique features that provide privacy, confidentiality, and data integrity without requiring physical control. This has led to the emergence of various research fields related to Blockchain. Essentially, Blockchain functions as a decentralized database with a constantly expanding list of system entries that are verified by an IP of nodes. The information related to each activity is recorded. This key must be a public database or private database, based on the requirements. The smart city is founded on a reliable design that values user convenience,

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security, and long-term solutions to urbanization-related challenges [2]. It involves the integration of edge technologies, including IoT and AI, to develop conventional infrastructure that enhances people's quality of life. This integration requires a secure cyber environment to prevent the compromise of infrastructure components and protect against asymmetric warfare. As we continue to advance in the era of data automation, cybersecurity must be integrated into each component of the database to ensure data privacy. Overall, the goal of an SC is to uphold the highest standards of security and data privacy. A solid foundation in large data technology is essential for the successful implementation of SC, as it supports the creation and execution of effective planning and management strategies. SC cities integrate various services, including SC government, SC transportation, SC energy, and SC healthcare, with a focus on clear data and decentralization [3]. To meet the high demands of these services, a robust big data platform is required, which must be developed and maintained with high reliability, performance, multifunctionality, anti-attack capabilities, and disaster recovery capabilities. Blockchain technology provides solutions to issues that are typically associated with centralized databases, such as poor flexibility and low openness [3]. Therefore, incorporating blockchain technologies into the big data service platform can address these challenges and contribute to the success of SC development.

Blockchain applications and smart contracts have found utility in various domains, ranging from insurance reimbursements and financial transactions to corporate operations, supply chain traceability, and intellectual property protection. As a result, an increasing number of companies are adopting blockchain and smart contract solutions [3], [4]. However, to meet the demands for high performance, scalability, and security, these applications must be meticulously designed and thoroughly tested.

Developing smart contracts follows a non-standard software life-cycle, which presents unique challenges compared to traditional software development approaches. Unlike typical software, smart contracts on the blockchain are immutable, making it difficult to update or resolve bugs by releasing new versions of the software. This necessitates extra caution during the development process. On one hand, developers must prioritize code security for smart contracts due to the immutability of the blockchain and the sensitivity of the digital information often handled within these contracts [5]. On the other hand, they must pay careful attention to gas consumption, as the execution of smart contracts in blockchain platforms like Ethereum is implemented through the gas mechanism. Gas represents the computational cost required to execute operations on the blockchain, and optimizing gas usage is essential for efficient and cost-effective smart contract execution. It is important to note that blockchain technology imposes specific constraints and characteristics on the applications that run on it [6]. Developers need to understand these constraints and design their applications accordingly to ensure compatibility and efficient utilization of the blockchain's features.

Motivation

Performing data transformation in a secure and trustworthy environment is paramount. Existing data transformation systems offer the ability to automate various methodological tasks, facilitating faster transactions between parties. However, relying solely on traditional healthcare application systems to establish trust has revealed two drawbacks.

Firstly, these situations often incur higher transaction fees compared to public blockchains. Secondly, they may require blind trust, overlooking the need to question aspects related to safety, internal policies, and ethics[7]. Such limitations underscore the importance of exploring alternative approaches. Embracing public blockchains can address these concerns by offering lower transaction costs and promoting transparency. By leveraging blockchain technology, healthcare applications can ensure trustworthiness while upholding safety, internal policies, and ethical considerations, thereby enhancing data transformation processes.

Paper Structure

This research article is designed for fellows. Section 2. provides a brief view of resource problems in current cities and provides an overview of resources use in smart cities. Section 3. Describes the security issues in smart cities regarding privacy and authorization issues. Section 4. A competitive survey of Pakistani cities to analyze the problems based on current resource assessments and discuss the benefits to convert the current centralized systems to a decentralized environment.

Resource Problems in Current Cities

The objective of this article is to showcase the secure applications of Blockchain to maintain a reliable infrastructure. Blockchain technology into various urban infrastructure areas such as healthcare, Land transfer, cryptocurrency, banking, car transfer, web applications, cellular network, and power. This article illustrates this design, which was developed by analyzing case studies and the perspectives of multiple researchers on Blockchain implementation[8]. The study collected data from various sources, including published research on Blockchain and journals, and conducted a literature review to explore the use of Blockchain technology in different industries and its potential to improve sustainability.

Water Resource Assessment

As availability declines and demand rises, the trading of water access rights is becoming an issue in many municipalities and states due to the unclear future of water management. One prominent example is the Ravi River in Pakistan, where specialists claim that the issue is straightforward: there are too many requests and not enough water resources. Despite the inevitable pattern of declining water availability, proper administration and technical assistance are essential for the survival of water infrastructure[9]. It is becoming more common to think of water supply as a commodity that can be traded, with buyers and sellers exchanging water access rights. The organization that has the right to gather a certain quantity of water may offer some of its quotas for sale at a set price determined by the market. Blockchain technology has the potential to greatly improve this system by enabling water area groups to manage the balancing and settling of transactions more efficiently than they currently can. Digitization is necessary to enable an increase in water trade, and Blockchain would be the best choice for keeping and precisely recording these transactions[10]. Furthermore, using Blockchain for water exchanges would call for extra security precautions, but the technology's security features could thwart cyberattacks by rival governments, states, or businesses trying to tamper with the transactions.

Energy Resource Assessment

Modern energy-consuming household appliances, such as SC lamps and SC security systems, are frequently connected to the internet via the "Internet of Things (IoT)." Both the physical infrastructure and the digital assets needed for this integration are usually supplied by conventional technologies. In addition to these advantages, blockchains provide an unchangeable method for collaborative decision-making that speeds up the implementation of logical operations and algorithms and produces accurate results[5], [6]. Once an agreement is achieved, there is a considerably lower chance of human error because the Blockchain provides a safe interface for running a new algorithm as a hash. The "Internet of Things (IoT)" allows energy-consuming household appliances like SC lamps, smart outlets, smart home appliances, and SC security systems to be connected to the Internet. Both the physical infrastructure and the digital assets needed for this integration are usually supplied by conventional technologies. In addition to these advantages, blockchains provide an unchangeable method for collaborative decision-making that speeds up the implementation of logical operations and algorithms and produces accurate results [10]. Once an agreement is achieved, there is a considerably lower chance of human error because the Blockchain provides a safe interface for running a new algorithm as a hash. Real-time data processing and administration, such as monitoring and reporting each user's energy usage data, is one possible use for blockchain technology. Data security with Blockchain is guaranteed by its immutability and transparency, which lowers the possibility of mistakes or oversights. Mobile applications can notify users of their power usage and related expenses by integrating this Blockchain feature into the power infrastructure. Real-time monitoring of energy use not only improves openness but also enables users to create and stick to an energy budget. Additionally, users of smartphone apps can access several interactive features [7]–[10].

Transport Resource Assessment

In Pakistan, 95% of households have at least one car, which presents a substantial task to the nation's infrastructure. Cities are becoming less attractive for both business and residential reasons due to the rising demand for parking spaces and the resulting land scarcity. Peer-to-peer (P2P) vehicle sharing in particular is getting momentum and has been shown to decrease car ownership as a solution to this problem. There are presently applications accessible that cost hundreds of millions of dollars, and even automakers like Uber are working on their vehicle rental software [11]. However, expensive service fees and worries about insurance coverage frequently discourage users of such platforms. It is possible to do away with the need for middlemen to handle insurance and service costs by using Blockchain technology to digitize the main shareable commodity. The Blockchain token can gather and document information about the vehicle's position and mileage, stopping theft and allowing insurance providers to charge unique rates based on individual customers' utilization habits rather than flat rates for all [12], [13].

Security Problems in Smart Cities

The security issues with adopting blockchain technology in SC cities are enumerated in this section. The issues are broken down into several categories, including the underlying cryptosystem used in the blockchain implementation, the distributed topology of the

blockchain network, the allocation of computing power among network nodes, the chosen scalability mechanics, and the issues with identity and trust that are specific to each network member [14]. To guarantee the security and dependability of blockchain technology in SC cities, these variables need to be meticulously taken into account.

Encryption base issues

Modern cryptography systems for Blockchain usually use public key algorithms like Elliptic Curve Cryptography (ECDSA) and message digests like SHA-256. The cryptosystem is an essential part of Blockchain technology. In the instance of Bitcoin, an Elliptic Curve key combination made up of a private key and a public key is created using Secp256K1 curves [15]. Before a transaction is disseminated to the network, it is signed using the private key, which is kept a secret. After validating the transaction signature using consensus methods, miners update the distributed database and execute the transaction. A Bitcoin address is created using the public key and is used to send and receive bitcoins. SHA-256 and RIPEMD-160 hashing algorithms are used to further secure the Bitcoin address [16]. Presently, a new technology called Hyper Elliptic Curve offers a powerful encryption system with a smaller key size than any other scheme.

Decentralization base issues

Due to network delay and message propagation among the involved nodes, distributed systems frequently experience information arriving at various periods. These components work together to create a sizable, linked network, where latency and network size affect how quickly messages are transmitted. Asynchronous systems are more common in internet-controlled services because precise information coordination is not always anticipated [13]. These systems depend on third-party systems to keep event order, date messages to ensure correct message ordering, and maintain event order using standard clock time. Since future events rely on past ones, event sequencing presents the main difficulty in asynchronous systems. Without precise ordering, a future event might take place before a node finds out about a recent previous event, producing inconsistent outcomes and failing to reach an agreement [17].

Blockchain Implementation Challenges In Different Sectors Of Pakistan. A Case Study

The following section showcases instances that demonstrate possible complications in implementing the system in a real urban setting, using Lahore, Pakistan, as an example. The accompanying Fig. 1 outlines the six primary infrastructure systems, namely communication, power, population, services, Finance, transportation, and water supply.

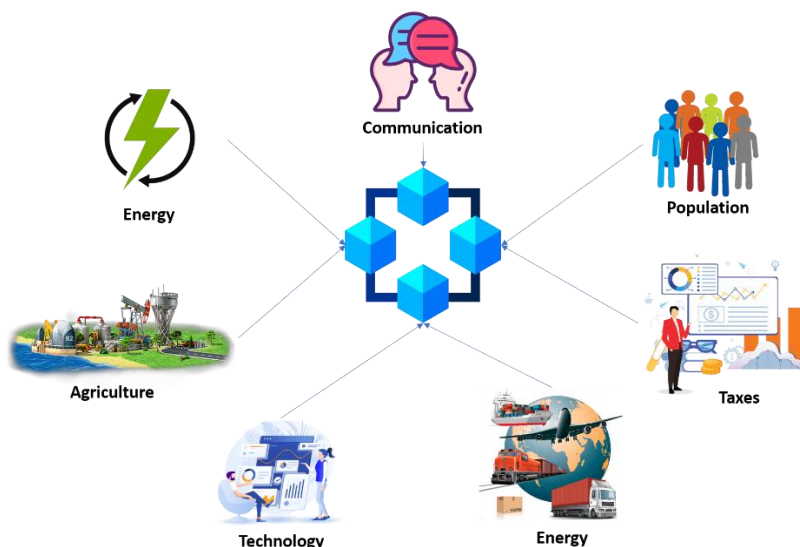


Fig. 1: Primary Infrastructure Systems

Transportation Sector

In the transportation sector, about 212.2 million population in Pakistan use highways including motorways and railways. The transportation system in Pakistan heavily relies on road transport, accounting for 90% of national passenger traffic and approximately 96% of freight movement. With a population of over 9 million, Lahore serves as the provincial capital of Punjab and is a highly populous city. The growing population has resulted in a surge in transportation demands, with over 13.5 million multi-purposed motorized trips, excluding walking, taken daily. [18] As the population is expected to rise to over 15 million by 2015, the travel demand is also anticipated to increase, thereby encouraging a rise in private cars and greater dependence on Paratransit. With a population of over 9 million, Lahore serves as the provincial capital of Punjab and is a highly populous city. The growing population has resulted in a surge in transportation demands, with over 13.5 million multi-purposed motorized trips, excluding walking, taken daily. As the population is expected to rise to over 15 million by 2015, the travel demand is also anticipated to increase, thereby encouraging a rise in private cars and greater dependence on Paratransit [19]. Blockchain-based systems provide an easy way to coordinate shared papers on a distributed database, virtually eliminating the need for paper-based records. Reduced processing periods for products at customs checkpoints are made possible by the use of SC contracts, which facilitate quicker and more effective permits and customs clearing. For businesses to make educated choices, they need reliable data. Blockchain, which is supported by the complete network, guarantees data validation throughout the transportation and logistics environment. According to a recent study, a straightforward refrigerated cargo necessitates over 200 distinct contacts between over 30 organizations, and any hiccups along the way could result in lost or delayed containers [20]. All of these actions can be safely and permanently documented using blockchain technology. Traditional tracking technologies may not grow as demand for same-day and one-hour delivery services rises, but Blockchain provides an instant, flexible answer for order tracking and verification. The supply line for used vehicles and truck components

could be digitally recorded on a ledger by using Blockchain. This will encourage Pakistanis to use public transit and make them more dependable [14], [20].

Power & Water Resource Sector

Punjab is the largest province in Pakistan in terms of both agricultural production and population. It is divided into three zones: southern, northern, and central. Punjab is known for its high agricultural productivity, which surpasses that of other provinces. In this research, peri-urban areas of Lahore were studied due to their availability of resources and time. Lahore serves as the capital city of Punjab. According to the information provided, WASA Lahore's typical monthly metered usage per connection was 44.02 m³, on average[8]. The expected daily water usage per person would be around 200 liters if we assumed an average of 7 people per link (LPCD). A water system would be implemented in Lahore, which would have several advantages, including decreasing inequality by enabling water systems with a surplus to exchange with those who are having a deficit.

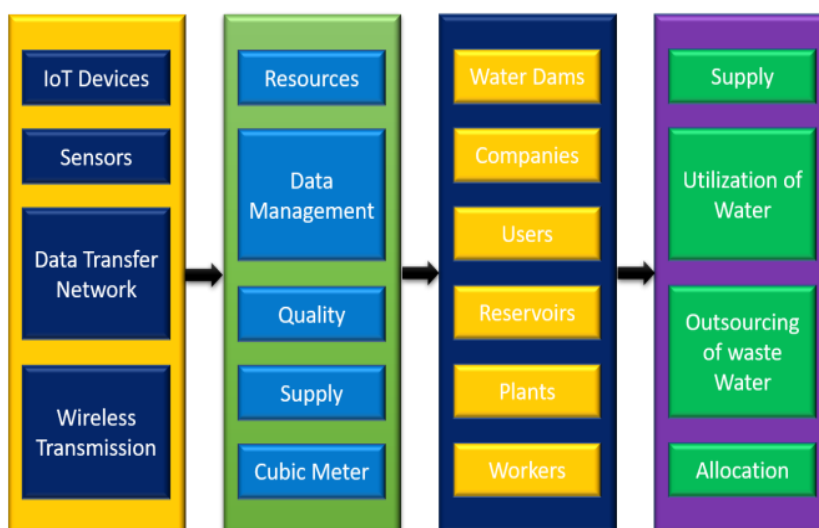


Fig. 2: Blockchain technology for water management

Utilizing resources like rainfall, effluent, and stormwater, would also encourage water systems to investigate new income streams and regional water sources. Supply diversification would increase resistance to the effects of climate change while encouraging water systems to recycle effluent. Thus, it is crucial to take into account both the technology and the organization and processes mentioned in Fig. 2 that go along with execution when talking about the deployment of Blockchain in Lahore [2]. The blockchain drives Lahore towards policies that are in line with these objectives by serving as a tool to support sustainability, diversify water technologies, and provide adequate data administration for any information received by water infrastructure. Technical and non-technical losses can both be categorized as energy losses. Technical losses are waste due to mistakes in the energy delivery process, whereas non-technical losses are waste due to electricity theft, malfunctioning meters, incorrect invoicing, and line loss. Between 10% and 40% of overall losses are non-technical losses, with deceit and power theft accounting

for a sizeable portion of these losses [21]. For instance, according to recent research, power theft accounts for 20% of power losses in India. Since established nations like the USA record a yearly economic loss of \$6 billion due to electricity theft, which accounts for roughly 80% of commercial losses, this problem is not unique to developing nations. Such losses lead to decreased income, subpar service, and eventually a failing economy. Pakistan's traditional energy sector must therefore change to keep up with the development of technology, changes in social habits and citizen demands, as well as the improvement of power monitoring methods.

Land Acquisition Sector

Land use and land cover (LULC) change has significant impacts on various environmental factors such as land surface temperature, haze, vegetation loss, impervious surfaces, environmental uncertainties, CO₂ emissions, water degradation, and urban flooding. Urban expansion has led to the conversion of a significant portion of vegetation cover to impervious surfaces, leading to adverse effects on the environment [22]. Monitoring the existing trends and future trajectory of LULC detection is crucial to gain a better understanding of previous research on LULC and mitigating the negative impacts of LULC change.

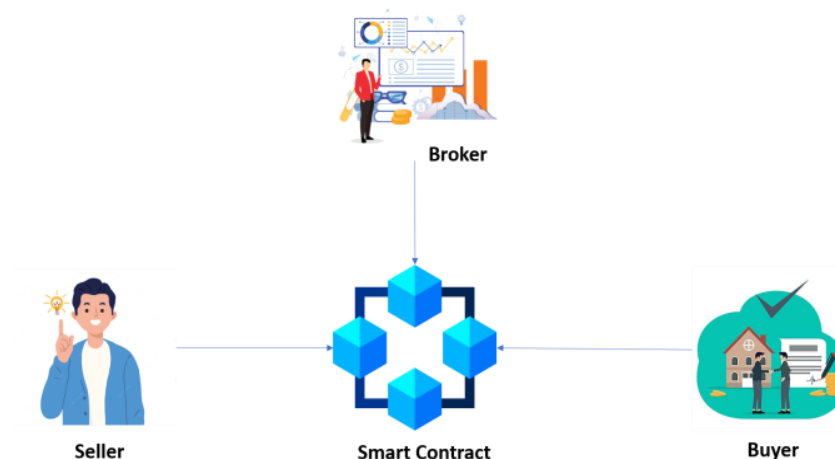


Fig. 3: Smart Contracts in Land Transfer

Despite the use of technology like web-based apps and centralized systems mentioned in Fig. 3, land record management in Pakistan is mainly conducted through physical processes. Numerous initiatives have been taken to resolve the flaws of manual methods, but many problems still exist. Several issues arise as a result of the pertinent agencies' separation from one another, including the National Database and Registration Authority (NADRA), Revenue, and Registrar's Office. For instance, to produce and verify documents, property sellers and buyers must make distinct visits to each agency [2].

The Punjab Land Records Authority (PLRA), which oversees the present system in Punjab, Pakistan, has been found to operate in a dispersed setting and incorporate several processes for land registration and title transfer. Unfortunately, the PLRA does not have a system in place to provide a thorough account of land possession [4], [5], [7], [8], [23].

Additionally, the system has a flaw that enables the simultaneous issuing of numerous sales certificates and lets authorities change property ownership records due to the use of a traditional database.

The transfer of land change from one owner to another owner includes much middle documentation including tokens and fard in front of a magistrate. The implementation of Blockchain technology in construction projects would ensure that all current and historical data is securely stored and easily accessible. With this system in place, all people and digital assets engaged in the construction industry can document changes and expert judgments on the Blockchain network, allowing for real-time updates and better adherence to building codes. Court officials can guarantee more effective building practices by monitoring life cycle updates and sourcing procedures for all ongoing or finished projects [15], [19], [24]. The tokenization of building assets can also increase community support and generate idle income. The city can better manage project cost overruns and procurement fairness through increased data transparency thanks to construction companies' ability to exchange Tempe tokens for yearly returns.

Tex Collection Sector

The government-authorized department tasked with gathering, overseeing, and keeping taxes on products, services, organizations, firms, and experts is known as the Taxation Department. These fees are essential for the nation's fiscal growth. The tax rate changes based on the group, but the main ones are businesses, products, societies, and people. Unfortunately, only 5% of Pakistan's population pays indirect taxes, and the other 95% hides their revenue or engages in dishonest behavior with top tax officials or professionals to avoid paying [25]. Due to the tax officials' lack of professionalism and lack of loyalty to the nation and their jobs, collecting indirect taxes has become a difficult chore in recent years.

There is a need to digitize taxes and converting them into various formats will modernize tax systems. The use of blockchain technology, which has transformed the process of paying and filing taxes into databases, has made this change feasible. This contemporary method of digitizing revenue systems has already been implemented by many nations, including several in Europe, Brazil, and South America. This technology has been shown to improve tax officials' compliance and effectiveness while also streamlining and speeding up the tax payment process [5]. The architecture or model of the blockchain-based revenue system used in Brazil and South America.

Discussion

Blockchain is a decentralized technology that functions as a distributed ledger, offering a secure and immutable record of business transactions. It operates on a peer-to-peer network, where multiple computers maintain identical copies of the ledger. The primary advantages of blockchain lie in data security and reliability, as the information stored within it cannot be easily altered, and the presence of redundant copies minimizes the risk of data loss. By eliminating the need for intermediaries like banks or brokers, transactions can be executed directly between parties [12]. Although the decentralization aspect of blockchain technology generates enthusiasm within the community, there are significant

advantages to be gained by efficiently managing a centralized database mentioned in Table.1 as well.

While newer blockchain implementations are making strides in improving performance, they still fall short when compared to the capabilities of a well-optimized centralized database. A prime illustration of this contrast can be seen in the Visa network, known as VisaNet, which can process an impressive 65,000 transactions per second. In contrast, the Bitcoin network can only handle a fraction of that volume, with only a few transactions per second [26]. It's worth noting that VisaNet currently operates at an average of 2,000 transactions per second, indicating considerable room for expansion and scalability. By leveraging a centralized database, organizations can achieve high levels of transactional efficiency and throughput that surpass current blockchain capabilities. While blockchain provides its unique benefits, recognizing the value of a well-managed centralized database is essential, particularly when performance and scalability are paramount considerations [27].

Table. 1. Comparison of blockchain with other technologies

Technology	Cost	Security	Performance	Scalability
Blockchain	Low	High	High	Low
Cloud	High	Medium	High	High
Distributed DB	High	Low	Low	High
Ledgers	High	High	Medium	Low

In recent times, the OrbitDB open-source project has surfaced as a solution for building distributed, peer-to-peer databases without relying on a conventional blockchain infrastructure. This innovative approach enables the development of decentralized applications that can function even in offline environments and seamlessly synchronize with other database nodes upon reconnection [28]. One notable advantage of OrbitDB is its ability to facilitate secure data sharing while maintaining privacy and transparency. It empowers companies to enforce privacy measures and gain insights into how data is being utilized, fostering a more accountable and trustworthy ecosystem.

Despite the increasing popularity of smart contracts and the ongoing research endeavors to address associated challenges, the proposed approaches are still in the early stages of consolidation. Consequently, there is a pressing need to identify software engineering tools, techniques, best practices, and testing approaches specifically designed to tackle the unique features introduced by decentralized programming on the blockchain [17]. To bridge this gap and gain a comprehensive understanding of research efforts aimed at enhancing the implementation, security, and reliability of these applications, this paper conducts a systematic review of the literature. The review focuses on software engineering

tools, techniques, and practices envisioned to address the complexities inherent in smart contracts and blockchain development. Furthermore, the study aims to identify potential future research directions and highlight unresolved issues that demand attention [14]. By undertaking this systematic review, we aim to contribute towards advancing the knowledge and understanding of the tools and methodologies available for enhancing the development and deployment of smart contracts and blockchain applications. By identifying current research efforts and shedding light on emerging challenges, we hope to provide valuable insights for researchers and practitioners in the field.

Conclusion

To evaluate problems, create fresh solutions, and make suggestions for the future, academics and governments have thoroughly studied the idea of resilient infrastructure in smart communities. To accomplish this, specialized data handling and recording tools are required. In addition to exploring possibilities for Blockchain technology in smart cities, this study seeks to contribute to the architecture of future energy markets. The literature study concentrated on works that dealt with topics like data management, cyber security, SC cities, enhancing government management systems with blockchain, water pollution, blockchain tracking, trading of water access rights, and electricity infrastructure. To comprehend how Blockchain will be incorporated into a city's operations and infrastructure in a future SC, the document offers a design framework. It prioritizes user convenience based on their requirements, secure financial activities, and improved data tracking while addressing the complicated issues of infrastructure sustainability in terms of security and resource management.

The use of Blockchain in infrastructure raises several concerns about how governing authorities can manage businesses that need to significantly change the cost-value specifications for their corporate responsibilities, which could be both expensive and time-consuming. To handle this, risk management plans must be created that divide related risks and model changes according to each use case. It's crucial to handle any challenges and related problems that might develop. Future study on the integration of Blockchain into SC infrastructure has the potential to address these problems.

Future work

This research aims to develop an environment of blockchain technology in Pakistan to secure data and provide high performance. We will develop a system based on blockchain to ease the people of Pakistan and contribute to the technology.

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