Received: 6 November 2023 | Revised: 23 April 2024 | Accepted: 2 June 2024

DOI: 10.1002/eng2.12948

REVIEW

Engineering Reports Open Access WILEY

Blockchain for sustainable city transformation: A review on Bangladesh

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Abstract

Blockchain (BCn) revolution across the world leads the global transformation by altering the existing structure and introducing the accessible and decentralized paradigm. This technology facilitates access to resources and redefines conventional frameworks, empowering people and communities globally. Motivated by these attention-seeking potentiality of BCn features, in this article, we examine the challenges, advancements, and emerging prospects of the BCn revolution in Bangladesh. With a specific focus on BCn implications for sustainability and smart development, this study addresses the urgent need to understand how BCn can facilitate sustainable development in rapidly evolving countries like Bangladesh. The goal of this research is to draw attention to the successful revolution of BCn in the world and use this knowledge to extract best practices and cutting-edge strategies for sustainable transformation of Bangladesh. The contribution of this study covers the underlying concepts of the BCn technology, showing the revolutionary state of BCn across the world, applications of BCn for sustainability, assessment of its current usage, and highlighting the BCn implementation problems. Furthermore, this study serves as a gateway to a transparent, decentralized future that fosters inclusive national progress and aligns with sustainable development goals. This study also strives to inspire individuals to use this transformational technology for the collective benefit of society by highlighting BCn's potential to empower communities while driving positive change.

KEYWORDS

blockchain, e-Governance, finance, fourth industrial revolution, healthcare, smart contract, sustainable development goals

1 | INTRODUCTION

The fourth industrial revolution (4IR) is moving at a remarkable pace around the world, and it will accelerate initiating more advanced technology in the upcoming future. Among many technologies, the emergence of the blockchain (BCn) creates more potential scope for the society and economy to address the requirements of Sustainable Development 2030.[1] The capacity to offer tamper-proof, transparent, and secure data storage without the need for third-party explicit

reasons for getting the popularity of BCn network in addressing the sustainable goals.[2] The BCn technology can confirm sustainability in society through various aspects like assuring secure and transparent supply chain tracking, establishing peer-to-peer energy marketplaces, promoting impartial decision-making, and improving data privacy and security. These mentioned dynamic nature make BCn a useful tool for encouraging eco-friendly behaviors, lowering waste, and eliminating supply chain abuses. Additionally, by eliminating third-party and ensuring decentralization, BCn-based solutions can aid in the development of a more egalitarian and sustainable economic society.[3]

A report named "Digital Economy Report 2019" published by UNCTAD notifies that only those countries, which have prepared themselves to use the potential of BCn in their economic growth and development, can effectively encounter challenges and leverage the opportunities presented by the digital economy.[4] This report also examines how the modern economy may affect public policy and offers suggestions for policymakers on using digital technology, such as BCn, for sustainable development. In many countries around the world, BCn technology has already been implemented in a number of projects which includes healthcare, voting, trade finance and so forth. Some notable examples are Switzerland, a hub for BCn startups with a supportive regulatory environment, and China and Estonia launching BCn networks for several initiatives and managing healthcare data, respectively.[5] The above interest and potential scope of BCn technology encourage other countries like Singapore, UAE, and Japan to explore the aspects of this technology in their industries.

Bangladesh is on the periphery of data-driven 4IR. In this context, the Government is trying to ensure that different sectors in the country can use the evolving technologies and construct the right skills to build next-generation sustainable technologies. Among these wide-scale technologies, the BCn attracts more attention because of its sustainable and extended features, making it a pivotal component in the adoption of the 4IR. The Bangladesh Govt. has started establishing the BCn network in the growing financial sectors such as digital banking, peer-to-peer payments, and identity verification. Also, they have contemplated adopting BCn technology in various sectors, like controlling the transportation of products, keeping track of health data, ensuring the security of elections, and minimizing corruption.[6] Because of having all these features, this technology has opened the door to large prospects in Bangladesh and has the ability to ease and secure existing application sectors.

Although the adoption of BCn technology is still in its early stage in Bangladesh, its potential use in a number of industries is promising. Money transactions, delivery services, and supply chain management systems can be exemplary industries that may interrupt due to the adverse effect of any pandemic.[7] Additionally, a report currently published by the WHO stated that the post-pandemic financial damage would be about $8.1 trillion. In the report, it has also been highlighted that business and supply chain management systems would crack up within a week, where the use of BCn can be a boon in this ruinous situation. After learning about the huge potential of BCn, many countries in the world have either started employing this technology or are about to initiate the process of executing BCn.

Because of this explicit planning in outstanding growth and development, Bangladesh can become a role model for other developing countries. Nevertheless, it may face a lot of challenges in the path of going forward. Many of those challenges can be proficiently handled with the actual and intelligent application of evolving technology such as computer vision, machine learning, and artificial intelligence. In 2016, cyberpunks pilfered $100 million from the central bank.[8] After that, the money was transferred to an account in the Philippines and subsequently laundered through casinos. If BCn can be effectively implemented in Bangladesh, it has the potential to prevent such obscene incidents from occurring in the future.

1.1 | Motivations and contributions

There are many scopes and application sectors in Bangladesh for BCn technology. Several extended features like decentralization, immutability, and anonymity of BCn can be very useful from Bangladesh's perspective to ease the working process and increase security. However, some challenges may arise including scalability, security, and obscure communication and identification during the implementation of BCn technology in different sectors of Bangladesh. These challenges may restrict confirming sustainability in Bangladesh. Challenges behind the sustainability inspire us to prepare an explicit roadmap to meet the sustainable development goals (SDGs) through BCn technology. In this article, we discuss and summarize the features, trends, and challenges of BCn in Bangladesh. The main findings of this article can be summarized as follows:

- ***Studying the fundamental features of BCn***: In this article, we discuss the basic architecture of BCn and investigated the mechanisms and features useful for applying BCn in different sectors of Bangladesh.

- ***Analyzing the outcome of executed BCn projects in different countries***: A thorough discussion of already executed BCn projects around the world is included in this study with an analysis of investment and its impact.
- ***Exploring the trends of BCn in Bangladesh***: This article entails a brief discussion of the current advancements and future trends of BCn technology in Bangladesh and also encompasses how BCn can ensure SDGs for Bangladesh.
- ***Investigating the opportunities and integration challenges of BCn***: This article highlights the importance of executing BCn in various sectors. Further, it discusses the barriers towards the implementation of BCn in different sectors of Bangladesh.

A brief discussion about the overview and architecture of BCn is presented in Section 2. Here, the history of BCn evolution and various types of BCn as well as their extended features are discussed. The outcome of BCn projects in different regions around the world is thoroughly discussed and analysed in Section 3 in terms of investments, impacts, and descriptions. In Section 4, the BCn agendas in Bangladesh's sustainability along with its technical visions are clearly highlighted. Section 5 describes the current advancement of BCn technology in Bangladesh and explores the future prospects of BCn to meet the SDGs. The implementation benefits and challenges of BCn technology in Bangladesh are discussed in Section 6. The concluding remarks of this work are presented in Section 7.

2 | BLOCKCHAIN: FRAMEWORK AND FUNDAMENTALS

BCn refers to several data blocks chaining together in a non-centralized, traceable, and unalterable frame using communication technology.[9] The primary goal of BCn is to create and establish a decentralized platform with the intention of storing data in blocks and connecting them with a chain. By keeping the interconnection, it is possible to gain a stabilized database, and recapture the necessary data as per the requirement. The term Bitcoin, also known as cryptocurrency, is the first BCn application ever.[10,11]

A cryptocurrency is a decentralized global ledger produced by joining the separate transaction data blocks.[12] The mining of cryptocurrencies is not possible without the hash. A hash, which is the name given to the resulting encrypted information, is made up of a string of characters unrelated to the original content. The process of hashing involves running the data from a block through a mathematical operation that produces an output with a predetermined length.[13] Using a fixed length, the output boosts security since a person trying to decrypt the hash will not be able to identify the length of the input.

The blockchain's ledger idea does away with the requirement for permission from outside parties. Four essential elements are necessary for it to work: the shared ledger, which maintains transparent and unchangeable transaction records throughout the network; the consensus algorithm, which verifies transactions and safely updates the ledger; the virtual machine, which runs decentralized applications or smart contracts. These elements work together to create blockchain, which allows for decentralized, trustless transactions without the need for middlemen as shown in Figure 1. Those components are BCn application, shared ledger, consensus algorithm, and virtual machine.[14] The blocks are interlinked with each other by hash values and checked at regular time intervals. So, malfunctioning in the blocks caused by hackers can be easily detected during the checking process. Miners get rewarded for playing a role in checking the records of transactions.[15] This entire process of BCn increases the security of any transaction.

2.1 | Blockchain categories

There are four types of blockchain technology available in the literature. Each BCn network has some separate features mentioned in Table 1. As per the security requirement, any industry can use any type of BCn network. A short description of various type of BCn networks is given in the following part.

2.1.1 | Public blockchain

Public BCn networks are completely decentralized, open to everyone, and permissionless. It can enable equitable access for all nodes, the addition of new blocks of data, and the validation of preexisting blocks of data.[16] The majority of today's

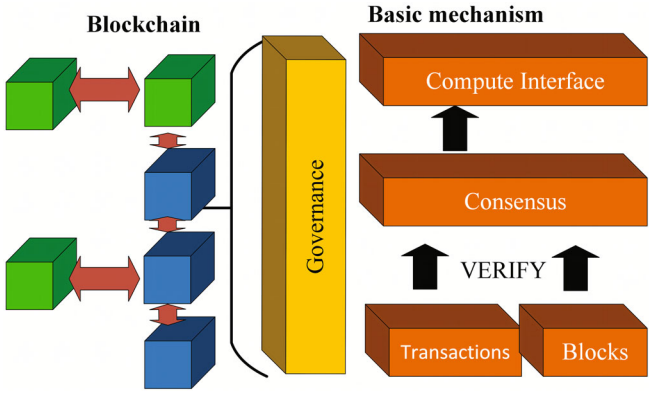

FIGURE 1 Architecture of blockchain.

Bitcoin mining and trading takes place on public BCn. In Reference 17, a description about some well-known public BCn including Bitcoin, Ethereum, and Litecoin is found. On these open BCn networks, nodes participate in the process of "mining" for Bitcoin by constructing blocks for transactions requested by the network and solving cryptographic challenges. Here, miners receive a small amount of cryptocurrency as compensation for their diligent work. In essence, they act as contemporary bank tellers who initiate a transaction and receive cash in return (Table 2).

2.1.2 | Private blockchain

Private BCn networks are permissioned BCn administered by a single entity.[18] They are also known as managed BCn. Who is permitted to be a node on a private BCn, is decided by the central authority. Additionally, the central authority may not always grant each node an equal right to execute certain responsibilities. Due to restrictions on public access, private BCn networks are only partially decentralized.[21] The business-to-business virtual currency exchange network Ripple and the open-source BCn application framework Hyperledger are the two examples of private BCn. The limitations of private BCn are more susceptible to fraud and bad actors whereas public BCn network typically offer shorter validation times for new data.[22] Consortium and hybrid BCn were created to overcome these issues.

2.1.3 | Consortium blockchain

Instead of being controlled by a single organization, consortium BCn networks are introduced with more decentralization than private BCn, which increases their security.[23] However, creating consortiums can be a difficult process because it calls for collaboration between several groups, which poses logistical problems and a possible antitrust risk.[24] Additionally, some supply chain participants may lack the infrastructure and technology required to use BCn. They also incur significant expenses in order to digitize their data and link to other participants in the supply chain. The corporate software company R3 has created a well-known set of consortia BCn solutions for the financial services industry and beyond.[20] It is a non-profit BCn consortium with the goal of digitalizing the shipping sector and enabling maritime industry operators to cooperate more effectively.

2.1.4 | Hybrid blockchain

Hybrid BCn networks are controlled by a single entity but have some oversight given by the public BCn, which is required to perform particular transaction validations. An example of a hybrid BCn is IBM Food Trust.[19] It was developed to boost productivity throughout the whole food supply chain.

The classification has been also mentioned in Table 2 where the table focuses on the characteristics and use cases in real life providing a simple explanation of all.

TABLE 1 Difference between blockchain types.

Features	Public blockchain	Private blockchain	Consortium blockchain	Hybrid blockchain
Year	2008	2008	2008	2008
Consensus technology	PoW, PoS, DPoS	Practical Byzantine fault tolerance (pBFT), Raft	Practical Byzantine fault tolerance (pBFT)	PoW, PoS, DPoS, pBFT, Raft
Category	Open	Controlled	Controlled	Controlled
User	Anonymous	Recognized	Recognized	Recognized
Permission to read	Permissionless	Permissioned	Permissioned	Permissionless but controlled
Centralization	Decentralized	Centralized	Partially centralized	Decentralized
Immutability	Tamper-proof	Possible to be tampered	Possible to be tampered	Tamper-proof
Scalability	High	High	Low	Very high
Transaction approval timeframe	Long	Short	Short	Short
Transparency	Low	High	High	Partially transparent
Energy consumption	High	Low	Low	
Efficiency	Low	High	High	High
Use case	Cryptocurrency	Medical organizations, supply chain	Hyperledger	Food supply chains, bank transaction

TABLE 2 Different blockchain types and their use cases.

Types of blockchain	Characteristics	Use cases
Public[16]	Independent	Cryptocurrency
	Transparent	Document validation
Private[18]	Access control	Supply chain
	Performance	Asset ownership
Hybrid[19]	Scalability	Medical records
	Good performance	Real estate
Consortium[20]	Security	Banking
	Scalability	Research

2.2 | Critical features of blockchain

A decentralized, open-source digital ledger called BCn technology can maintain safe, immutable transaction records due to their extended features. Together, these features make BCn a viable technology with applications in fields as diverse as banking, supply chain management, healthcare, and decentralized software.[25] It has the power to transform many industries and alter how we trade value and trust online by enabling its features. The main features that differentiate BCn from conventional centralized databases are discussed as follows.

2.2.1 | Persistency

The persistency feature of BCn technology is one of its key features that has changed the way we store and share data in a wide range of industries and applications.[26] It refers to the ability of the system to store data in a permanent and immutable way. Once data is recorded on the BCn, it cannot be altered or deleted, providing a high degree of security and trust in the data. This can be achieved through the use of cryptographic algorithms and consensus mechanisms.[27] Each block on the BCn contains a cryptographic hash of the previous block, creating a chain of blocks that cannot be tampered.[28] Any attempt to modify data in a block would change its hash, invalidating all subsequent blocks in the chain. Additionally, the use of consensus mechanisms ensures that all nodes on the network agree on the contents of each block before it is added to the chain. This consensus process helps to prevent fraudulent or malicious actors from altering the data on the BCn.[29,30]

2.2.2 | Decentralized

The decentralized feature of BCn technology is another key strength and has the potential to revolutionize a wide range of industries and applications.[31] In a conventional transaction system, each transaction must be validated by a central agency. While in decentralization, there is no central authority or single point of control for the system.[32] It uses a consensus mechanism to address trust issues in decentralized peer-to-peer (P2P) transactions. Since all transactions are recorded on the BCn, they can be viewed by anyone at any time, making the system transparent and helping to prevent fraud and corruption. The decentralized nature of BCn makes it difficult for hackers to attack the system. Additionally, the use of cryptography and consensus algorithms ensures the security of data on the BCn. The presence of multiple copies of the ledger maintained by nodes on the network enhances reliability. Even if one node fails or goes offline, the data on the BCn remains accessible and accurate. Moreover, once data is recorded on the BCn, it becomes immutable and cannot be altered or deleted, ensuring a tamper-proof system and instilling a high level of trust in the data.[33]

2.2.3 | Distributed

The distributed feature of BCn allows it for making a more decentralized and transparent system that is more secure and efficient than traditional centralized systems.[34] The distributed feature refers to the way in which the system is designed to

operate as a decentralized network of nodes, rather than relying on a central authority or point of control.[35] In a traditional centralized system, data is stored and controlled by a single entity, such as a company or government. In contrast, a distributed system like a BCn is composed of a large number of nodes, and each node which maintains a copy of the ledger or database, recording all the transactions that have taken place on the network.[36] The ledger is available to all network users. A public ledger will give complete details on all users and transactions on the network. A better result is guaranteed by the spread of computational power among the machines.[37]

2.2.4 | Consensus

Every BCn contains a consensus mechanism to ensure the security and integrity of the system.[38] In this way, the system ensures that all nodes on the network agree on the contents of each block before it is added to the chain. This agreement is achieved through a consensus mechanism. This mechanism consists of set of rules and protocols that govern how the nodes on the network validate and add transactions to the BCn.[39] Consensus mechanisms are designed to prevent fraudulent or malicious actors from altering the data on the BCn. They typically involve a process of validation and verification, where the nodes on the network compete to solve complex mathematical problems or prove ownership of assets, in order to earn the right to add the next block to the chain. There are several different consensus mechanisms used in BCn technology, such as Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS), Byzantine fault tolerance (BFT) and so forth.[40]

2.2.5 | Anonymity

The anonymity feature of BCn also provides a high degree of privacy and security. With this feature, the system allows users to transact without revealing their true identity.[41] Though transactions on the BCn are public and transparent, users can generate anonymous addresses or use pseudonyms to transact on the network. Anonymity is achieved through the use of cryptographic algorithms.[42] These allow users to generate public and private keys that can be used to sign and verify transactions on the BCn. Public keys are shared publicly, while private keys are kept secret and used to sign transactions. When a user sends a transaction on the BCn, they use their private key to sign the transaction, proving that they are the legitimate owner of the funds being transferred. The transaction is then broadcast to the network and validated by nodes using consensus mechanisms.[43] Once the transaction is validated and added to the BCn, it becomes part of a public ledger that can be viewed by anyone, but the identity of the user remains anonymous.

2.2.6 | Quicker and cheaper settling

BCn technology has the potential to significantly reduce the time and cost involved in settling transactions, making it an attractive option for many industries.[44] In traditional financial systems, settling transactions can take several days due to the involvement of intermediaries such as banks and clearinghouses. However, with BCn technology, transactions can be settled almost instantly, as the process is automated and does not require intermediaries.[45] When a transaction is initiated on a BCn network, it is broadcasted to all nodes on the network, who then validate and verify the transaction.[46] Once the transaction is validated, it is recorded on the BCn and becomes a permanent part of the ledger. This process is automated and does not require intermediaries to verify or settle the transaction, which makes it much faster than traditional methods. Additionally, BCn technology enables peer-to-peer transactions, which means that parties can transact directly with each other without the need for intermediaries.[47] This further reduces the time and cost involved in settling transactions.

2.2.7 | Auditability

The transparency, immutability, and automation features of BCn technology make it an ideal platform for auditing and verifying transactions.[48] The BCn is a distributed ledger that is maintained by a network of computers, also known as nodes. Each node in the network has a copy of the ledger and can verify the transactions recorded on it. Once a transaction is recorded on the BCn, it cannot be altered or deleted, which ensures that the transaction history is immutable.[49]

This transparency and immutability of the BCn makes it possible to audit transactions in a way that is not possible with traditional accounting systems. Auditors can easily verify the authenticity of transactions and track the movement of assets on the BCn. Also, the use of smart contracts on the BCn enables automated auditing processes. Smart contracts are self-executing contracts that can be programmed to automatically perform certain actions when certain conditions are met.[50] This means that auditors can program smart contracts to automatically check for compliance with certain rules or regulations, reducing the need for manual audits.

2.3 | Implemented cases of blockchain in different sectors

Several ongoing projects are exploring the use of blockchain technology (BCn) in the energy sector for applications such as secure energy trading, grid maintenance, carbon emission tracking, renewable energy certificate management, tokenization methods, and IoT integration.[51] While these applications offer theoretical potential, current projects are in early stages and not yet mature for full implementation. Various agencies are involved in these projects, conducting simulations and testing to assess feasibility, stability, and reliability. Table 5 shows the agencies using BCn on energy applications.

2.3.1 | PowerLedger

PowerLedger employs a dual-layered approach for energy trading, utilizing both public and private layers. Initially built on Ethereum, it has shifted to Solana blockchain for improved efficiency.[52] Solana's PoH and PoS mechanisms enable faster transaction speeds, surpassing 50,000 transactions per second with a block creation time of 400 ms.[53] PowerLedger promotes renewable energy adoption through projects in India, Thailand, North America, and beyond.

2.3.2 | LO3 energy: Brooklyn microgrid

It is a pilot project launched in April 2016 to deliver real-time metering data of the energy generation locally to the local MG.[54] They conducted P2P transactions between consumers and prosumers through MG wire.[55] It is not only implemented in the US but also works actively in Japanese energy markets. Primarily, it is a private BCn system based on Ethereum conducted by Tendermint based on the PBFT consensus mechanism.[56]

2.3.3 | Tennet

In 2017, TenneT, a TSO jointly established by Germany and the Netherlands, collaborated with partners like IBM and Vandebron to develop a system for managing electric grids between the two countries. This initiative aimed to enable decentralized energy sources to contribute to grid management and align with European standardization for future smart grid communication technologies.[53]

2.3.4 | MotionWrek

MotionWrek, founded in 2017, is a Germany-based energy blockchain (BCn) company focused on electromobility solutions. Their main project, "Share & Charge," connects EV users with charging point operators. They aim to scale up charging infrastructure by collaborating with large companies. MotionWrek's projects, like P2P Germany and UK Pilot, focus on EV charging networks.[51]

2.3.5 | Alliander and spectra

Alliander, a Dutch energy network company, is developing a P2P energy-sharing platform called Jouliette using blockchain technology at De Ceuvel in Amsterdam. By 2018, it served over one million households, with a 40% increase

in renewable energy injection. Collaborating with Spectral Energy, Jouliette aims to enable locals to share and manage locally produced renewable energy using a token-based system. The project showcases the effectiveness of blockchain in P2P energy trading, with a focus on integration into the De Ceuvel community's daily activities.[57]

3 | BLOCKCHAIN REVOLUTION: WORLD PERSPECTIVE

Blockchain is becoming a major innovation in the global technical scene, drawing interest from nations all over the world. Its secure and decentralized structure presents a viable answer to many of the problems that contemporary communities face. A wide spectrum of reactions to blockchain's disruptive potential may be seen in the way that certain countries have welcomed it enthusiastically while others have handled it carefully. Notably, blockchain has an impact on social, political, and economic systems in addition to technology. Table 5 offers a thorough summary of multiple blockchain initiatives and their concrete effects on various industries. These initiatives, which cover everything from supply chain management to medical records, highlight how flexible and useful blockchain technology is. Furthermore, Figure 2 highlights how blockchain adoption could lead to social and environmental change and illuminates the sustainability implications of this trend in different parts of the world. Moving on, it can be seen in Table 3 where the table discusses the impact of using BCn in various field of operation in the basis of number of projects. Furthermore, Figure 3 provides insights into how blockchain solutions' cost dynamics are changing over time from 2016 to 2021, demonstrating how blockchain technology is becoming more and more accessible and affordable. Table 4 shows the global commitment to blockchain innovation by breaking down the investments made by various nations. The United States' substantial investment highlights its role as a major force behind the development and uptake of blockchain technology. The extensive application of blockchain technology in cross-border payment and settlement is further highlighted in Figure 4, which highlights the technology's vital role in enabling safe and effective financial transactions globally. Beyond financial applications, blockchain is being used more and more for creative use cases like digital currency management and asset tracking, suggesting that it has

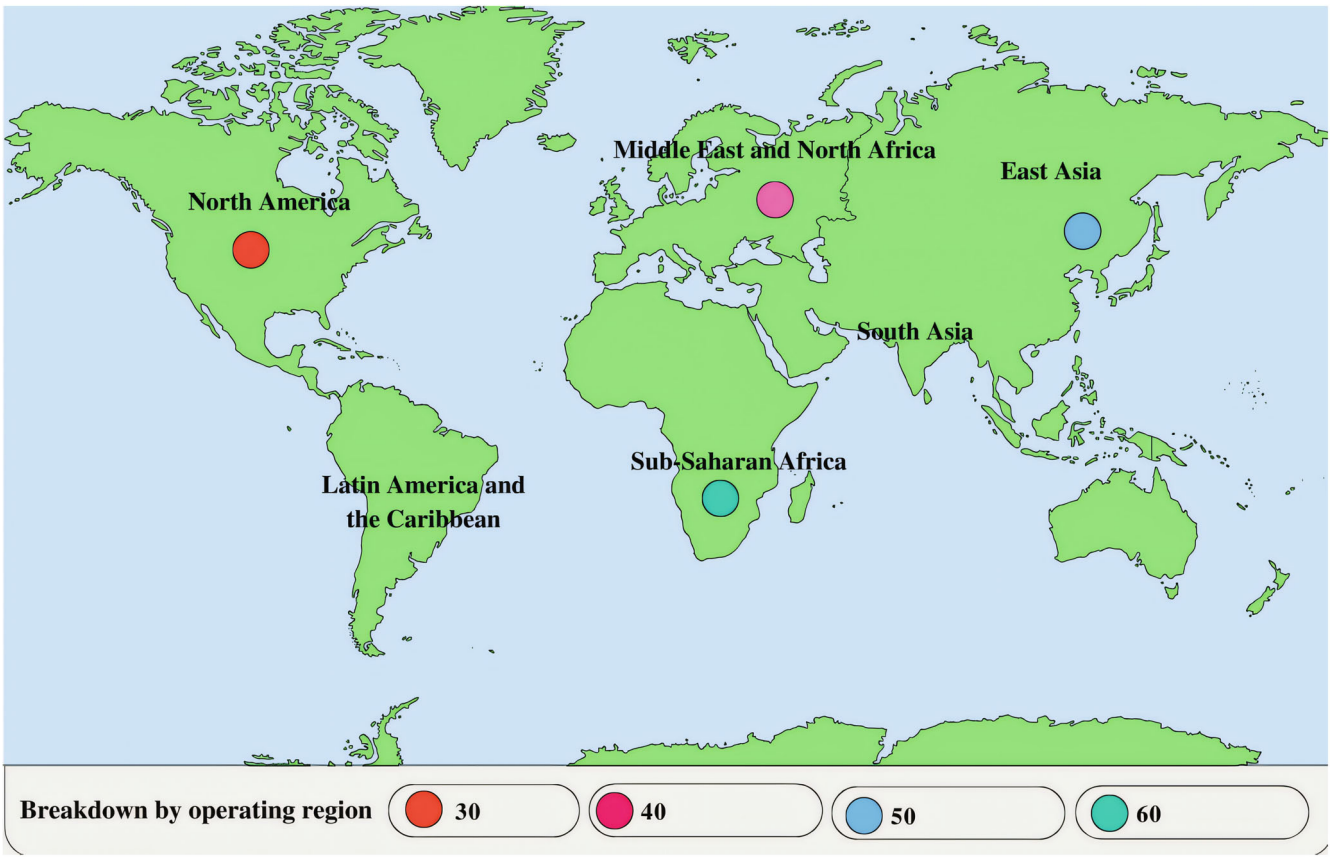

FIGURE 2 Contribution of BCn projects to the SDGs per area.

TABLE 3 Global BCn projects in different fields with their impact on sustainability.

Field	Number of projects	Impact
Research	51	Very high
Record (health, transaction)	25	High
Identity (licenses, attestations)	25	High
Economic advancement	23	High
Monetary services	20	High
Land registry	19	Moderate
Digital transaction	19	Moderate
Entitlement	13	Moderate
Compliance	12	Moderate
Supply chain management	10	Moderate
Voting	7	Low
New product	7	Low
Payment	6	Low
Asset registration	6	Low
Public transport	6	Low
Data monetization	6	Low
Public record	6	Low
Public utility	5	Low
Regulatory	4	Low
Tax	4	Low
Government finance	4	Low
Cyber security	3	Low
Legal	2	Low
Military	2	Low
Digital token	1	Low
IOT	1	Low

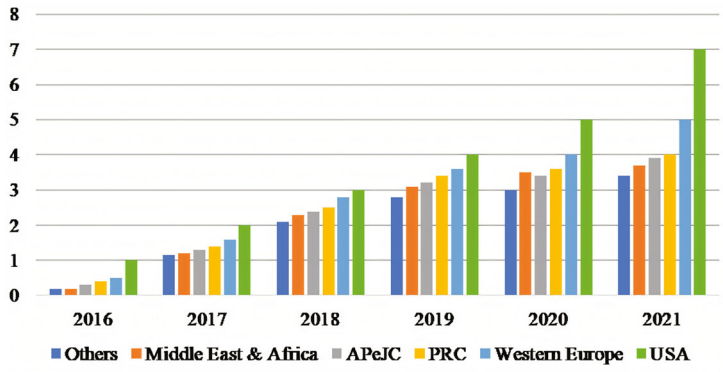

FIGURE 3 Expense on blockchain solution (in billion $) according to region.

TABLE 4 Countrywise blockchain projects and investment.

Country	Number of projects in 2018	Investment in 2021
United States	2712	$11.1 billion
United Kingdom	1674	$1.9 billion
Russia	721	$1.5 billion
France	679	$1.2 billion
Canada	675	$1.2 billion
Spain	383	$900 million
Switzerland	338	$700 million
Sweden	306	$600 million
Italy	276	$550 million
Poland	273	$540 million
Singapore	292	$455 million
Japan	283	$120 million
South Korea	273	$210 million

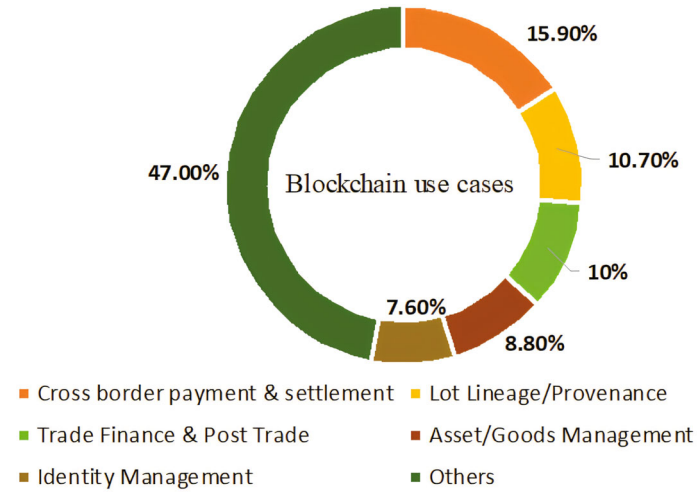

FIGURE 4 Blockchain market share in different use cases.

the ability to completely transform a wide range of global industries. The United States was the most significant regional spender on BCn solutions in 2021, spending roughly $11.1 billion US dollars on these solutions. The most common use case for BCn technology around the world described in Figure 4 was cross border payment & settlement, which takes 15.9% market share due to its extended security features. BCn applications also include tracking and managing assets, using digital currencies like Bitcoin and Ethereum, and more.

Almost every country in the world is trying to explore the most reliable technology "Blockchain" to cope with the modern era of evolution. Mixed responses have been observed with some openly accepting the concept while others providing feedback with lukewarm reactions. It is playing a dominant role both in the public and private sectors to enhance business growth and ease human life in those areas. An overview of the number of projects and their impact is given in Table 4. Again from Figure 2, we can see the sustainability impact of BCn in different regions all around the world. Further, the cost of BCn solutions by various regions of the world from 2016 to 2021 is shown in Figure 3. Also, an insight into investments of different countries on BCn networks is given in Table 5.

The global market for BCn and cryptocurrency continues to attract interest from the online payments sector and retailers. Studies have shown that both developing and well-established nations are dominating the space of cryptocurrency

TABLE 5 Different blockchain projects and results.

Projects	Country	Year	Result
Power Ledger	Australia	2016	P2P energy sharing platform
Vandebron	Netherland	2014	P2P energy sharing platform
SonnenCommunity	Germany	2015	P2P energy sharing platform
Community First Village	USA	2015	Saving utility bills for poor people
Smart Watts	Germany	2011	Internet of energy
PeerEnergy	Germany	2012	Cloud-oriented platform for smart houses

TABLE 6 Top 10 blockchain projects in 2022–2023.

Projects name	Company	Country	Description
TradeLens	MAERSK	Denmark	Play role in digitalizing supply chain data
Libra Chain	BAIDU	China	It works to establish internet court
SkyGrid	BOEING	USA	Tracking and communication by using drone
Paxos	CREDIT SUISSE	Switzerland	Payment with delivery versus payment assurance
GoDirect	HONEYWELL	USA	BCn-based marketplace for aerospace products
IBM	IBM	USA	Verify COVID-19 test
Bulletproofs	ING	Netherland	Security of data within any distributed ledger
Swisscom Blockchain	SWISSCOM	Switzerland	Provides distributed ledger solutions for companies
MineHub	BHP	Australia	Mine supply chain process
FISCO	TENCENT	China	Fast and secure banking

and blockchain technology, with the digital market gaining momentum worldwide. Currently, countries like Japan and the United States rank highest in terms of accepting and implementing cryptocurrencies. Despite facing various infrastructure challenges, several African countries have also emerged as leaders in BCn adoption. Additionally, Asian countries are actively participating in this race, with many of them being listed among the top 20 countries for cryptocurrency implementation. As the user-base of BCn continues to grow, numerous BCn projects are underway worldwide. Table 6 provides examples of some renowned projects in the year of 2022–2023.

(i) ***North America***: BCn-based industries in North America are poised to flourish in the coming years since some of the largest companies in the USA have started embracing this modern technology. Despite being the worst year for the market, 2018 witnessed a spending production rate of 110% on BCn in the USA.[58] According to a report, the BCn market in the USA is anticipated to experience an increase of more than $37 billion by the year 2025. A report recently published by Forbes stated that among 50 giant companies spending on BCn, 22 are from the North America.[59] Aside from giant companies, numerous BCn start-ups are also playing a pivotal role in advancing the country through the adoption and utilization of this technology. It is estimated that the spending on BCn solution may rise from $3.12 to $41 billion in the near future.

(ii) ***Europe***: Countries of Europe like Malta, the United Kingdom, Estonia, and Switzerland are using crypto and executing BCn to make examples for others to follow. From the very beginning, the government of the United Kingdom provided funds and support towards the execution of BCn-based projects. They used BCn in the health sector, and Blockchain-as-a-service (BaaS) was implemented to track the dispense of student loans and prosperity grants.[60] CryptoUK is the first cryptocurrency organization in the country. It is a self-ruling body that targets to safeguard the people investing in cryptocurrency and the interest of the BCn companies. Again, e-Estonia refers to the digital society of Estonia, which facilitates its citizens' and residents' interactions with the state through the use of ICT solutions. As one of the most wonderful projects, e-Estonia in Estonia is executed by incorporating BCn to run the whole public service division[61] that can be an example for other countries. Figure 5 shows the different sectors

FIGURE 5 Glimpse of e-Estonia by blockchain revolution.

of e-Estonia, and BCn has a significant impact there where the projects that are implemented are described properly. Here, the BCn is a mathematically ensured cyber security technology for rapid and immutable identification of modifications in digital data and intelligent devices. It makes possible to discover any and all changes made to digital data, regardless of their scale or authorship, immediately and with zero error.

Malta, also known as the BCn island, has executed the BCn technology in their documentation system and supported various BCn-related projects.[62] They are a nation enriched with the utilization of cryptocurrency, and their policy stimulates the advancement and expansion of the crypto market. The government of Switzerland has been providing both political and regulatory support for the enhancement of BCn-based business exponentially.

(iii) ***Asia Pacific***: The Asia Pacific region has shown good prospects in the case of adopting BCn technology from the early stage.[63] This region has always been very positive about practicing new technology. In the recent past, it was forecasted that the BCn market may grow at a rate of 87% in the upcoming years. It will be crystal clear when the activities of individual countries are observed separately. The government of Thailand has implemented crypto projects and taken steps to establish licenses to allow initial-coin-offerings (ICOs) and various exchanges. In fact, there are some guidelines in place that encourage companies to incorporate BCn technology. According to a report, they are almost ready to introduce digital currency into the market. Monetary Authority of Singapore (MAS) is working with a board of tech companies and other banks on the project Ubin with an aim to establish a BCn-based payment system.[64] Here, the industry is working together on Project Ubin, which is depicted in Figure 6, to investigate the application of BCn and Distributed Ledger Technology (DLT) for clearing and settling payments and securities. Other countries like South Korea, Hong Kong, and Japan are highly contributing to several BCn projects.

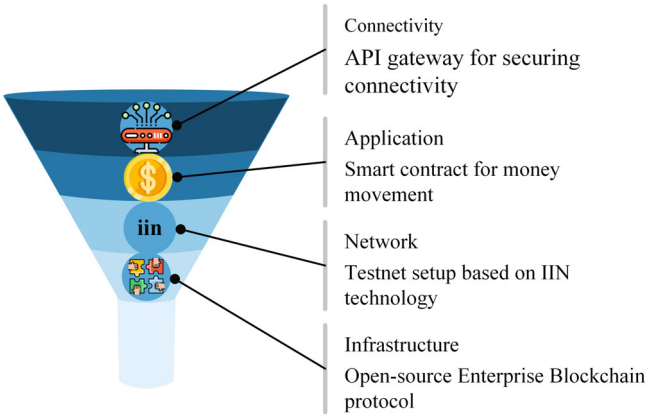

FIGURE 6 Ubin project in Singapore.

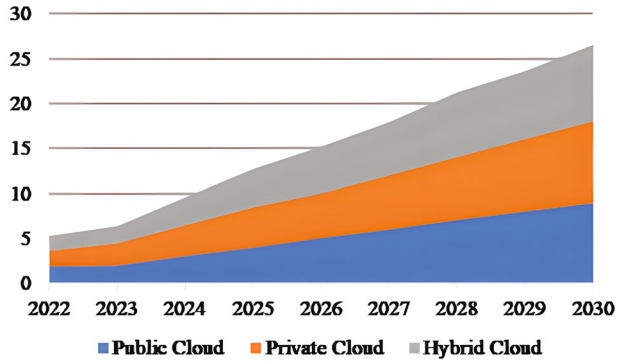

FIGURE 7 Forecasted blockchain technology market in USA from 2022 to 2030 (in billion $).

South Korea has invested nearly $880 million for projects related to BCn.[65] The government of Hong Kong is working in such a way that BCn can make the monetary sector more feasible and secure.

(iv) ***Latin America***: BCn technology received mixed reactions when it was first introduced. Argentina currently has no governance on cryptocurrencies. SystemaD is a BCn-dependent digital identity platform used for money transactions in Argentina. The SystemaD and BCn Federal Argentina can be the examples of sustainable initiatives that have been implemented in the country. Many banks in Brazil are trying to improve the existing banking system by utilizing BCn technology and showing a high perspective in the crypto market. Again, the authority of Chile is trying to integrate BCn technology in various public service areas.[66] Ministry of Energy has already started using Ethereum BCn for tracking and recording energy prices and other data. Other countries like Colombia, Uruguay, Mexico, and Panama have shown interest in utilizing BCn in the near future.[67]

(v) ***Middle-East***: Middle-East countries like Bahrain, Saudi Arabia, and the UAE are trying to adjust BCn technology with great prospects. UAE government has already started encouraging crypto usage.[68] The rise of BCn-based startups has brought the country ahead of the USA and the UK in the topmost sale list of tokens. In Figure 7, we see in the USA, the market for BCn technology was estimated to be worth $5 billion in 2022 and is anticipated to increase to almost $16.3 billion by 2026, with a compound annual growth rate (CAGR) of 65.8% over the course of the projection period.

In 2019, Bahrain had also taken some notable crypto decisions. The central Bank of Bahrain has recently announced a financial structure that can be affected by the digital asset term. A pilot project has been started by the government of Bahrain along with UAE and Saudi Arabia to ease the cross-border payment system between these countries.[69] Again, the BCn firm "Ripple" in collaboration with Saudi British Bank is ready to start a service that will enable the immediate cross-border transaction. BCn-based remittance collection system has already been launched by the Saudi Arabian Monetary Authority with a view to achieve flawless transactions among banks in UAE and

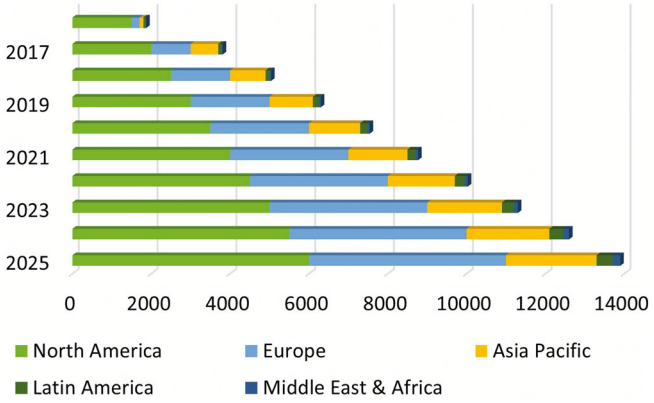

FIGURE 8 Blockchain revenue in world market (in $): 2016–2025.

the Saudi Arabia.[70] The BCn-based ventures could be a great sign that the Middle East has higher prospects in the BCn sector from the universal point of view.[71]

(vi) ***Africa***: From the emergence of BCn technology and cryptocurrency, African countries like South Africa, Nigeria, and Morocco have presented enormous interest in this new-age technology. However, the market of Africa remains vastly untapped in the BCn and crypto zone. The fluctuation of national currencies is the fundamental problem in the economy of Africa.[5] Major investments in BCn are encouraging startups to work on different projects. Although Africa faces numerous challenges, it holds immense prospects as a feasible market for BCn development, and even abstinent regions can benefit greatly from such endeavors. Despite significant obstacles, BCn has the potential to make a profound impact on many other businesses. Tractica's investigation has identified 29 unique use cases for corporate BCn, several of which offer considerable advantages over conventional systems and business processes in terms of cost savings, efficiency, security, and compliance. Figure 8 shows the global market for corporate BCn applications, indicating an expected expansion from $2.5 billion in 2016 to $19.9 billion in 2025, or a CAGR of 26.2%.

4 | BLOCKCHAIN AGENDAS IN BANGLADESH'S SUSTAINABILITY

Some countries have already released their national BCn strategies to accentuate how they are going to approach BCn technology. Like in other countries, the Government of Bangladesh has also released the national BCn strategy where a roadmap about the adoption of BCn technology is exhibited as shown in Figure 9. The figure explains entire adaptation process of implementing BC in regional aspect.

With an outstanding record of growth and advancement of BCn around the world, Bangladesh is also stepping forward to achieve the position of a higher middle-earning country through the implementation of advanced technologies. Nevertheless, it faces a lot of challenges that can be efficiently mitigated to attain the SDG goals. It is certain that the appropriate use of emerging technology, such as BCn, can play a vital role in undertaking those challenges.[72] SDGs are a set of 17 goals designed to ensure a sustainable future. The goals were set by United Nations General Assembly in 2015, and are desired to be achieved by 2030. Bangladesh has a firm commitment to achieving those targets as much as possible within the specified time period.

4.1 | Critical needs of blockchain for Bangladesh

BCn technology is becoming popular in Bangladesh due to its potential capabilities to tackle the problems, such as corruption, the absence of accountability, and unsustainable processes. This technology can assist in minimizing corruption and enhancing transparency, offering more safety and privacy, accelerating the supply chain management process, and boosting financial inclusion because of its capacity to provide a decentralized and immutable ledger. The reasons why the implementation of BCn technology accelerates the Bangladesh to meet the SDGs are given below.

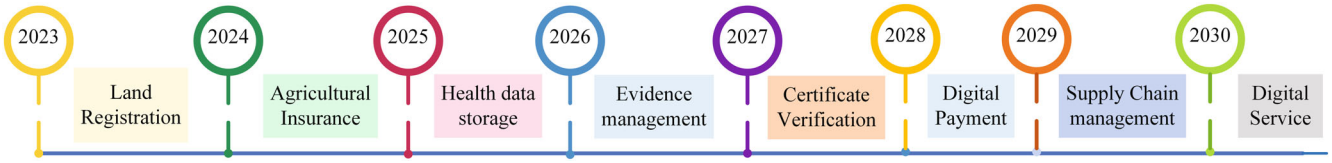

FIGURE 9 Tentative roadmap of various blockchain applications.

4.1.1 | Reduce corruption

Corruption can be one of the major hindrances behind the development of Bangladesh. The implementation of BCn technology in Bangladesh will help reduce corruption, improving transparency and traceability. It will also lessen the risk of breaching important data.

4.1.2 | Enhance transparency

BCn offers a crystal clear and tamper-proof system for the documentation of data and transactions. Execution of BCn may ensure secured operations both in government and non-government organizations in Bangladesh.

4.1.3 | Ensure better life

BCn can improve the quality of life of every citizen of Bangladesh by offering secure, sound, and efficient systems for education, healthcare, supply chain management, e-commerce, and other services.

4.1.4 | Acceleration of economic growth

BCn keeps contributing to the industrial revolution by providing greater financial inclusion and speeding up transactions. This technology offers a decentralized platform for commercial services. That's how BCn contributes to accelerating the economic growth of Bangladesh.

4.1.5 | Sustainable development

The economy of Bangladesh is highly dependent on the garment industry, so implementing BCn technology in supply chain management can ensure ethical sourcing, distribution, and traceable production practices. The BCn also improves security in online business and reliability between traders and clients. All of these can lead to sustainable development in Bangladesh.

4.1.6 | Easier remittance transactions

BCn helps in speeding up remittance transactions in a cheaper way benefiting both senders and receivers of Bangladesh.

4.1.7 | Real estate industry

The real estate industry is becoming a more and more important part of Bangladesh's economy. BCn technology is able to offer a secured system of property ownership and dealings, decrease theft and enhance transparency in this concerned field.

4.1.8 | Carbon credit

BCn technology can alter the carbon credit market by ensuring the precise tracking of carbon credits and eliminating fraud through automated verification. The market for carbon credits becomes accessible and transferable due to fractional ownership and global market integration. Furthermore, real-time monitoring reduces the risk of double counting, ensuring precise credit calculations and trading activities. In this context, BCn can encourage sustainable practices by establishing a direct relationship between actions and marketable credits.

4.1.9 | Energy management

The distribution and management of renewable energy resources can be done securely and efficiently thanks to BCn technology. This could encourage Bangladesh to utilize clean energy and lessen its dependency on fossil fuels.

The implementation of BCn technology can play an essential role in addressing these various prevailing issues and properly utilizing the available resources of Bangladesh.

4.2 | Technological visions

Bangladesh can be a developed country in the next few years. By deploying evolving technologies in different sectors, Bangladesh can go forward to attain its SDGs. Some technological visions which need to be fulfilled are:

- ***(i)*** ***e-Governance***: Technologies can be incorporated to provide services to citizens within a country. It allows interaction in various modes between citizens and government through Citizens to Government (G2C) or Government to Citizens (G2C), among several agencies of government, between the government and business holders, and so forth.[73] e-Governance can assure higher efficiency and reduce the rate of corruption. Thus, it can be considered a crucial part of impregnable development.
- ***(ii)*** ***Intermediary reduction***: Intermediary can cause huge congestion, introduce less efficiency and draw excessive financial burden in application areas such as agriculture sectors. To ensure sustainable development, intermediaries should be reduced as much as possible in large application sectors.[74]
- ***(iii)*** ***Clarity along with accountability***: One of the primary obstacles in the way of advancement is the lack of clarity and accountability in both the public and private sectors. In order to ensure sustainable development, it is compulsory to establish systems that can boost accountability and clarity in various sectors.
- ***(iv)*** ***Data security and privacy***: Malicious attacks can be executed in business and money transaction systems to obtain financial gain or steal data. Adoption of BCn technology can assure data security and privacy.[75]

BCn technology with its attractive features can ensure the required resiliency and decentralization which can easily handle the above-mentioned faults. In this way, all the BCn-enabled applications can play a significant role in executing e-Governance in an efficient way and meeting the SDGs.

5 | BLOCKCHAIN REVOLUTION IN BANGLADESH: CURRENT AND FUTURE PROSPECTS

Bangladesh's use of blockchain technology is depicted in the Table 7. It presents the state of affairs at the moment, as well as governmental programs, business applications, difficulties, and prospects. It also presents opportunities for collaboration, future prospects, and a development roadmap. Stakeholders can learn more about Bangladesh's accomplishments, obstacles, and possible advantages of adopting blockchain technology from this visual portrayal.

5.1 | Current prospects of blockchain revolution

To deal with the advancement of digitalization, most of the developing countries have already started to employ the BCn technology in different sectors.[76] A few financial organizations in Bangladesh, as shown in Figure 10, have so far begun

TABLE 7 Application sectors of BCn with potential stakeholders in Bangladesh.

Sectors	Use-cases	Potential stakeholders
Land	Mutation	Ministry of Land
	Registration	
	Verification	
Agriculture	Procurement	Ministry of Agriculture
	Agricultural insurance	Ministry of Food
	Disintermediation	Ministry of Livestock
Health	Health data storage and management	Ministry of Health and Family Welfare
Judiciary	Digital evidence preservation	Ministry of Law
Document verification	Educational certificate	Ministry of Education
	Government certification	
Finance	Pension	Ministry of Finance, Ministry of Commerce
	Payment	
	Stock market	
Supply chain	Production chain	Ministry of Power
		Ministry of Industries
Smart city	Citizen service	Ministry of Local Government
	Smart structure	

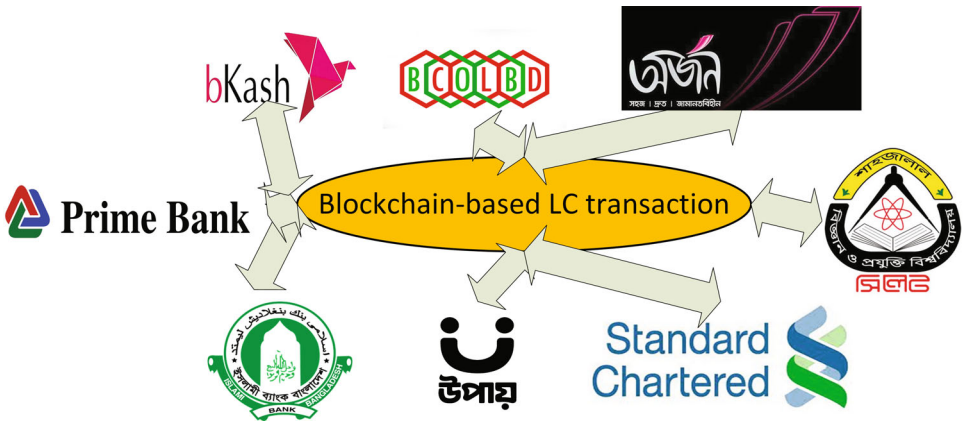

FIGURE 10 Ongoing uses of blockchain technology in Bangladesh.

to use BCn technology, including bKash, Prime Bank, Standard Chartered Bank, and HSBC Bank. Additionally, a few agro-tech businesses, like Krishi Swapno, have implemented the technology as a trial project. Though the government of Bangladesh has been trying to focus on technological advancement in every sector, no such policy for supporting automation in industries has been published yet. Some official procedures have been started, such as Bangladesh Bank will conduct a feasibility study of introducing Central Bank Digital Currency (CBDC).[77] However, some individual execution and trials have already been launched here. Some of the non-government financial agencies are imposing the concept of BCn at a tiny scale. Islami Bank Bangladesh Limited (IBBL), as the first financial organization in Bangladesh, has started to use BCn technology. Abu Dhabi Commercial Bank (ADCB) of the UAE completed the cross-border letter of credit (LC) process with IBBL on September 12, 2019. The IBBL had received the exported amount around $6.5 million LC of wheat from Canada.

Again, in Bangladesh, IPDC launched a BCn-based digital supply chain finance platform named "ORJON" on December 6, 2019.[78] In a press conference, that organization claimed, "Orjon is an extensive supply chain financial service which

TABLE 8 Current advancement BCn in Bangladesh.

Organization	Date of commencement	Usage
Islami Bank	September 12, 2019	Letter of credit
IPDC	December 6, 2019	Digital supply chain finance platform
SUST	March 11, 2020	Certificate security
Bank Asia	May 2020	Remittance transfer
Standard Chartered Bank	August 16, 2020	Letter of credit
HSBC	October 31, 2020	Cross-border blockchain LC
Standard Chartered Bank & Bkash	September 9, 2020	Remittance platform
Prime Bank	December 1, 2020	Letter of credit
The City Bank	January 7, 2021	Letter of credit (consortium)
Upay	March 17, 2021	Mobile financial service

offers some advantages over conventional financial service." The goal of "Orjon" is to make a combined supply chain financing ecosystem and to provide low-interest loans to small enterprises via the development of a digital supply chain platform. Further, the Standard Chartered Bank (SCB) launched LC service via BCn on August 16, 2020. On this day, SCB implemented the BCn transaction by issuing an LC for Viyellatex.[79] The SCB in cooperation with bKash and Valyou of Malaysia declared the launch of a BCn-based remittance service in Bangladesh on September 9, 2020. Now, through this Bangladeshi people in Malaysia can send stipend remittances instantly at safe and low expenses by using a wallet. With the success of these financial institutions, the HSBC launched BCn-based LC service on October 31, 2020.[79] On this day, HSBC implemented the cross-border BCn LC transaction to import 20,000 tonnes of fuel for United Mymensingh Power Limited (UMPL). After the execution of the LC transaction, the UMPL said to mass media, "The processing time of LC is reduced from standard 5–10 days to less than 24 h."

Another organization named Prime Bank launched a BCn-based LC transaction service on December 1, 2020. On January 7, 2021, the City Bank, as the first-ever financial organization of Bangladesh, launched a cross-border Shariah-based BCn LC transaction in just 38 min. The "Upay," a mobile banking financial corporation, started its journey as a first-ever mobile financial service (MFS) using BCn technology on March 17, 2021. Because of using BCn technology, there is no scope to hack the transaction system. One university named Shahjalal University of Science and Technology (SUST), as the first university in Bangladesh, started using BCn technology on March 11, 2020. The legitimacy of the certificate is assured in such a way that none can tamper and issue duplicate certificates.[80] A summary of the current advancement of BCn in Bangladesh is reported in Table 8. Through the successful application of BCn in all of the above sectors, Bangladesh started to receive the benefits of this emerging technology, and a Blockchain Olympiad of Bangladesh (BCOLBD) is arranged every year with a view to helping participants to cope with the advancement and dissemination of BCn technology all over the world. This event is a novel opportunity for youths to share knowledge with experts and be a part of making sustainable Bangladesh.

5.2 | Future prospects of blockchain revolution

It is indicated by the Kepios analysis between 2021 and 2022 internet users in Bangladesh increased to 5.5 million.[81] This percentage is rising quickly due to the increasing affordability and usability of smartphones. The increasing rate of internet users confirms that BCn can be a higher benefit rate for developing countries like Bangladesh than the developed countries, especially in the case of the evolution of an overall sustainable environment.[82] To attain the SDGs, BCn technology plays a vital role as an enabling technology. It can facilitate the creation of sustainable and secure solutions by offering accountability, transparency, traceability, and cyber-resilience. Some potential contributions of BCn-based solutions to achieving SDGs are represented in Table 9. Additionally, BCn has the potential to enhance operational efficiency in global partnerships. Because in developing countries, there is a lack of formal institutions which are really effective in the chase of rules, regulations, laws, and also their enforcement. The main concerns regarding the institutions of Bangladesh will be discussed in the next parts, and the future trends of BCn to solve them will also be evaluated. The Future software

TABLE 9 Potential contribution of BCn-enabled solutions to the SDGs.

SDGs	BCn-enabled solutions	Purpose
No poverty	Asian Development Bank partners with M-Pesa Mojaloop	Cross border payment mobile money system and digital payment system
Zero hunger	AgriLedger Token	Seed-to-customer platform, coffee value chain
Good health and well-being	Asia-Pacific, e-Estonia, Nebula Genomics, HashLog Shanzong	Mutual aid platform, health insurance, patients' record, DNA sequencing, data visualization, donation platform
Quality education	ODEM, MIT Media, Lab	Education platform, digital credentials
Water and sanitation for all	SPENN, VipiCash, eARZIKI	Digital wallet, money transfer community, finance platform
Decent work and economic growth	CVerification	Record and reference
Industry, innovation and infrastructure	IBM and partners	Ewallet
Sustainable cities and communities	Government of Malta, Government of Estonia	Transport and logistics, data registries
Peace, justice and strong institutions	Civil	Network for journalism
Partnership for the goal	Disberse platform	Money transfer

and solutions for the following sectors can be introduced in Bangladesh with the integration of BCn technology to ensure sustainability.

5.2.1 | e-Governance

In the public administration sector, a unique thought was introduced by the ICT in the late 1990s called e-government (electronic government). Till now, to run and maintain the characteristics of e-government, many technologies have already been applied to introduce a sustainable governing system,[83] such as email, voice mail, data interchange by electronic technique, delivery of web services, voice with the feature of interaction, important public infrastructures and so forth. Though the government has started the use of the internet to improve the performance, they can start to use the BCn to get sustainable benefits soon.[84] As a result, the effectiveness of the e-government can be increased with lower transaction cost, and the system will be much simpler, and quicker to run.[85] It may bring more convenient ways for common people to interact with the government, and can establish a more effective administration system.

In practice, the performance of an administrative procedure amounts to making a record in an official registry of civil status, property rights, health and so forth. In consequence, BCn technology can be viewed as a unique and universal technology that helps streamline and automate nearly all administrative procedures while increasing the transparency and effectiveness of e-government.[86] This technology will also create a synergistic relationship between the institutes enabling citizens to get multiple services in one single online outlet.[87] Also, BCn may create a hassle-free sustainable system for citizens while receiving governmental services. Actually, the effectiveness of administrative works is obtained by recording the civil status, health, property rights and so forth.[88] Here, the BCn comes into play to automate the administrative tasks and make them more transparent, which are the most important features of e-government. There are some sectors in which BCn may be applied to facilitate e-governance, with notable examples being the voting system, and tax payment system.

(i) ***Voting***: A highly transparent and robust voting system can be conducted using the BCn technology. This system is incredibly trustworthy and eliminates the need of relying on the conventional voting process, which is often opaque and centralized. Breaching an electronic voting system can have extensive consequences. The design of a BCn-based network is depicted in Figure 11. In this design, it is ensured that fraud is theoretically impossible as long as the

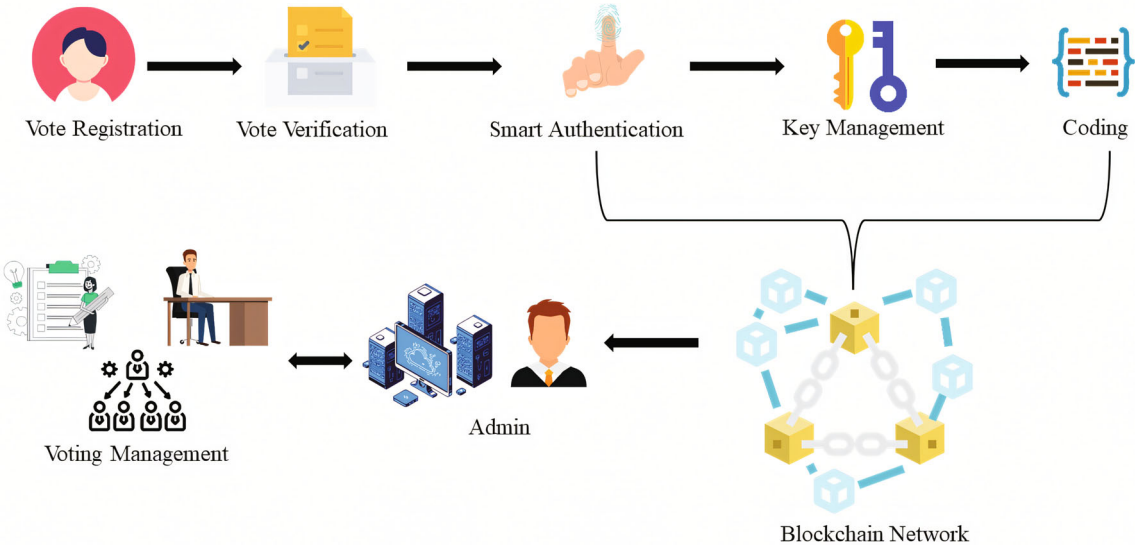

FIGURE 11 Voting system with blockchain.

system is properly implemented. A BCn network is complete, decentralized, open, and driven by consensus. The conventional voting process often takes a long time to declare results. However, by implementing the BCn technology, real-time results can be obtained swiftly.

(ii) ***Tax***: The current tax systems are primarily designed for the trading of physical goods, but with the rapid digitalization and expansion of the sector, and thus complexities are increasing day by day. As a result, the present tax management authorities of the government are struggling. However, BCn technology can alleviate administrative complications and enable more efficient tax collection.[89] Due to its nature as an open ledger, all transactions in a BCn are clearly visible, making it possible to determine whether value-added-tax (VAT) has been paid or not, thereby reducing VAT fraud to zero.

5.2.2 | Controlling corruption

BCn utilizes an immutable digital ledger that securely stores all transactions, making it nearly impossible to alter or remove any data. This ledger is distributed among all nodes or entities within the network, ensuring transparency and eliminating the possibility of fake transactions or untraceable resource transfers.[90] To access the ledger, highly secure cryptography is employed, allowing only authorized individuals to add or view specific data. These individuals are restricted from interfering with other parts of the ledger. With no third-party interference, the system minimizes the need for middlemen, and reduces corruption, fraud, centralization, and reliance on trust in specific individuals or entities. Moreover, this approach reduces energy and capital waste, aligning with the SDGs by combating corruption and bribery. The integrity of the data is upheld, as exemplified by China's successful detection of a fraudulent trade transaction worth $10 billion in 2014 through their implemented BCn system.[91]

5.2.3 | Land ownership issues

In the present scenario, there are a lot of conflicts among the people of Bangladesh about the ownership of the property. The property-related tasks are mostly paper-based and controlled by a single central authority. Many people claim the same property as their own. The documented ownership and the practical ownership are not the same for many lands and properties.[92] Also, because of the conventional documentation, people can't get proper solutions to these conflicts. The processes are very slow and inefficient, leading to additional costs caused by official rules and corruption. Due to its immutability and transparency features, BCn technology can be crucial in preventing such unauthorized alterations.[93]

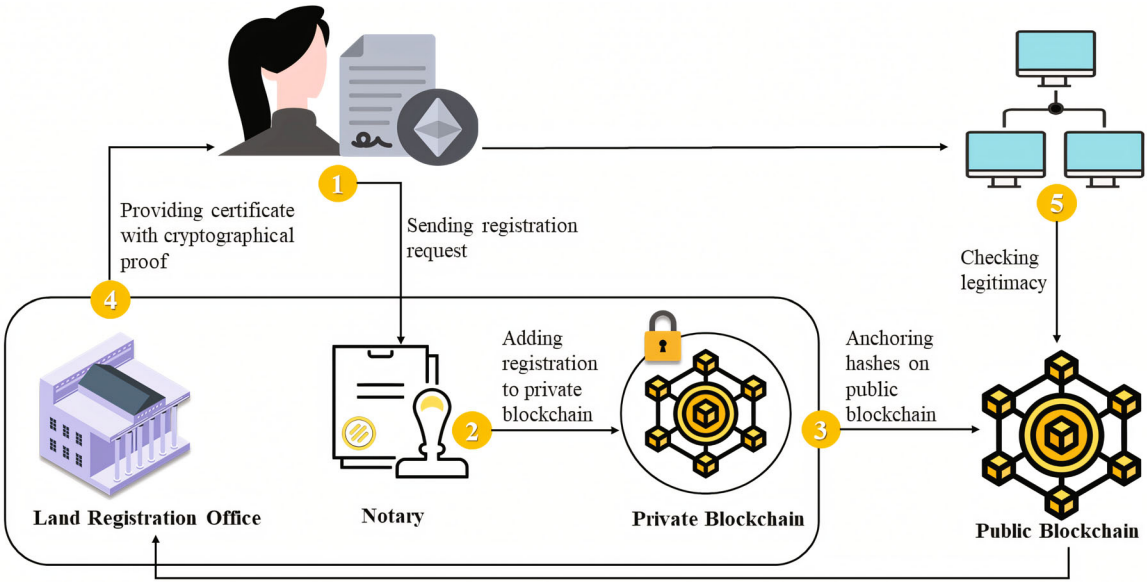

FIGURE 12 Blockchain-based land registration system.

A BCn-based distributed ledger technology is expected to revolutionize land registration by offering a secure architecture to store land transactions with the use of cryptographic protocol; see Figure 12. This system offers several advantages, including reducing the time required to sell or buy land from months to just a few days. This is achieved by eliminating the need for cumbersome paperwork and simplifying the purchase procedure. Additionally, it prevents fraud and minimizes the need for manual intervention, thereby enhancing the level of ownership security through the use of digital signatures.[94] For Bangladesh, where land registration and ownership transfer are still manual processes with low transparency, BCn technology can have a lot of potential.[95] If a legal authority with access to the same system completes the registration of property using a BCn-based solution, they can readily verify it. Such a system can also be utilized to offer land recording, right of ownership deeds, and title certification.[96] An established BCn-based land registration institute can enforce a sustained environment for keeping records and protecting citizen's land.

5.2.4 | Banking sector

In the present banking system, transactions are recorded by banks in a large ledger, which can be an old thick book or maintained using software. As long as a transaction is added and exists in the ledger, it is considered valid. However, this system relies on a centralized third-party authority. Transaction processing and interoperability have become slow and expensive due to the increasing demand for scalability. Furthermore, institutions that rely on software technologies have experienced numerous security breaches. The rapid increase in cyber-attacks has outpaced technology upgrades. By using BCn technology, there may have significant changes in the near sustainable future in the banking sector.[97]

In the BCn-based system, the consumers don't need to relay on the central authority to validate or permit any transaction as in Figure 13. They need to just relay on a computer program which is very trustworthy. The different monetary procedures, like instalments, will be handled by the BCn algorithm itself.[98] There will be no need of involving any outsider authority or agent like banks. Because of the decentralized recording, management processes will become quicker.[99] The transaction cost and interest rates will also be reduced. Also, the protections like bonds, stocks, property documents, and elective resources will be automatically set and shown in the open BCn.[100] This can be very beneficial and productive in the sector of capital business. Using the smart-contract of the BCn, the conditional transactions will be automatically triggered after meeting the conditions totally.[79] Real-time information will be provided, and the speed and operational cost of transactions can be reduced significantly. Moreover, the introduction of BCn-based virtual currency or cryptocurrency can omit the need for physical currency, which will further assist in establishing a sustainable environment with less waste and less energy consumption.[101]

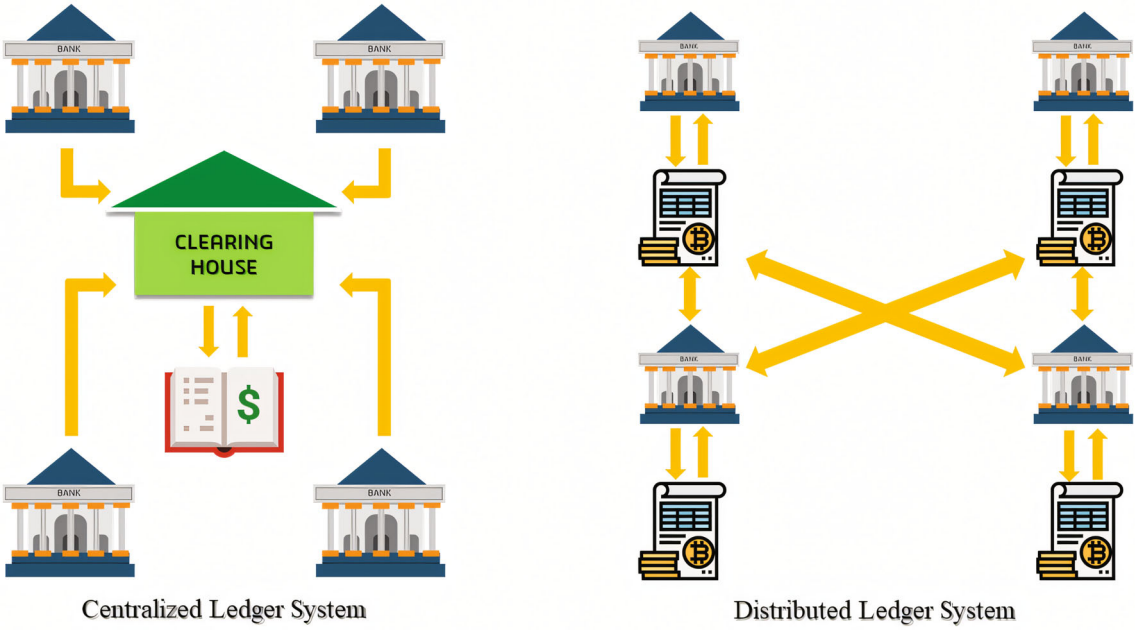

FIGURE 13 Blockchain based bank ledger system.

5.2.5 | Cybershopping sector

Online shopping is only now beginning to gain traction in Bangladesh. When making online purchases, consumers heavily rely on online reputation systems (such as social media rating and recommendation systems). Unfortunately, there are a number of problems with the current systems of online reputation because some fake customers even provide fake ratings in exchange for payments.[102] By validating and generating distinct digital identities for each user, a BCn-based reputation system can prevent this criminal activity and collect reputation data across the web. As a result, the reputation system will be trusted and transparent. Consumer confidence and trust in this new industry will be crucial to ensuring its long-term viability.

5.2.6 | Agriculture sector

Agriculture's greatest difficulty is tracking and paying for products. Third parties control coordination in today's agriculture sector, which is a great blockade towards sustainability. Food delivery and payment agents for both sellers and buyers add expense to the system.[103] Thus, a BCn system may guarantee farmers a large selling. As shown in Figure 14, the BCn system will be effective in ensuring a sustainable agricultural system as farmers in Bangladesh will be able to sell crops or delicacies directly to consumers, eliminating the need for middlemen as each of the steps have their own digital footprint.[104] As a result, it will lower the expenses incurred by middlemen and ensure the proper distribution of agricultural goods both within Bangladesh and to other nations when there is a surplus. Additionally, the agricultural insurance systems in this country are mostly non-formal, private mutual, and community-based crop and livestock enterprises. Some low-cost farm insurance systems provide coverage for natural disaster victims. However, the uptake of insurance is low because the advantages are poorly explained.[105] A BCn-based insurance system can assist insured farmers in enjoying the advantage instantaneously in unfavorable weather through autonomous data feed and local hype data without claim assessment. BCn can eliminate intermediaries in agricultural supply chains, reducing waste, inefficiency and so forth and ensure Bangladeshi farmers get paid in a sustainable agricultural system.[106]

5.2.7 | Health sector

Enhancing patient data security and improving the overall healthcare experience, the implementation of BCn technology may alleviate the challenges of the existing system.[107]

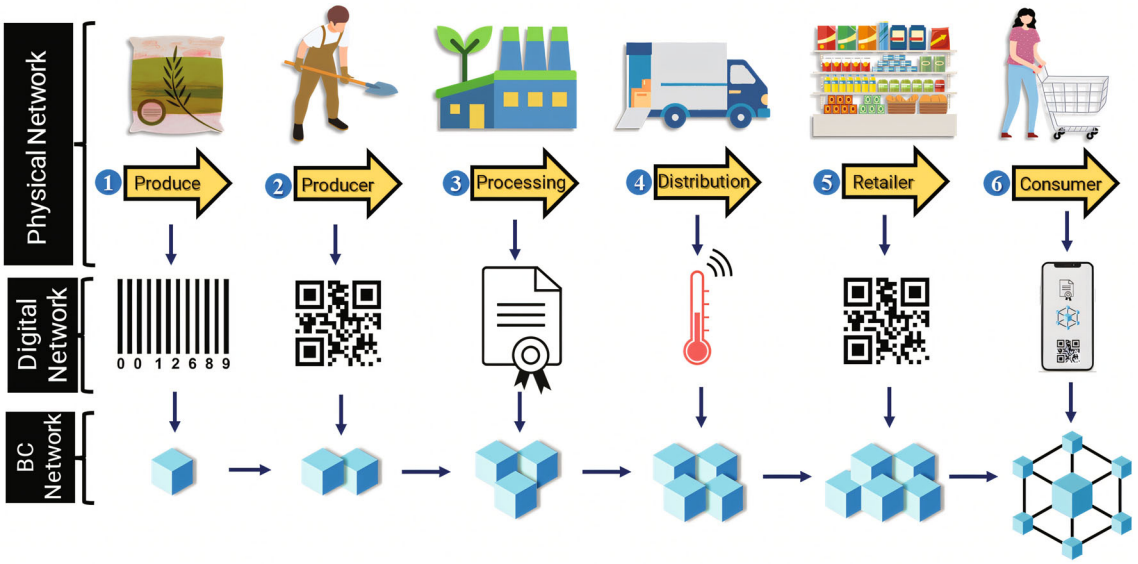

FIGURE 14 Blockchain based agriculture supply chain.

(i) ***Healthcare gateways***: In the present context, the medical records of patients and the medicine supply chain are stored, managed, and transferred manually, either through paper documentation or software facilities. Both systems are slow, inefficient, costly, and insecure. However, BCn, which utilizes distributed ledger technology, can automate these processes through computer programs. This eliminates the need for manual operations. The processes can be carried out quickly, easily, transparently, and without errors due to the BCn's ability to keep data incorruptible and immutable. Therefore, implementing BCn is the best technological solution to address data security issues.[108] In BCn, the real identity of each patient can be hidden, and only the hash number or public key may represent the ID. This ensures the privacy and sensitivity of the patients. The distributed ledger technique of BCn enables easy sharing of data between patients and doctors.[109] This may reduce processing time while ensuring a sustainable healthcare management system. Access to the data can be classified based on the permissions granted by the data owner, ensuring appropriate accessibility. Furthermore, it will facilitate research work by increasing data availability and reducing data retrieval complexity. Several practical use cases of BCn in healthcare include recording and securely managing COVID-19 proof of vaccination,[110] laboratory test results, and health visits.[111]

(ii) ***Electronic health care***: The e-government electronic health care (EHC) is becoming a very popular technology in the health sector.[112] It contains the medical data corresponding to the patients' health care, for example, laboratory test reports, progress notes, medications, health problems and so forth. At present, it is being maintained over time by the service providers. However, in the future, by implementing BCn in the EHC, we will provide large-scale accessibility of the data by maintaining the privacy, security and transparency of the data.[112] Connecting to existing electronic medical record (EMR) systems at various healthcare providers may be possible with a BCn-based application shown in Figure 15. It describes how BCn would receive encrypted information about any new information entered into one of these EMR systems. Only with the patient's permission through utilizing the BCn app, the other healthcare providers can be granted access to this data. Implementing BCn in the network may reduce the cost of intermediate service providers and eliminate the need to rely on them. Data processing and fetching may also be much faster automatically. By implementing BCn, we can eliminate the centralization of patients on limited healthcare providers, creating a sustainable EHC system.

(iii) ***Pharmaceuticals***: At present, many stores and supply mediums in Bangladesh are accused of supplying drugs that are sub-standard. Here, a BCn-based system can be implemented to ensure the authenticity of the products which are supplied to the customers. It can be used to keep track of the products from the point where the raw materials are generated, and tested to the end consumers of the final products. Also, maintaining immutable records of the actual manufacturer ensures that the data remain untampered, with no possibility of alteration. This tracking system may enable us to track if the manufacturer is using sustainable means for product manufacturing. The new updates will be automatically provided to the consumers and doctors, and the sub-standard drugs can be eliminated from the supply chain.[113]

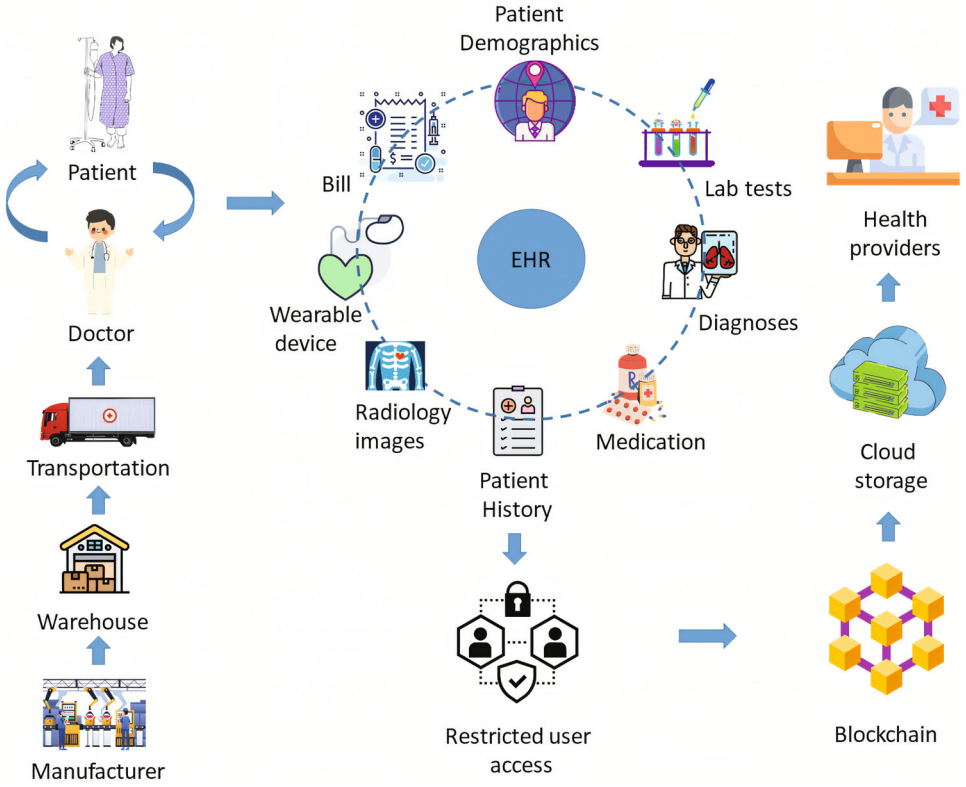

FIGURE 15 A conceptual framework for using the blockchain in the health sector.

5.2.8 | Education sector

The BCn technology is an emerging and innovative technology that has a huge potential to bring revolutionary change and to secure a sustainable education system in Bangladesh.[114] In this sector, BCn can be used from storing and managing data to authenticating them. It can also be used to enlist and authenticate the issued certificates and educational credentials.[115] Here, the BCn can be implemented at any degree, such as students' competencies, technical skills, transcripts, qualifications and so forth. All these things of a person can be accessed and verified at any time with proper authentication by using the distributed ledger technology.[116] Technical protections, such as digital signatures, are used to prevent modification of digital certifications, diploma supplements and so forth. Digital signatures are asymmetric cryptosystems that create a signature from a file using a private key. Technically speaking, the certificate's legitimacy can be clearly confirmed by this digital signature, the public key, and the original file. Credit card transactions, encrypted communication, and many other features of the internet can be primarily supported by this technology. It will consume less time and make the process easy to verify any credential of a candidate and verify his/her skills as well as abilities. The track of the students' accomplishments and skills throughout their whole life will be kept on a safe infrastructure. This will guarantee a secure and sustainable online academic management system with less waste and minimized power consumption.

5.2.9 | Facilitating IOT implementation

Because of the quick digitalization and increase of the use digital instruments in day to day life of the people of developing countries like Bangladesh, the application of IoT is increasing quickly. Because of the largely expanding applications, it is becoming critical to control and keep track of the devices and systems, and manage them.[117] Though the application of IoT is very helpful and has many advantages, various threats and security issues are outnumbering the advantages of the countries without properly secured systems.[118] Because of the lack of enough hardware capability and the conventional mechanism, cryptography is not enough to solve the issues. So, here the BCn comes into play. An IoT network that will provide a secured and interoperable digital system can be provided by a BCn-based IoT platform. By using its features, BCn can provide proper listing and tracking of the devices and systems. It may also facilitate the maintenance of the systems,

security, privacy and transparency. As a result, there will be no obstacle that can hinder the scalability and advancement of IOT applications in our country. Additionally, CCTV footage, mobile phone data, internet activity statistics, and crucial files from confiscated computers can be used as evidence in many nations. Digital evidence can be easily manipulated; therefore, its validity and integrity are often questioned. BCn can be beneficial in this sector.

5.2.10 | Smart city

To fulfill the target of becoming a developed country, Bangladesh can move towards the establishment of smart cities. The most important feature of any smart city is the long-lasting sustainability. To make this happen, there may be the necessity of more efficient and intelligent urban management system than the present scenario.[119] Here, BCn can play crucial roles to achieve such sustainable cities. First of all, in the present context, there are a lot of stakeholders in the cities. It is very important to obtain interoperability between them without any centralized authority; this may increase the interoperability speed, reliability and transparency, and reduce the cost and dependence on a single entity. BCn can provide all the facilities with its exclusive features.[120] Moreover, it is not possible for any single smart city to solve the social issues to improve the quality of services and operate efficiently and independently alone. It is very important to ensure interoperability and co-ordination among multiple smart cities that can easily be achieved by BCn.

5.2.11 | Digital currency

At present, Bangladesh has stopped the implementation of cryptocurrency because of the risk of money laundering, violations of other financial laws and terrorism. But in many developing and developed countries, central banks are initiating the process of CBDC (central bank digital currency) development. It is becoming effective because of the development and implementation of the BCn. As the use of virtual currencies, such as cryptocurrencies, continues to grow worldwide, soon Bangladesh may also launch digital versions of their currencies as an alternative to cryptocurrencies using BCn technology. As a result, the risk factor of the cryptocurrency, like volatility, may be removed. Unauthorized or untracked transactions will not happen, which stops the money laundering and law violations. All the financial activities with the digital currency may be under supervision and authentic. This system will facilitate currency in virtual transactions and to encourage startups and e-commerce businesses.

5.2.12 | Freelancing

As the availability of the internet and smart devices are increasing rapidly, the market of freelancing is increasing so quickly in our country. The world is moving towards an open economy. So, big companies invite freelancer for different tasks like designing, software designing, website designing and developing and so forth. They have already started to offer cryptocurrency as a payment method.[121] In the future, there may be a standard digital currency developed by the central bank of Bangladesh that will facilitate the freelancer to freely accept the offers. As a result, for the freelancer, there may be less restriction, and the field will be wider open. The cost of currency exchange will also be reduced.[122] More remittance will flow into our economy. Moreover, the lack of printed currency could be a massive step towards a green environment.

5.2.13 | Helping the disadvantaged groups

In the present scenario, the system that provides help to the displaced people because of different natural calamities or the refugees is very corrupted and inefficient. It has become increasingly common to witness frauds and misallocation of the essential resources required for supply. It is estimated that nearly 30% of the funds allocated for development fail to reach the intended recipients. All these issues arise due to theft by involved third parties, lack of proper management and various other problems. Here, a BCn developed system can ensure that donations from donors go to the right people.[123] For instance, when donors choose to send money through a digital currency via a bank, a smart contract can be utilized. The money is automatically transferred to the bank after fulfilling the condition of providing the funds to the intended recipients' block or account.[124] This process eliminates the need for any third-party involvement. Additionally, donors can calculate the amount of money received by the intended recipients and compare it with the amount of their donation.

TABLE 10 Potential benefits of BCn in specific goals of the SDGs.

Industry	SDGs	Potential benefits of BCn
Health sector	Goal 1	Storing important data of patients'
	Goal 2	
	Goal 3	
Insurance	Goal 8	Reduces corruption and fraud
	Goal 9	
	Goal 10	
	Goal 17	
Foreign trade	Goal 8	Logistic recording of data in case of cross-border payment
	Goal 9	
	Goal 10	
International transactions	Goal 8	Prevent hacking and fraud in case of financial transactions
	Goal 9	
	Goal 10	
Supply chain management	Goal 8	Trust and security in case of the maintenance of supply chain
	Goal 9	
	Goal 10	
	Goal 12	

5.2.14 | Remittance

Bangladesh earns a lot of foreign currencies from the remittance sector. The currencies go through several intermediary institutions or entities and finally come to our country, which takes much time and also costs a lot of the transaction fees. BCn can eliminate these from the remittance supply chain.[125] In the future, the implementation of the right policies on our own digital currency and the use of it for money transfers will also eliminate the risk factor of currency fluctuations. The government will be able to track the flow of remittances as well. This will help to solve tax problems related to remittances sent by Bangladeshis.[3] The lead time to send money back to the country may also decrease significantly, establishing a self-sustained currency transfer system.

Considering the above cases, it is concluded that the BCn technology can contribute greatly to meeting the SDGs in Bangladesh. Table 10 shows how BCn can assist Bangladesh in attaining SDGs. By offering safe and open financial services, BCn can encourage financial inclusion. The transparency offered by BCn technology can lessen corruption and enhance governance. Traceability in supply chains enables moral sourcing and environmentally friendly manufacture. Digital identity systems built on the BCn can give excluded groups more power. It can also promote climate action and make it easier to use renewable energy sources. It is crucial to remember that while BCn has the potential to help accomplish the SDGs, its effective implementation requires a supportive regulatory framework, the development of infrastructure, and stakeholder understanding. To fully utilize BCn technology for sustainable development in Bangladesh, cooperation between the public and business sectors as well as civil society is necessary.

6 | IMPLEMENTATION CHALLENGES

At the time of implementing a new technology, existing institutions must consider their strategic changeover with the transformation of the whole systems. Otherwise, overall the implementation can bring disaster to the institution, and eventually, the approach can lead to a total failure.[126] So, existing institutions need to think from the user point of view and need to determine if the implementation of the BCn to the system will be beneficial or not. They also need to analyze the impact of the technology on a regular basis. Similarly, before implementing BCn technology and getting maximum outcomes, Bangladesh should consider the following challenges that they are going to face.

6.1 | Spreading technical knowledge

For a newly invented technology, it is really important to know about it properly before implementing or rejecting it. For that reason, it is necessary to have enough experts to provide the proper knowledge and training. BCn is one of the latest technologies which is rapidly increasing its use cases day by day. So, the demand for experts is outnumbering the current supply of experts. The gap between the demand and supply of expertise is getting bigger and bigger. For a developing country, it is not easy to bring technical experts and retain them here in the context of BCn.[127] Also, experts are not generally interested in moving towards the developing countries. So, for a country like Bangladesh, it can be a major challenge.

6.2 | Compatibility

At present, not all functions of an organization can be fully managed by BCn technology. Therefore, it is necessary to develop systems that are compatible with existing systems. The implementation of this new technology will also have an impact on business strategies and existing software, requiring interoperability among them.[128] Therefore, compatibility with business and networking policies is also important. For a country like Bangladesh, coping with a new and constantly evolving technology like BCn presents a significant challenge.

6.3 | Complexity

Complexity of a technology is the measure of the difficulty to understand and implement it. As BCn is a complex and new technology, specialized skills are required to store, manage and transfer data among the people or entities involved in this network.[129] In Bangladesh, the lack of expertise and clear understanding about the technology adds an extra layer of complexity to any progress or initiatives.

6.4 | Financial resources

Operations of BCn technology, like mining, data sharing, and validating heavily rely on the capacity of the hardware used. Operating a BCn-based system efficiently demands very high configuration hardware. Moreover, it will cost a lot to integrate the BCn system with the existing system. This huge amount of investment in a short span of time is a big challenge for a country like Bangladesh. Also, there is a risk of wasting resources in the present structure.

6.5 | Government regulations

In Bangladesh, currently, there is no protocol or framework available for the implementation of BCn technology. The establishment of such rules would incentivize certain companies and their stakeholders to adopt BCn-based systems for information sharing, as they would benefit from doing so. However, the strict rules and protocols that need to be followed may also discourage firms from implementing the technology.[130] Consequently, in the present scenario, the biggest challenge lies in creating a completely new regulatory framework that effectively governs this innovative technology in Bangladesh, without adversely affecting any entity.

7 | CONCLUSION

The galloping demand in Bangladesh due to Industry 4.0 is going to be dispatched via the incorporation of Blockchain. In this article, a study on the unique features of BCn, BCn-based projects and SDG has been presented. First, the architecture, various mechanisms and categories of BCn are discussed. Then, the exclusive features like anonymity, immutability, security and privacy are highlighted. Again, the ongoing and recently executed BCn projects in developed countries are analyzed to understand the superb impact of BCn technology. Afterward, the agendas and technological visions of

Bangladesh are discussed. Then, the present and future prospects of BCn in different sectors to solve existing problems are presented. Finally, the opportunities and integration challenges of BCn in various sectors are outlined.

AUTHOR CONTRIBUTIONS

Rahul Joysoyal: conceptualization; methodology; writing – original draft. **Shekh S. Uddin:** investigation; conceptualization; data curation; writing – original draft. **Touhid Islam:** conceptualization; investigation; writing – original draft; resources. **Subrata K. Sarker:** conceptualization; investigation; validation; visualization; project administration; writing – review and editing; supervision. **Li Li:** supervision; writing – review and editing; validation; conceptualization. **Faiaz Ahsan:** data curation; validation; visualization; writing – original draft. **Uzair Aslam Bhatti:** writing – review and editing; methodology; validation; visualization. **Ehsanul Islam Zafir:** writing – original draft; investigation; conceptualization; formal analysis.

CONFLICT OF INTEREST STATEMENT

Authors have no conflict of interest relevant to this article.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/eng2.12948.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Joysoyal R, Uddin SS, Islam T, et al. Blockchain for sustainable city transformation: A review on Bangladesh. *Engineering Reports*. 2024;6(9):e12948. doi: 10.1002/eng2.12948