Categorizing and relating implementation challenges for realizing blockchain applications in government

Luthra, Sunil; Janssen, Marijn; Rana, Nripendra P.; Yadav, Gunjan; Dwivedi, Yogesh K.

DOI
10.1108/ITP-08-2020-0600

Publication date
2022

Document Version
Final published version

Published in
Information Technology and People

Citation (APA)
Luthra, S., Janssen, M., Rana, N. P., Yadav, G., & Dwivedi, Y. K. (2022). Categorizing and relating implementation challenges for realizing blockchain applications in government. *Information Technology and People*, *36*(4). https://doi.org/10.1108/ITP-08-2020-0600

The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/0959-3845.htm

Categorizing and relating implementation challenges for realizing blockchain applications in government

Sunil Luthra
*Department of Mechanical Engineering,
Ch. Ranbir Singh State Institute of Engineering and Technology, Jhajjar, India*
Marijn Janssen
*Faculty of Technology, Policy and Management, Delft University of Technology,
Delft, The Netherlands*
Nripendra P. Rana
College of Business and Economics, Qatar University, Doha, Qatar
Gunjan Yadav
*Department of Mechanical and Automobile Engineering,
Swarrnim Startup and Innovation University, Gandhinagar, India, and*
Yogesh K. Dwivedi
*Emerging Markets Research Centre (EMaRC), School of Management,
Swansea University, Bay Campus, Swansea, UK and
Department of Management, Symbiosis Institute of Business Management, Pune,
Symbiosis International (Deemed University), Pune, India*

Received 28 August 2020
Revised 4 July 2021
4 April 2022
Accepted 21 June 2022

Abstract

Purpose – Blockchain technology (BCT) can be used for a wide variety of applications across domains and can bring many benefits. BCT-based applications can be beneficial for the government as well as businesses. Despite the many promises, BCT implementation lags behind. The purpose of this research is to identify a roadmap of critical implementation challenges that influence BCT implementation by governments.

Design/methodology/approach – The study develops an ISM-based model spread across seven levels to analyze the inter-relationship among the selected BCT challenges. The MICMAC analysis further helps in evaluating the variables based on their driving power and dependencies.

Findings – The findings show that all challenges have a strong impact on implementing BCT. The foundation for implementation BCT is to define standards and develop appropriate regulations. Next, the findings show the need for a shared infrastructure meeting the basic technical and societal requirements and developing viable business models to advance BCT implementation. Many challenges hinder the development of blockchain applications meeting the technical and ethical requirements.

Originality/value – Existing research has analyzed the relationship among challenges. To the best of the authors' knowledge this is the first paper to collate these implementation challenges and incorporate them to develop a hierarchical model using interpretive structural modeling technique. The results can be used to prioritize the tackling of the challenges.

Keywords Blockchain, Blockchain technology, Implementation, Challenges, Interpretive structural modeling, MICMAC analysis

Paper type Research paper

1. Introduction

Blockchain technology (BCT) has been considered a key innovation for conducting transactions over a network (Choi and Luo, 2019). BCT has recently emerged as a primary

Information Technology & People

0959-3845
DOI 10.1108/ITP-08-2020-0600

source for a transaction layer for Internet services (Ertz and Boily, 2019). BCT creates strong chances for disruptive innovation by providing a novel approach to execute and govern transactions resulting in higher levels of trust.

High risks transactions need to be executed with utmost care. Accordingly, BCT promises for executing secured transactions and for storing documents have started to attract governments' attention (Lu, 2019). BCT can be viewed as a general-purpose technology for the effective exchange of information and perform the transactions of digital assets across the distributed networks. The essence of BCT applications is the storage of information in a distributed ledger that can record transactions and other information in a verifiable and permanent manner (Hughes *et al.*, 2019; Khan *et al.*, 2020). Information cannot be easily removed or tampered, and only new information can be added when the nodes in the distributed ledger have consensus, which results in higher levels of security and better information integrity. Previously entered information of all the transactions cannot be removed (or at least are hard to remove) and enable all the available nodes to track the history (Ølnes *et al.*, 2017). BCT applications can provide benefits like minimized costs and process complexity, the creation of shared trusted processes, less dependency on one part, transparency by meliorated tracking of audit trials and secured recordkeeping (Chen *et al.*, 2019).

Apart from cryptocurrency, distributed ledger technologies are nowadays highly used by government agencies across the globe (Jesus *et al.*, 2018; Gozman *et al.*, 2020). Information-based administrative processes make up the heart of government. Typically the amount of data processed across public organizations is much larger than the private organizations. Furthermore, warranting the public values of security and privacy is essential for governments. For example, in 2018, the UK food standards agency conducted a pilot project using BCT for tracking the main distribution in a cattle slaughterhouse (Gao *et al.*, 2018). They further claimed that it was the very first time when the distributed ledger technology was utilized across the food sector. India also progressed toward using BCT for facilitating the land titling process (Thakur *et al.*, 2020). Furthermore, its application has been extended across the department of work and pensions to provide better facilities for the claimants to manage their saved money (Wang *et al.*, 2020). BCT can further help them to track the digital and physical assets of the workers and citizens across the country. It might also help the government authorities for the smooth handling of budgets and financial management as the government will be able to track the transactions immediately without facing any errors (Woodside *et al.*, 2017). All these examples show the promise of BCT, but despite its potential, the actual implementation and use of BCT across the government organization is limited (Feng *et al.*, 2020). Many of the initiatives remain in the piloting phase.

Several studies are discussing the BCT challenges (Ayed, 2017; Lin and Liao, 2017; Zambrano *et al.*, 2017), however, very few of them could highlight the specific challenges faced by the government organizations. Furthermore, the studies portraying BCT challenges by the government (e.g. Huckle *et al.*, 2016; Banerjee *et al.*, 2018), but do not shed light on the inter-relationship between the challenges and leaves a void in which implementation challenges are dominating and need to be tackled before next challenges can be addressed. Although some researchers have addressed adoption challenges (Pan *et al.*, 2017; Francisco and Swanson, 2018; Janssen *et al.*, 2020), no studies provided a roadmap or a structural hierarchy for the implementation of BCT by governments. What implementation challenges should be tackled first by governments and which implementation challenges should be addressed first is not known. There is a need for insight into the challenges based on their driving power and dependencies and to understand the different pathways to adopt BCT.

Based on the above-mentioned gaps, we will identify implementation challenges and develop a structural hierarchy that projects the relationship among each BCT implementation challenge. This will provide insight into which implementation challenges are dominating and need to be tackled first. Hence, the objective of this study is to develop a roadmap addressing structural relationships among the challenges and compute their driving and dependence power. The specific objectives of the present investigation are as follows:

(1) To identify the implementation challenges for realizing BCT applications in government

(2) To investigate the contextual relationships among recognized challenges for realizing BCT applications in government

(3) To develop a structural model for eradicating identified challenges for realizing BCT applications in government

The model development methodology follows an approach in which an extensive literature review on existing BCT studies is conducted to identify the various challenges for realizing BCT applications in government. To verify/validate the challenges, expert's inputs were sought and used. The resulting data were analyzed using the integrated ISM-MICMAC methodology to explore the inter-relationships among the identified challenges as well as categorize them in accordance with their dependence and driving power (Janssen *et al.*, 2019). The used ISM-MICMAC integrated technique also helps in developing a challenges specific hierarchical structured framework, which assists the government and policy-makers in promoting BCT applications in government.

This paper is structured as follows. The related literature review of BCT implementation challenges is reviewed in Section 2. Section 3 presents the research methodology for the study. Section 4 showcases the data analysis and the results of the study. Findings have been discussed in Section 5 along with managerial implications. Finally, Section 6 highlights the conclusions, limitations and future research directions.

2. Literature review

This section discusses the key challenges for realizing BCT applications in government and highlights the gaps for this research as well. The identification of key inhibitors is important in effectively realizing BCT applications in government. In this sense, a literature survey was conducted using critical search words, e.g. "challenges to Blockchain applications + Government"; "Inhibitors to Blockchain applications"; "Barriers to realizing Blockchain applications in Government"; "Hurdles to Blockchain applications" *e*. The Google and Google Scholar search was used to link various databases like Science direct, ISI WoS, Emerald, Scopus, Taylor & Francis, DOAJ, EBSCO, Wiley and Inderscience. This resulted in the identification of 123 papers. The corresponding papers were then downloaded, reviewed and coded using data displays. After reading the papers in total 52 papers remained for analysis. From these papers, a total of 11 challenges were derived, which were extended with two challenges derived from expert input.

The literature reveals that a lack of appropriate regulations for guiding transactions and smart contracts emerged as a critical implementation challenge hindering the use of BCT by governments. For governments all transactions need to be guided through contracts and regulations (Hackius and Petersen, 2017). Smart contracts face the challenges of legality to get processed. Furthermore, judiciary procedures for processing the smart contracts differ from one country to another country (Aras and Kulkarni, 2017).

The transformation of organizational networks emerges as another challenge (Choi and Luo, 2019). In the majority of the cases, the BCT acts as the linkage between the system and the interaction parties, which impacts the structure of organizational networks. This further creates ambiguity and confusion among the authorities to define the organizational network (Janssen *et al.*, 2020). Trusted third parties are not needed anymore in these networks, and direct transactions among participants are possible.

Creating the governance of BCT application is another critical challenge that restricts BCT implementation (Ertz and Boily, 2019). Parties need to collaborate to extract the maximum benefit out of BCT (Scholl and Bolívar, 2019). It is extremely essential to identify the authorities across the government system that should be made responsible for decision-making, ensure smooth execution and upgrading of BCT applications (Lu, 2019). It is critical to identify the technical experts and policy-makers and define their responsibilities (Khan *et al.*, 2020). Another challenge is developing information sharing and transaction arrangements. BCT can be used for smart contracts; so, it is critical to understand how the information is exchanged, and which transactions take place within the smart contracts. Similarly, it is essential to capture all the requirements that help in building the smart contract and generating the transaction (Chen *et al.*, 2019).

Once the information sharing and transaction arrangements are made, it becomes critical to create a shared operating platform and partnerships. BCT requires the involvement of many organizations (Feng *et al.*, 2020). Hence, it is essential to identify the correct platform, vendor and other partners effectively and co-ordinate with them to develop a shared operating platform that can easily capture, monitor and analyze the data obtained through different providers (Ali *et al.*, 2020). Maintaining the synchronization between different providers and finally creating the shared operating platform and partnerships is observed as one of the critical implementation challenges for government organizations (Warkentin and Orgeron, 2020). This challenge becomes even more important when it comes to organizational transformation, as existing processes of government organizations are generally designed and structured in different ways. So, transforming the existing organizational structures and processes to benefit from BCT applications is a difficult task (Yoo, 2017).

Although the organizational transformation helps in realizing benefits from the BCT applications, developing a value proposition and value creation mechanism is not easy. It is important to understand the value proposition of the execution of BCT by looking at the whole system (Jesus *et al.*, 2018). However, capturing the value of BCT and its benefits is extremely challenging. The expected benefits of BCT cannot be obtained easily, and there always remains a discussion about whether the expected benefits can be achieved without BCT (Queiroz and Wamba, 2019). For governments, it is essential to ensure public values like privacy, data protection, equal access, security and trust. However, the realization of public values can be challenging (Turk and Klinc, 2017).

The implementation of any system needs investments. Hence, the high implementation cost is viewed as a challenge (Ying *et al.*, 2018). Implementation cost not only covers the initial cost, but also includes the continuous development cost, operational cost, maintenance cost and security-related costs (Presthus and O'Malley, 2017). While considering the cost, realizing the desired system quality is another challenge (Vishwakarma *et al.*, 2018). Here the system quality refers to the speed, scalability, flexibility and security. BCT can offer various benefits, but there is a trade-off with the cost per transaction, speed, scalability, flexibility and response time required by the organization. The level of security needed will directly increase implementation cost (Hou *et al.*, 2018).

However, BCT is in the starting stage with known implementation challenges in the areas of performance, scalability and interoperability with other systems. Along with technical challenges, enterprises face daunting management challenges because blockchain applications must be assimilated within complex institutional, regulatory, social, economic and physical systems (Lacity, 2018). It has been noticed that BCT still exists in its initial development phase, and BCT lacks commonly accepted standards. It offers a variety of application that includes a distributed ledger, encryption, security and identification, but the majority of these elements are still under development (Tiwari *et al.*, 2018). This creates confusion and discussions about how to implement. Furthermore, often there is a lack of expertise resulting in understanding (Saberi *et al.*, 2018). Misconceptions among the practitioners and the technical advisors happen frequently (Kshetri, 2018).

Finally, resistance to change by the organizations and their staff involved during its implementation process is another critical challenge (Govindan *et al.*, 2018). The users prefer to work and continue to operate using their past habits and processes instead of adopting changing work processes and procedures. The challenges that influence BCT implementation in government are listed in Table 1.

S. No.	Challenge	Implied meaning	References
1	Lack of appropriate regulations for guiding transactions and smart contracts (Ch1)	Transactions are guided by contracts and regulations. More advanced contracts face the challenges of legislation and requirements by the legal environment. This is further complicated for contracts passing the juridical boundaries of a country	Ayed (2017), Lin and Liao (2017), Gupta *et al.* (2018)
2	Transforming organizational networks structure and the role of the trusted middleman (inter-organizational change) (Ch2)	Blockchain technology (BCT) can transform organizational networks. BCT is expected to facilitate direct interaction between parties, in which BCT replaces the middleman. How the organizational networks will look like is unclear	Huckle *et al.* (2016), Zambrano *et al.* (2017), Banerjee *et al.* (2018), Lacity and Van Hoek (2021)
3	Creating (inter-organizational) governance of BCT applications (Ch3)	Organizations need to collaborate to take advantage of BCT. Governance should determine the decision-making authority of maintaining and updating BCT applications. All too often, there might be a few technical experts who lead, and policy-makers are not being able to make decisions (technocratic governance)	Ayed (2017), Kim and Kang (2017), Chen *et al.* (2018), Gozman *et al.* (2020)
4	Developing information sharing and transactions arrangements (Ch4)	BCT is used for governance transactions and smart contracts. How this process of information exchange and transactions between users should look like and how it fulfills the requirements is challenging	Vojdani *et al.* (2013), Pan *et al.* (2017), Banerjee *et al.* (2018), Francisco and Swanson (2018)
5	Creation of shared operating platform and partnerships (Ch5)	BCT require typically the involvement of many organizations. Identifying the right platform, vendor, and partner is crucial. There are already coalitions of software providers	Hackius and Petersen (2017), Lacity (2018), Choi and Luo (2019)
6	Organizational transformation to benefit from BCT applications (organizational change) (Ch6)	BCT applications can have significant effects on the way organizational processes are designed, and organizations are structured. Yet, if and how such organizations should be transformed to serve as owners and guardians of the BCT application is challenging	Aras and Kulkarni (2017), Chen *et al.* (2019), Lu (2019), Warkentin and Orgeron (2020)

(*continued*)

Table 1.
Description of the challenges of BCT in government

S. No.	Challenge	Implied meaning	References
7	Developing a value proposition and value creation mechanisms (Ch7)	BCT applications are diverse and can be used in different domains. Yet what is the value of applications and the creation of value logic is challenging. Benefits might not be easily accomplished and can be challenged or can be accomplished without BCT	Huckle *et al.* (2016), Hackius and Petersen (2017), Chen *et al.* (2018), Ertz and Boily (2019)
8	Ensuring public values like privacy, data protection, equal access, security and trust (Ch8)	The realization of public values can be challenging. For example, the right to be forgotten might require that data can be removed from the ledger	Li *et al.* (2017), Pedersen *et al.* (2019)
9	High costs (Ch9)	This factor covers the investment and development costs, the operation costs by different nodes, and the maintenance costs for adapting to changes, dealing with security hacks and so on	Hackius and Petersen (2017), Pan *et al.* (2017)
10	Realizing the desired system quality (speed, scalability, flexibility and security) (Ch10)	The advantages of BCT come at a cost of limitations like the cost per transaction, speed, scalability, flexibility, and response time. Higher levels of security might be at the expense of scalability and speed of transactions resulting in higher costs	Presthus and O'Malley (2017), Hou *et al.* (2018), Jesus *et al.* (2018), Lacity (2018), Pedersen *et al.* (2019)
11	Lack of standards (Ch11)	BCT foundation consists of a variety of technologies (distributed ledger, encryption, security and identification) and is still under development. There is no standard for BC	Turk and Klinc (2017), Frizzo-Barker *et al.* (2019), Perera *et al.* (2020)
12	Lack of understanding and expertise (Ch12)	Misunderstanding of the true abilities of BCT coupled with the lack of expertise needed for realizing BCT implementations	Ayed (2017), Lin and Liao (2017), Zambrano *et al.* (2017)
13	Resistance to change (Ch13)	The resistance to change by organizations and staff during the implementation process	Tapscott and Tapscott (2017), Banerjee *et al.* (2018), Chen *et al.* (2018), Walsh *et al.* (2020)

Table 1.

3. Research methodology

The goal of this work is to investigate the contextual relationships among various identified challenges and to develop a structural model for eradicating identified challenges for realizing BCT applications in government. For this, a combination of ISM and MICMAC methods will be employed. ISM uses expert's input (Warfield, 1974) to model a group of factors that are related with the problem. ISM can structure the involved variables into a systematic hierarchical model to depict the interrelations among variables (Janssen *et al.*, 2019). MICMAC analysis helps to evaluate the variables based on their driving power and dependencies (Duperrin and Godet, 1973). The combined ISM-MICMAC method has become a well-accepted methodology and is used by various researchers and practitioners in their problem-specific context (Luthra and Mangla, 2018; Kapse *et al.*, 2018; Rana *et al.*, 2019).

An integrated ISM-MICMAC approach has several merits to use as compared to others modeling approaches like DEMATEL, analytic network process (ANP) and structural equation modeling (SEM) (Luthra and Mangla, 2018; Mangla *et al.*, 2018; Janssen *et al.*, 2019; Rana *et al.*, 2019). The comparison is shown in Table 2.

The integrated ISM-MICMAC approach has several steps (Janssen *et al.*, 2019; Yadav and Desai, 2017), which are described, as follows: [1] Step 1 – Identify the factors related to the research domain for which structural hierarchy is required. For instance, in this study, BCT challenges in government are identified through exhaustive literature review and expert opinion, [2] Step 2 – Develop the contextual relationships among the identified BCT challenges in government. For the purpose, data are required to be collected from the experts, [3] Step 3 – Develop a structural self-interaction matrix (SSIM) (also known as relationship matrix) of the identified BCT challenges developing the pairwise comparisons among BCT challenges. The authors' utilized expert opinion to develop this matrix, [4] Step 4 – Develop the initial reachability matrix (RM1) by utilizing SSIM. RM1 is further converted into the final reachability matrix (RM2) by removing the transitivity among the relations of BCT challenges. The transitivity relations (Rana *et al.*, 2019) are considered among listed challenges, which follows the relation that if factor A is related to B and factor B is related to C then factor A must be related to C, [5] Step 5 – Compute the driving and dependencies of all the identified BCT challenge. It is achieved by adding all the rows and columns of RM2. This provides the co-ordinates for each BCT challenges to identify its location across the four quadrants (Yadav *et al.*, 2019), [6] Step 6 – Compute the levels of the structural model. For computing levels, a reachability set, antecedent set and intersection set are prepared. Reachability set comprises of the BCT challenge itself and the other challenges which are influenced by that specific BCT challenge. While the antecedent set comprises of the BCT challenge and other challenges involved in influencing that specific challenge, the intersection set is prepared by obtaining the common points of reachability set and antecedent set across each specific BCT challenge, [7] Step 7- Compute the graph by conducting MICMAC analysis. The initial inputs for preparing graph are obtained by the driving power and dependencies computed in step 5. Furthermore, the authors developed four different quadrants (autonomous, dependent, linkage and independent) in the graph. The authors approached the experts again to obtain the intensity of relation among BCT challenges, [8] Step 8 – Construct the digraph for identified BCT challenges. The digraph is constructed through the inputs of RM2. The digraph assists in computing the hierarchical structure and inter-relationship among the BCT challenges. Finally, the ISM model is

ISM-MICMAC	SEM	DEMATEL	ANP
This structural hierarchical decision-making approach assists in computing the contextual relationships among factors according to their driving and dependent powers	This is "*a priori*" approach, mostly opted for computing the theoretical development of a structural model; however, SEM proves to be as successful only in the case of availability of large sample sizes	This decision-making approach captures the causal relationships among the factors according to their cause and effect potentials. It develops inter-relationships but does not assist in constructing a structural hierarchy	This decision-making approach helps in estimating the individual interdependencies among the factors; however, due to its high complexity, it is least preferred

Table 2.
ISM uses/benefits compared with other modeling approaches

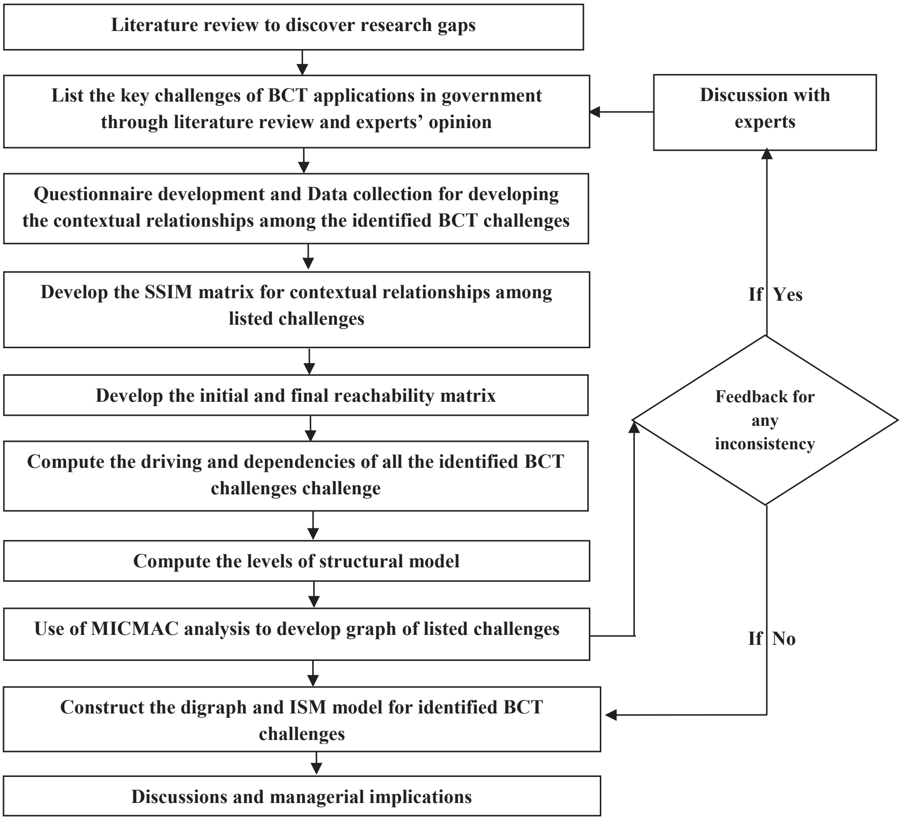
prepared by replacing the challenge codes with actual challenges. The entire group of identified BCT challenges is placed in the form of structural hierarchy across different levels obtained through iterations and [9] Step 9 – Conduct the consistency check. The developed ISM model is further shared with the experts to seek their opinion on its consistency and applicability. However, in case of any inconsistency, the corrective actions are required to be taken. The ISM-MICMAC based research flowchart of this research work is presented through Figure 1.

4. Data collection and analysis

The data needed for this work were collected from experts involved in BCT related projects. Data collection, analysis and related results have been discussed in the following subsections.

4.1 Questionnaire development and collection of data

BCT still exists in its early stage. The authors struggled for data collection of this study, as there are only a few experts with deep knowledge in this area and there is limited experience with the actual BCT implementation. To receive authentic and focused inputs, it was ensured



Source(s): Adapted from Janssen *et al.,* 2019

Figure 1.
ISM-MICMAC based Flowchart

that the experts understand BCT technology, were involved in BCT government implementation projects, and being independent (e.g. not employed by a software vendor or preferring a particular solution). Various sequential phone calls and e-mails were needed to find experts. We contacted almost 32 experts, working in this domain and wide range of experience. After rigorous follow up, the authors finally succeeded in collecting data from nine experts. The demographic information of the experts is provided in Table 3.

To shortlist the most critical barriers that actually help in developing the appropriate structural model essential measures were taken. The experts selected for this study were extremely strong according to their qualifications, work experience, knowledge and decision-making in BCT-related projects. The experts were selected from various sectors, including the private and public sector, who were working on the implementation of BCT for governments. The experts originate from consultancy, multi-national organizations, government and regulatory bodies. This ensures sufficient diversity of the experts. Most of them are from the private sector, which can be explained by the outsourcing of the implementation by governments to this sector. Many studies in the literature have clearly indicated that 7 to 10 experts are suitable for applying interpretive structural modeling (Yadav *et al.*, 2019). Also many good research studies (Mangla *et al.*, 2017; Yadav *et al.*, 2020; Goyal *et al.*, 2022) have derived their results with limited number of experts and published in reputed journals. This results in the awkward situation that the private sector often has more knowledge than the governments concerning the implementation of BCT. All the experts were having less than five years of domain experience, which can be explained due to the novelty of this emerging area.

4.2 Selection of the challenges for realizing blockchain applications

In the initial stage, the challenges for realizing BCT applications in government were derived. This work listed 13 challenges of BCT applications in government, which were derived using a literature review, as mentioned in Section 2.2. To confirm these challenges into practice, a questionnaire was developed and circulated among the experts. To have a consensus among experts, the authors decided to conduct a brainstorming session. All the experts who participated were asked to rate the identified BCT challenges in government on 5 point Likert

Expert	Industry	Profile	Experience (in yrs.) total; in blockchain	Sector	Project implementation domain (no. of projects completed)
1	Financial	Senior IT Architect	>10 yrs.; <5 yrs	Public	Banking (3)
2	E-commerce	Manager Operations	>10 yrs.; <5 yrs	Private	Payments (4)
3	Automotive	Design Manager	>10 yrs.; <5 yrs	Private	Supply chain (3)
4	Financial	Senior Data analyst	>10 yrs.; <5 yrs	Public	Banking (2)
5	Payments	Information Security Officer	10 yrs.; <5 yrs	Private	Security protocols in Payments (3)
6	Insurance	Project Manger	10 yrs.; <5 yrs	Government	Asset tracking (3)
7	Shipping	Project Manager	10 yrs.; <5 yrs	Private	Smart contracts (4)
8	E-commerce	Manager Operations	10 yrs.; <5 yrs	Private	B to B sales; payment (3)
9	Healthcare	Manager Operations	10 yrs.; <5 yrs	Public	Electronic health records (2)

Table 3. Demographic information of experts

scale (1-not significant to 5-extremely significant). The significance of the challenges for realizing BCT applications in government is shown in Table 4.

4.3 Development of SSIM, RM1 and RM2

After finalizing the challenges, the contextual interactions among the challenges were evaluated. This assessment of pairwise interactions by experts uncovers the direction of relations between the challenges. For this, the expert panel was contacted, and their feedback was collected using a questionnaire. The experts were asked to pairwise rank the contextual relationship of "facilitates to" type meaning that one challenge leads to another challenge. Besides, we used several symbols to develop contextual relations, which are (1) V – BCT challenge *i* will assist in attaining for BCT challenge *j*; (2) A – BCT challenge *j* will assist in attaining for BCT challenge *i*; (3) *X* – BCT challenge *i* and *j* will assist in attaining each other; (4) O: BCT challenges *i* and *j* are not related to each other.

In this way, the contextual relations among the challenges were developed. The combined use of these symbols and experts' feedback results in Table 5, the relationship matrix for BCT challenges in government.

Based on the ISM execution procedure, a structured, self-interaction matrix is converted to the initial reachability matrix (RM1). To develop RM1, the authors utilized binary numbers

Table 4.
Significance of the challenges for realizing BCT applications in government

S. No.	BCT challenges in government	Experts' rating on Likert scale* 1	2	3	4	5	6	7	8	9	Mean score	Standard deviation
1	Transforming organizational networks structure and the role of the trusted middleman (inter-organizational change) (Ch2)	4	5	5	5	4	5	5	5	5	4.78	0.441
2	Resistance to change (Ch13)	4	5	5	5	5	5	5	4	4	4.66	0.500
3	Creating (inter-organizational) governance of BCT applications (Ch3)	5	4	4	4	4	5	5	5	5	4.56	05.27
4	Lack of standards (Ch11)	5	5	5	4	5	4	5	4	4	4.56	0.527
5	Lack of appropriate regulations for guiding transactions and smart contracts (Ch1)	5	4	5	5	5	4	4	4	4	4.44	0.527
6	Ensuring public values like privacy, data protection, equal access, security and trust (Ch8)	5	3	3	4	5	5	4	5	5	4.33	0.866
7	Developing information sharing and transactions arrangements (Ch4)	5	4	4	4	4	4	4	4	4	4.11	0.333
8	Organizational transformation to benefit from BCT applications (organizational change) (Ch6)	4	5	3	5	3	4	4	4	4	4.00	0.667
9	Realizing the desired system quality (speed, scalability, flexibility, security) (Ch10)	4	4	5	4	5	3	3	3	3	3.78	0.833
10	Developing a value proposition and value creation mechanisms (Ch7)	4	5	3	5	4	3	3	3	3	3.67	0.866
11	Lack of understanding and expertise (Ch12)	4	5	3	3	5	3	3	3	3	3.56	0.882
12	Creation of shared operating platform and partnerships (Ch5)	4	4	3	5	3	3	3	3	3	3.44	0.726
13	High costs (Ch9)	3	3	5	3	3	3	3	3	3	3.22	0.667

Note(s): *1-not important, 2-somewhat important, 3- important, 4-very important, and 5-extremely important

Variable *i*	Variable *j* Ch13	Ch12	Ch11	Ch10	Ch9	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2
Ch1	X	X	X	O	O	X	O	O	A	V	V	X
Ch2	X	O	V	X	X	V	O	X	A	A	X	
Ch3	A	A	A	O	A	A	O	X	X	X		
Ch4	A	A	X	A	V	V	O	X	X			
Ch5	X	A	A	A	V	V	X	V				
Ch6	X	X	A	O	V	X	O					
Ch7	X	O	O	A	O	O						
Ch8	V	A	A	O	O							
Ch9	V	X	X	A								
Ch10	O	A	A									
Ch11	X	X										
Ch12	X											

Table 5. Relationship matrix for BCT challenges in government

that replaced the VAXO analysis symbols. The rules for replacing VAXO symbols by binary numbers are described in Table 6.

Accordingly, the authors developed the RM1 for BCT challenges applications in government (see Table 7).

Further, the authors converted RM1 to the final reachability matrix (RM2) by removing transitivity according to the steps defined earlier. By incorporating the transitivity relations among the BCT challenges, RM2 for BCT challenges was constructed, as shown in Table 8. Later, the authors derived the driving and dependence power of all the identified BCT challenges by adding all rows and columns values of the RM2.

Symbol	(*i*, *j*) entry	(*j*, *i*) entry
V	1	0
A	0	1
X	1	1
O	0	0

Table 6. Rule for replacing VAXO symbols by binary numbers

Challenges	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13
Ch1	1	1	1	1	1	0	0	1	0	0	1	1	1
Ch2	0	1	1	1	1	1	0	1	1	1	0	0	1
Ch3	0	0	1	1	1	0	1	1	1	1	0	1	1
Ch4	0	0	0	1	1	0	0	1	1	1	0	0	0
Ch5	0	0	0	1	1	0	1	1	1	1	0	0	0
Ch6	0	1	1	1	1	1	0	1	1	0	0	1	1
Ch7	0	0	0	0	0	0	1	1	0	1	0	0	0
Ch8	0	0	0	0	0	0	0	1	0	0	0	0	0
Ch9	0	0	0	1	1	0	0	0	1	1	0	0	0
Ch10	0	0	0	0	0	0	0	0	0	1	0	0	0
Ch11	1	1	1	1	1	1	0	1	1	1	1	1	1
Ch12	0	0	1	1	1	0	0	1	1	1	0	1	1
Ch13	0	0	0	1	1	0	1	1	1	0	0	0	1

Table 7. RM1 for the challenges for realizing BCT applications in government

Table 8. RM2 for the challenges for realizing BCT applications in government

Challenge	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Driving power
Ch1	1	1	1	1	1	1*	1*	1	1*	1*	1	1	1	13
Ch2	0	1	1	1	1	1	1*	1	1	1	0	1*	1	11
Ch3	0	0	1	1	1	0	1	1	1	1	0	1	1	09
Ch4	0	0	0	1	1	0	1*	1	1	1	0	0	0	06
Ch5	0	0	0	1	1	0	1	1	1	1	0	0	0	06
Ch6	0	1	1	1	1	1	1*	1	1	1*	0	1	1	11
Ch7	0	0	0	0	0	0	1	1	0	1	0	0	0	03
Ch8	0	0	0	0	0	0	0	1	0	0	0	0	0	01
Ch9	0	0	0	1	1	0	1*	1*	1	1	0	0	0	06
Ch10	0	0	0	0	0	0	0	0	0	1	0	0	0	01
Ch11	1	1	1	1	1	1	1*	1	1	1	1	1	1	13
Ch12	0	0	1	1	1	0	1*	1	1	1	0	1	1	09
Ch13	0	0	0	1	1	0	1	1	1	1*	0	0	1	07
Dependence Power	02	04	06	10	10	04	11	12	10	12	02	06	07	96/96

Note(s): * = Transitivity

4.4 Partitioning of levels

From the inputs of RM2, the BCT implementation challenges were separated and allocated to different levels that were further utilized in constructing the structural hierarchy of BCT challenges. To achieve different levels of structural hierarchy initially the reachability set, antecedent set and intersection set were developed. Reachability set comprises the BCT challenge itself and the other challenges which are influenced by the specific BCT challenge. While the antecedent set comprises the BCT challenge and other challenges involved in influencing that specific challenge. The intersection set is prepared by obtaining the common points of reachability set and antecedent set across each specific BCT challenge. This procedure was repeated for all the challenges. For this purpose, level 1 was marked, for the case when the reachability set and the intersection set becomes equal for any challenge. For instance, the challenges "Ensuring public values like privacy, data protection, equal access, security and trust (Ch8)" and "Realizing the desired system quality (speed, scalability, flexibility, security) (Ch10)" were assigned to level 1. After marking the level to the challenges, those challenges were removed. This procedure was iterated until each of the challenges was allocated to at least one level. A total of seven iterations (see Annexure-II) were performed in developing the ISM-based hierarchical model of challenges for realizing BCT applications in government. The final importance levels of the challenges are shown in Table 9.

4.5 MICMAC analysis

MICMAC analysis is utilized to compute the driving and the dependence power of BCT challenges for the government. For this purpose, the desired matrix is obtained by adding all the rows and columns of RM2. This provides the co-ordinates for each BCT challenge to identify its location across the four quadrants. After this, the MICMAC analysis diagram was plotted, as shown in Figure 2.

Furthermore, the authors developed four different quadrants in the graph. The authors approached the experts again to obtain the intensity of relation among BCT challenges. These four quadrants are explained as follows.

(1) *Autonomous quadrant*: The variables falling in this quadrant possesses low driving and low dependence power. In this study, none of the variables falls in this quadrant. This finding indicates that all the selected challenges have a strong impact on realizing BCT applications in government.

S. No.	Level	Challenges of realizing BCT applications in government
1	1st	• Ensuring public values like privacy, data protection, equal access, security and trust (Ch8) • Realizing the desired system quality (speed, scalability, flexibility, security) (Ch10)
2	2nd	• Developing a value proposition and value creation mechanisms (Ch7)
3	3rd	• Developing information sharing and transactions arrangements (Ch4) • Creation of shared operating platform and partnerships (Ch5) • High costs (Ch9)
4	4th	• Resistance to change (Ch13)
5	5th	• Creating (inter-organizational) governance of BCT applications (Ch3) • Lack of understanding and expertise (Ch12)
6	6th	• Transforming organizational networks structure and the role of trusted middleman (inter-organizational change) (Ch2) • Organizational transformation to benefit from BCT applications (organizational change) (Ch6)
7	7th	• Lack of appropriate regulations for guiding transactions and smart contracts (Ch1) • Lack of standards (Ch11)

Table 9. Final levels for the challenges for realizing BCT applications in government

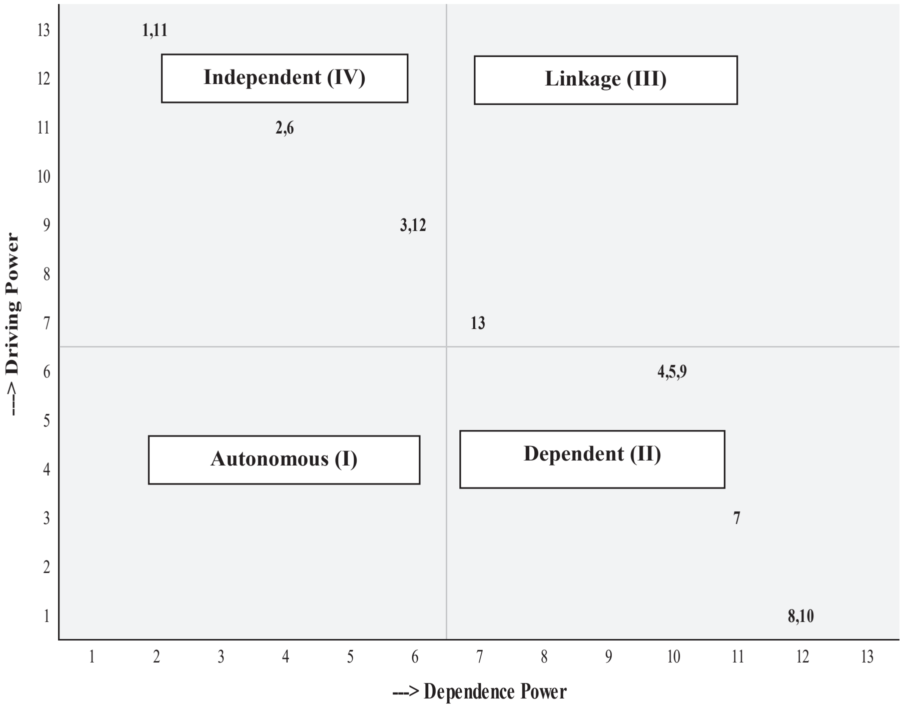


Figure 2.
MICMAC analysis for the challenges for realizing BCT applications in government

(2) *Dependent quadrant*: The variables falling in this quadrant possesses low driving and high dependence power. The variables found in this quadrant possess strong depending power. In this study, there are six challenges that belong to the dependent quadrant. Developing the information sharing and transactions arrangements (Ch4), realizing the desired system quality (Ch10), ensuring public values like privacy, data protection, equal access, security and trust (Ch9), refers to the need to have a common infrastructure (Ch5) which fulfills the basic requirements. The high costs (Ch9) and developing a value proposition and value creation mechanisms (Ch7) suggest that the blockchain applications are not viable yet. The strong dependence on these challenges indicates that they need all the other challenges to diminish the effect of these challenges during implementation.

(3) *Linkage quadrant*: The variables falling in this quadrant possess high driving and high dependence power. The variables found in this quadrant acts as a linkage to driving and dependent variables. They establish a linkage among these two and occupy comparatively lower levels in the final structural hierarchy.

(4) *Independent quadrant*: The variables falling in this quadrant possess high driving and low dependence power. The variables found in this quadrant possess strong driving power but low dependence power. These include a lack of appropriate regulations (Ch1), lack of standards (Ch11) and the need for expertise (Ch12). Furthermore, the need for network transformation (Ch2) and Organizational transformation (Ch6) and governance (Ch3). The variables that occur in this quadrant are structured at the bottom of the structural hierarchy.

4.6 Development of ISM-based hierarchical structural model

Following the MICMAC analysis, the digraph and ISM model was developed. The earlier developed RM2 allows the forming of the structured ISM model utilizing nodes/vertices and lines of edges. In this sense, the structural model of the challenges for realizing BCT applications in government is formed, which is known as a digraph. Later, this digraph is transformed into ISM-based hierarchical model. For this, we removed the transitivity links and put assigned challenges on the place of their nodes. Considering this, the ISM-based hierarchical model for the challenges was formed, as shown in Figure 3.

5. Discussion

The objective of our study is to develop a roadmap addressing structural relationships among the implementation challenges encountered by governments. Governments face unique implementation challenges which are different from other sectors. In contrast to the financial sector, where markets play a main role (Janssen *et al.*, 2020), their focus is on operating BCT in organizational networks. This makes their implementation challenges different from those in the private sector. BCT transactions need to be founded in regulations and standards are needed to ensure cross-organizational and cross-country interoperability.

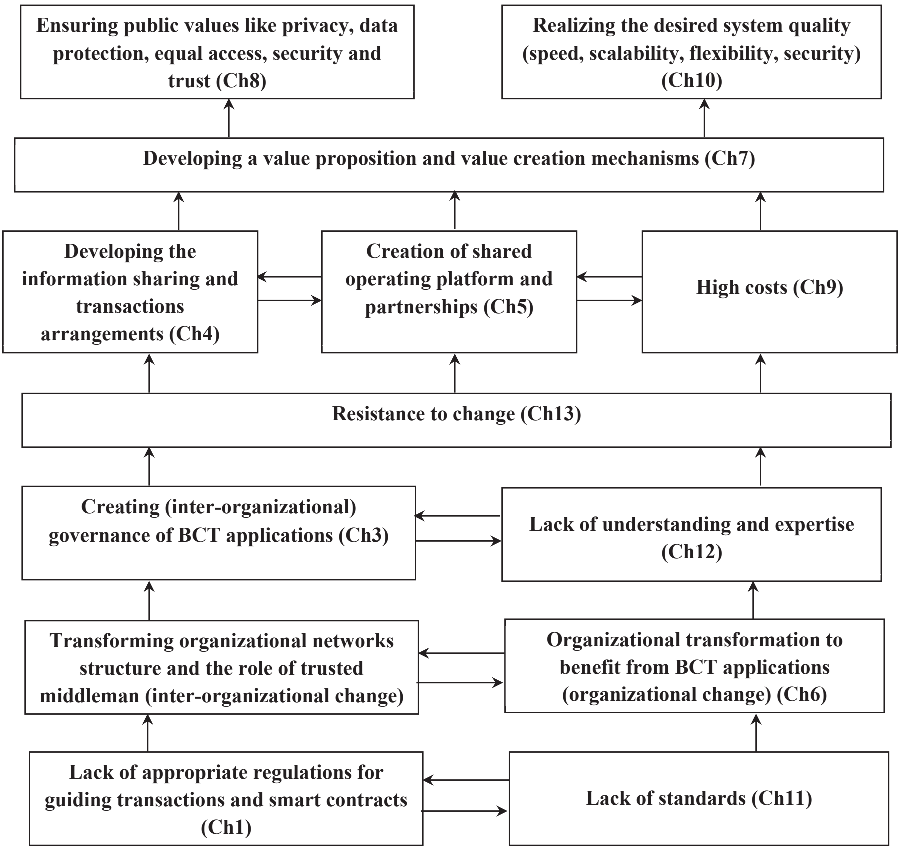


Figure 3.
ISM-based model for the challenges of BCT in government

The financial sector and insurance industries have seen a transformation in the last few years. "Fintech" innovators are the pioneers in bringing new culture, introducing software, technology and business practices beyond those traditionally associated with the financial services sector. Likely, governments will also be transformed by BCT. The traditional role of government as trusted third party might be overtaken by BCT, in which the government takes a different role and will focus on the governance of BCT operated in public organizational networks. Their focus will be more on ensuring public values and ensuring the desired quality once the blockchain application has been implemented.

There are two main findings from our study. Firstly, 13 BCT implementation challenges across the government got shortlisted through literature review and expert opinion. Next, experts were utilized to develop an ISM-based model and conduct MICMAC analysis. Secondly, the ISM model was developed across seven different levels using the above-identified 13 challenges. According to the ISM model, level 1 includes two challenges (supporting each other), namely; Lack of appropriate regulations for guiding transactions and smart contracts (Ch1) and lack of standards (Ch11). This suggests that it is essential to define standards for BCT and appropriate regulations. The major concern of the country is the lack of clarity in the regulatory norms. The government needs to define a standardized framework for BCT transaction and information storage taking into account the nature of BCT. The legislative framework should be able to deal with that there is no single entity/central authority being responsible for each distributed ledger, include policies for recourse since transactions in blockchain are immutable and tamper-proof, ensure validity of smart contracts, assets registered and reports generated by blockchain. This finding is confirmed by the work of Aras and Kulkarni (2017), found that regulation for smart contracts is the key foundation for BCT.

Further, level 2 includes two challenges supporting each other, namely, transforming organizational network structure and the role of the trusted middleman (inter-organizational change) (Ch2) and organizational transformation to benefit from BCT applications (organizational change) (Ch6). Once the regulations are appropriately formed; the next step is to transform the organizational network structure and organizational transformation. Li *et al.* (2018) reported that without organizational transformations, the benefits of BCT applications cannot be accomplished. The government needs to ensure that only the authorized and interested parties should have access to the appropriate data.

Later, the level 3 includes two challenges (supporting each other), namely, Creating (inter-organizational) governance of BCT applications (Ch3) and lack of understanding and expertise (Ch12). The existence of governance and a clear understanding of BCT are very significant to adopt BCT. Haddud *et al.* (2017) and Janssen *et al.* (2020) argued in their respective studies that the pathway to BCT adoption remains blocked unless the necessary governance is created and expertise is developed. The government needs to provide training and consultancy services for enhancing the knowledge and expertise to advance implementation of BCT.

Level 4 includes one challenge, e.g. resistance to change (Ch13). Government employees typically resist to change, which hinders the adoption of new technologies (Feng *et al.*, 2020). With the government support providing the platform and necessary directions, the onus is on the organizations to build the blockchain framework and implement to create solution for the future.

Level 5 includes three challenges (supporting each other), e.g. developing the information sharing and transaction arrangements (Ch4), creation of shared operating platform and partnerships (Ch5) and high costs (Ch9). This finding is confirmed by Lu (2019), who argues that once the employees accept the change, then it becomes easier to develop information sharing and transaction arrangements and the creation of shared operating platforms to facilitate BCT adoption.

Level 6 includes only one challenge; developing a value proposition and value creation mechanisms (Ch7). After the development of a shared operating platform and computation of adoption costs, the most essential is to develop a value proposition and value creation mechanisms to extract maximum benefits out of BCT (Perera *et al.*, 2020). Level 3 includes two challenges, namely ensuring public values like privacy, data protection, equal access, security and trust (Ch8) and realizing the desired system quality (speed, scalability, flexibility and security) (Ch10). As the final output it can be considered that after developing the value creation mechanisms, it is necessary to ensure the public values and realize the desired system quality (Gupta *et al.*, 2018).

A MICMAC analysis was conducted to compute the driving and dependence power of BCT implementation challenges. The analysis helped to capture a cluster diagram where all the selected BCT implementation challenges were spread across four different quadrants namely autonomous, dependent, linkage and independent. Among the selected BCT implementation challenges, no challenge falls under the autonomous quadrant. There are six challenges that belong to the dependent quadrant, which includes – "Developing the information sharing and transactions arrangements (Ch4)", "Creation of shared operating platform and partnerships (Ch5)", "High costs (Ch9)", "Developing a value proposition and value creation mechanisms (Ch7)" "Ensuring public values like privacy, data protection, equal access, security and trust (Ch8)" and "Realizing the desired system quality (speed, scalability, flexibility, security) (Ch10)". These challenges are also equally important to be focused due to their strong dependence on other challenges. Therefore, managers should not only remove the dependent set of challenges, but need to focus on all challenges to realize BCT applications in governments successfully.

The only challenge that belongs to the linkage quadrant is. "Resistance to change (Ch13)". This challenge is relatively less stable in nature, and therefore, policymakers' need to be monitored continuously at each stage in realizing BCT applications in governments. There are six challenges that belong to independent quadrant, which includes – "Creating (inter-organizational) governance of BCT applications (Ch3)", "Lack of understanding and expertise (Ch12)", "Transforming organizational networks structure and the role of trusted middleman (inter-organizational change) (Ch2)", "Organizational transformation to benefit from BCT applications (organizational change) (Ch6)", "Lack of appropriate regulations for guiding transactions and smart contracts (Ch1)" and "Lack of standards (Ch11)". Government organizations need to address these independent set of challenges in accomplishing the required objectives. Challenges with higher driving power can easily be influenced by other challenges as well, and hence policy-makers and practitioners should address these types of challenges with high priority (Huckle *et al.*, 2016).

5.1 Theoretical contributions

Several studies in literature captured the generalized applications of BCT and adoption (e.g. Aras and Kulkarni, 2017; Haddud *et al.*, 2017; Li *et al.*, 2018) but, none highlight the government-specific implementation challenges. Janssen *et al.* (2020) has proposed a framework for analyzing the adoption of BCT and mapped the adoption challenges for financial organization. The authors have drawn primarily to the need to take institutional and market aspects into account, but this is a conceptual framework without empirical grounding, focused on private organizations and focused on adoption and not on implementation. There are no markets, but BCT needs to be arranged in organizational networks in government. The present study encompasses 13 unique challenges from the government perspective that restricts BCT implementation. This is the first study to make an overview for government implementation challenges and to capture the inter-relationship among the identified challenges. Furthermore, the ISM method used to develop the hierarchical structure for BCT implementation can serve as a ready reference for researchers, who can then apply it in their own research. The relationship between each challenge and the developed structure forms a strong theoretical foundation for future researchers. Researchers can use this structure to conduct additional research in order to overcome individual challenges and increase BCT adoption. The presented work also demonstrates the need for additional research in this domain and may attract more researchers to work in this domain in order to overcome these challenges and increase BCT implementation in government organizations.

5.2 Managerial implications

The following implications may be relevant for the government officials involved in making managerial decisions related to BCT adoption. (1) The study identifies 13 unique BCT challenges that obstruct its adoption process. The managers involved in the implementation process can focus on these challenges initially and develop the overcoming strategies accordingly. Furthermore, the identified challenges can assist government organizations in preparing budgets because managers can predict expenditures to some extent. (2)Not all challenges can be overcome simultaneously, but the driving and dependence power of the BCT implementation challenges computed in this study builds a roadmap for overcoming the BCT challenges. (3) The structural hierarchy developed through ISM-based model will help the managers in developing their roadmap or framework for BCT adoption process. Accordingly, they will be aware of all the challenges that might occur across each level. This can assist in the step-by-step implementation of BCT and the prediction of challenges at each stage of implementation. (4) This study will help policy-makers to assess the feasibility and need of application to create the benefits of BCT. The developed structure can serve as a motivation tool for policymakers in the implementation of BCT. (5) The BCT challenges specifically for government organizations are addressed in this study, which helps them to develop a specific approach for implementing BCT.

6. Conclusions, limitations and future research

For conducting transactions over a network, BCT has been considered as the main technological innovation. Both government and private organizations have started to use BCT applications across their system. Although BCT applications promise to have many benefits, the actual implementation of BCT across the government organization lags behind. The current study contributes in this direction and addresses the most critical challenges that restrict BCT adoption across government organizations. Initially, through extensive literature review and experts' opinion the 13 most critical challenges were extracted. Expert inputs were sought to develop an ISM-based model and conduct a MICMAC analysis. A structural hierarchy, including the BCT implementation challenges, was developed across seven levels indicating the relationship between each BCT implementation challenge. Lack of standards and appropriate regulations for guiding transactions and smart contracts are at the bottom of the hierarchy, which suggests that these challenges are foundational to be addressed before BCT implementation. It is extremely difficult to develop any viable BCT project without having addressed these two foundational challenges. In contrast ensuring public values like privacy, data protection equal access, security and trust and realizing the desired system quality are positioned at the top of the hierarchy. They can be viewed as already close to the objectives of the BCT project, in which the system quality is improved, and public values are realized by addressing the ethical issues. In between are the challenges dealing with organizational and network transformation, developing expertise and creating an effective governance model. The creation of a standardized shared BT infrastructure based on standards will reduce costs and can facilitate the easy development and realization of transaction arrangements.

The ISM-based model provides a roadmap for addressing these challenges, which will eventually help BCT adoption. The challenges at the lower level of the structural hierarchy hold strong driving power, whereas the challenges found on the upper levels are the challenges with strong dependence power. Similarly, resistance to change is observed in the linkage quadrant; hence, it holds moderate driving and dependence power.

The outcomes of this study guide new directions for the governments to adopt BCT within their system. The structural model developed by applying ISM approach will help the government officials in developing the strategies and improving BCT adoption. However, the present study includes only 13 critical challenges that hinder BCT adoption across the government. The researchers can extend the present study by enhancing the number of challenges influencing BCT adoption. Furthermore, a comparative study by using the same set of challenges and different structural mapping approaches can be developed to generalize the findings. The researchers working in the domain of BCT are further encouraged to conduct a large-scale survey of government organizations with more number of experts to find better insights and other critical challenges faced by the Government employees.

References

Ali, O., Shrestha, A., Chatfield, A. and Murray, P. (2020), "Assessing information security risks in the cloud: a case study of Australian local government authorities", *Government Information Quarterly*, Vol. 37 No. 1, 101419.

Aras, S.T. and Kulkarni, V. (2017), "Blockchain and its applications–A detailed survey", *International Journal of Computer Applications*, Vol. 180 No. 3, pp. 29-35.

Ayed, A.B. (2017), "A conceptual secure blockchain-based electronic voting system", *International Journal of Network Security and Its Applications*, Vol. 9 No. 3, pp. 1-9.

Banerjee, M., Lee, J. and Choo, K.K.R. (2018), "A blockchain future for internet of things security: a position paper", *Digital Communications and Networks*, Vol. 4 No. 3, pp. 149-160.

Chen, G., Xu, B., Lu, M. and Chen, N.S. (2018), "Exploring blockchain technology and its potential applications for education", *Smart Learning Environments*, Vol. 5 No. 1, p. 1.

Chen, J., Lv, Z. and Song, H. (2019), "Design of personnel big data management system based on blockchain", *Future Generation Computer Systems*, Vol. 101, pp. 1122-1129.

Choi, T.M. and Luo, S. (2019), "Data quality challenges for sustainable fashion supply chain operations in emerging markets: roles of blockchain, government sponsors and environment taxes", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 131, pp. 139-152.

Duperrin, J.C. and Godet, M. (1973), *Method of Hierarchizing the Elements of a System*, CEA Economic Report, Paris, pp. 45-51.

Ertz, M. and Boily, É. (2019), "The rise of the digital economy: thoughts on blockchain technology and cryptocurrencies for the collaborative economy", *International Journal of Innovation Studies*, Vol. 3 No. 4, pp. 84-93.

Feng, H., Wang, X., Duan, Y., Zhang, J. and Zhang, X. (2020), "Applying blockchain technology to improve agri-food traceability: a review of development methods, benefits and challenges", *Journal of Cleaner Production*, Vol. 260, 121031.

Francisco, K. and Swanson, D. (2018), "The supply chain has no clothes: technology adoption of blockchain for supply chain transparency", *Logistics*, Vol. 2 No. 1, p. 2, doi: 10.3390/logistics2010002.

Frizzo-Barker, J., Chow-White, P.A., Adams, P.R., Mentanko, J., Ha, D. and Green, S. (2019), "Blockchain as a disruptive technology for business: a systematic review", *International Journal of Information Management*, Vol. 51, 102029, April 2020.

Gao, Z., Xu, L., Chen, L., Zhao, X., Lu, Y. and Shi, W. (2018), "Coc: a unified distributed ledger based supply chain management system", *Journal of Computer Science and Technology*, Vol. 33 No. 2, pp. 237-248.

Govindan, K., Cheng, T.C.E., Mishra, N. and Shukla, N. (2018), "Big data analytics and application for logistics and supply chain management", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 114, pp. 343-349.

Goyal, S., Luthra, S. and Garg, D. (2022), "Shifting systematically towards sustainable consumption and production: a solution framework to overcome the impacts of covid-19", *International Journal of Information Technology and Decision Making*, Vol. 21 No. 3, pp. 933-968.

Gozman, D., Liebenau, J. and Aste, T. (2020), "A case study of using blockchain technology in regulatory technology", *MIS Quarterly Executive*, Vol. 19 No. 1, pp. 19-37.

Gupta, A., Patel, J., Gupta, M. and Gupta, H. (2018), "Issues and effectiveness of blockchain technology on digital voting", *Investopedia, Smart Contracts*, available at: https://www.investopedia.com/terms/s/smart-contracts.asp (accessed 12 Apr 2018).

Hackius, N. and Petersen, M. (2017), "Blockchain in logistics and supply chain: trick or treat?", *Digitalization in Supply Chain Management and Logistics: Smart and Digital Solutions for an Industry 4.0 Environment. Proceedings of the Hamburg International Conference of Logistics (HICL)*, Berlin, Vol. 23, Epubli GmbH, pp. 3-18.

Haddud, A., DeSouza, A.R., Khare, A. and Lee, H. (2017), "Examining potential benefits and challenges associated with the Internet of Things integration in supply chains", *Journal of Manufacturing Technology Management*, Vol. 28 No. 8, pp. 1055-1085.

Hou, J., Wang, H. and Liu, P. (2018), "Applying the blockchain technology to promote the development of distributed photovoltaic in China", *International Journal of Energy Research*, Vol. 42 No. 6, pp. 2050-2069.

Huckle, S., Bhattacharya, R., White, M. and Beloff, N. (2016), "Internet of things, blockchain and shared economy applications", *Procedia Computer Science*, Vol. 98, pp. 461-466.

Hughes, L., Dwivedi, Y.K., Misra, S.K., Rana, N.P., Raghavan, V. and Akella, V. (2019), "Blockchain research, practice and policy: applications, benefits, limitations, emerging research themes and research agenda", *International Journal of Information Management*, Vol. 49, pp. 114-129.

Janssen, M., Luthra, S., Mangla, S., Rana, N.P. and Dwivedi, Y.K. (2019), "Challenges for adopting and implementing IoT in smart cities", *Internet Research*, Vol. 29 No. 6, pp. 1589-1616.

Janssen, M., Weerakkody, V., Ismagilova, E., Sivarajah, U. and Irani, Z. (2020), "A framework for analysing blockchain technology adoption: integrating institutional, market and technical factors", *International Journal of Information Management*, Vol. 50, pp. 302-309.

Jesus, E.F., Chicarino, V.R., De Albuquerque, C.V. and Rocha, A.A.D.A. (2018), "A survey of how to use blockchain to secure internet of things and the stalker attack", *Security and Communication Networks*, Vol. 2018, 9675050.

Kapse, C.P., Kumar, A., Dash, M.K., Zavadskas, E.K. and Luthra, S. (2018), "Developing textile entrepreneurial inclination model by integrating experts mining and ISM-MICMAC", *International Journal of Production Research*, Vol. 56 No. 14, pp. 4709-4728.

Khan, F.A., Asif, M., Ahmad, A., Alharbi, M. and Aljuaid, H. (2020), "Blockchain technology, improvement suggestions, security challenges on smart grid and its application in healthcare for sustainable development", *Sustainable Cities and Society*, Vol. 55, 102018.

Kim, K. and Kang, T. (2017), "Does technology against corruption always lead to benefit? The potential risks and challenges of the blockchain technology", in *Paper Submitted to OECD's Anti-corruption and Integrity Forum*, available at: https://www.oecd.org/cleangovbiz/Integrity-Forum-2017-Kim-Kang-blockchain-technology.pdf.

Kshetri, N. (2018), "1 Blockchain's roles in meeting key supply chain management objectives", *International Journal of Information Management*, Vol. 39, pp. 80-89.

Lacity, M.C. (2018), "Addressing key challenges to making enterprise blockchain applications a reality", *MIS Quarterly Executive*, Vol. 17 No. 3, pp. 201-222.

Lacity, M. and Van Hoek, R. (2021), "What we've learned so far about blockchain for business", *MIT Sloan Management Review*, Vol. 62 No. 3, pp. 48-54.

Li, X., Jiang, P., Chen, T., Luo, X. and Wen, Q. (2017), "A survey on the security of blockchain systems", *Future Generation Computer Systems*, Vol. 107, pp. 841-853.

Li, Z., Wang, W.M., Liu, G., Liu, L., He, J. and Huang, G.Q. (2018), "Toward open manufacturing", *Industrial Management and Data Systems*, Vol. 118 No. 1, pp. 303-320.

Lin, I.C. and Liao, T.C. (2017), "A survey of blockchain security issues and challenges", *International Journal of Network Security*, Vol. 19 No. 5, pp. 653-659.

Lu, Y. (2019), "The blockchain: state-of-the-art and research challenges", *Journal of Industrial Information Integration*, Vol. 15, pp. 80-90, doi: 10.1016/j.jii.2019.04.002.

Luthra, S. and Mangla, S.K. (2018), "When strategies matter: adoption of sustainable supply chain management practices in an emerging economy's context", *Resources, Conservation and Recycling*, Vol. 138, pp. 194-206.

Mangla, S.K., Govindan, K. and Luthra, S. (2017), "Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process", *Journal of Cleaner Production*, Vol. 151, pp. 509-525.

Mangla, S.K., Luthra, S., Mishra, N., Singh, A., Rana, N.P., Dora, M. and Dwivedi, Y. (2018), "Barriers to effective circular supply chain management in a developing country context", *Production Planning and Control*, Vol. 29 No. 6, pp. 551-569.

Ølnes, S., Ubacht, J. and Janssen, M. (2017), "Blockchain in government: benefits and implications of distributed ledger technology for information sharing", *Government Information Quarterly*, Vol. 34 No. 3, pp. 355-364.

Pan, S., Ballot, E., Huang, G.Q. and Montreuil, B. (2017), "Physical Internet and interconnected logistics services: research and applications", *International Journal of Production Research*, Vol. 55 No. 9, pp. 2603-2609.

Pedersen, A.B., Risius, M. and Beck, R. (2019), "A ten-step decision path to determine when to use blockchain technologies", *MIS Quarterly Executive*, Vol. 18 No. 2, p. 3.

Perera, S., Nanayakkara, S., Rodrigo, M.N.N., Senaratne, S. and Weinand, R. (2020), "Blockchain technology: is it hype or real in the construction industry?", *Journal of Industrial Information Integration*, Vol. 17, p. 100125, doi: 10.1016/j.jii.2020.100125.

Presthus, W. and O'Malley, N.O. (2017), "Motivations and barriers for end-user adoption of bitcoin as digital currency", *Procedia Computer Science*, Vol. 121, pp. 89-97.

Queiroz, M.M. and Wamba, S.F. (2019), "Blockchain adoption challenges in supply chain: an empirical investigation of the main drivers in India and the USA", *International Journal of Information Management*, Vol. 46, pp. 70-82.

Rana, N.P., Luthra, S. and Rao, H.R. (2019), "Key challenges to digital financial services in emerging economies: the Indian context", *Information Technology and People*, Vol. 33 No. 1, pp. 198-229.

Saberi, S., Kouhizadeh, M. and Sarkis, J. (2018), "Blockchain technology: a panacea or pariah for resources conservation and recycling?", *Resources, Conservation and Recycling*, Vol. 130, pp. 80-81.

Scholl, H.J. and Bolívar, M.P.R. (2019), "Regulation as both enabler of technology use and global competitive tool: the Gibraltar case", *Government Information Quarterly*, Vol. 36 No. 3, pp. 601-613.

Tapscott, D. and Tapscott, A. (2017), "How blockchain will change organizations", *MIT Sloan Management Review*, Vol. 58 No. 2, p. 10.

Thakur, V., Doja, M.N., Dwivedi, Y.K., Ahmad, T. and Khadanga, G. (2020), "Land records on blockchain for implementation of land titling in India", *International Journal of Information Management*, Vol. 52, 101940.

Tiwari, S., Wee, H.M. and Daryanto, Y. (2018), "Big data analytics in supply chain management between 2010 and 2016: insights to industries", *Computers and Industrial Engineering*, Vol. 115, pp. 319-330.

Turk, Ž. and Klinc, R. (2017), "Potentials of blockchain technology for construction management", *Procedia Engineering*, Vol. 196, pp. 638-645.

Vishwakarma, P., Khan, Z. and Jain, T. (2018), "A brief study on the advantages of blockchain and distributed ledger in financial transaction processing", *International Journal of Latest Technology in Engineering, Management and Applied Science*, Vol. 7, pp. 76-79.

Vojdani, N., Lootz, F. and Rösner, R. (2013), "Optimizing empty container logistics based on a collaborative network approach", *Maritime Economics and Logistics*, Vol. 15 No. 4, pp. 467-493.

Walsh, C., O'Reilly, P., Gleasure, R., McAvoy, J. and O'Leary, K. (2020), "Understanding manager resistance to blockchain systems", *European Management Journal*, Vol. 39 No. 3, pp. 353-365, doi: 10.1016/j.emj.2020.10.001.

Wang, Q., Zhu, X., Ni, Y., Gu, L. and Zhu, H. (2020), "Blockchain for the IoT and industrial IoT: a review", *Internet of Things*, Vol. 10, 100081.

Warfield, J.N. (1974), "Developing interconnection matrices in structural modeling", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 1 No. 1, pp. 81-87.

Warkentin, M. and Orgeron, C. (2020), "Using the security triad to assess blockchain technology in public sector applications", *International Journal of Information Management*, Vol. 52, 102090.

Woodside, J.M., Augustine, F.K. Jr and Giberson, W. (2017), "Blockchain technology adoption status and strategies", *Journal of International Technology and Information Management*, Vol. 26 No. 2, pp. 65-93.

Yadav, G. and Desai, T.N. (2017), "Analyzing lean six sigma enablers: a hybrid ISM-fuzzy MICMAC approach", *The TQM Journal*, Vol. 29 No. 3, pp. 488-511.

Yadav, G., Mangla, S.K., Luthra, S. and Rai, D.P. (2019), "Developing a sustainable smart city framework for developing economies: an Indian context", *Sustainable Cities and Society*, Vol. 47, 101462.

Yadav, G., Luthra, S., Huisingh, D., Mangla, S.K., Narkhede, B.E. and Liu, Y. (2020), "Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies", *Journal of Cleaner Production*, Vol. 245, 118726.

Ying, W., Jia, S. and Du, W. (2018), "Digital enablement of blockchain: evidence from HNA group", *International Journal of Information Management*, Vol. 39, pp. 1-4.

Yoo, S. (2017), "Blockchain based financial case analysis and its implications", *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 11 No. 3, pp. 312-321.

Zambrano, R., Seward, R.K. and Sayo, P. (2017), "Unpacking the disruptive potential of blockchain technology for human development", *International Development Research Centre*, p. 85, available at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56662/IDL-56662.pdf.

Further reading

Bindu, N., Sankar, C.P. and Kumar, K.S. (2019), "From conventional governance to e-democracy: tracing the evolution of e-governance research trends using network analysis tools", *Government Information Quarterly*, Vol. 36 No. 3, pp. 385-399.

MacDonald, T.J., Allen, D.W. and Potts, J. (2016), "Blockchains and the boundaries of self-organized economies: predictions for the future of banking", in *Banking beyond Banks and Money*, Springer, Cham, pp. 279-296.

Pilkington, M. (2016), "Blockchain technology: principles and applications", in *Research Handbook on Digital Transformations*, Edward Elgar Publishing.

Scholta, H., Mertens, W., Kowalkiewicz, M. and Becker, J. (2019), "From one-stop shop to no-stop shop: an e-government stage model", *Government Information Quarterly*, Vol. 36 No. 1, pp. 11-26.

White, G.R. (2017), "Future applications of blockchain in business and management: a Delphi study", *Strategic Change*, Vol. 26 No. 5, pp. 439-451.

Witthaut, M., Deeken, H., Sprenger, P., Gadzhanov, P. and David, M. (2017), "Smart objects and smart finance for supply chain management", *Logistics Journal: Referierte Veröffentlichungen*, Vol. 2017 No. 10, pp. 1-10.

Corresponding author
Nripendra P. Rana can be contacted at: nrananp@gmail.com