Blockchain technology implementation challenges in supply chains – evidence from the case studies of multi-stakeholders

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Abstract

Purpose – The aim of the research is to identify and prioritise the implementation challenges of blockchain technology and suggests ways for its implementation in supply chains.

Design/methodology/approach – Underlined by the technology, organisational, and external environment model, a conceptual framework with four challenge categories and sixteen challenges is proposed. Data collected from three stakeholder groups with experience in the implementation of blockchain technology in India is analysed by employing an analytical hierarchy process method-based case study. Further, a criticality–effort matrix analysis is performed to group challenges and suggest ways for implementation.

Findings – The analysis revels that all stakeholders perceive complexity challenge associated with the technology, organisational structure, and external environment, and issues of compatibility with existing systems, software, and business practices to be high on the criticality and effort scales, which thus require meticulous planning to manage. Likewise, top-management support issues related to insufficient understanding of how technology fits with the organisation's policy and benefits offered by the technology requires high effort to address this challenge.

Research limitations/implications – The results were obtained by focusing on the Indian context and therefore may not apply to other nations' contexts.

Practical implications – By investigating the challenges that the developers, consultants, and client organisations need to address, this study assists managers in developing plans to facilitate coordination among these organisations for successful blockchain implementation.

Originality/value – To the authors' knowledge this study is the first to identify and prioritise the challenges from the perspectives of multiple stakeholder groups with experience in blockchain technology implementation.

Keywords Blockchain, Analytical hierarchy process (AHP), Technology, Organisation, And environment framework (TOE), Case study, Supply chain management

Paper type Research paper

1. Introduction

Blockchain refers to a ledger of data transactions recorded on a distributed database and shared with a network of independent participants (Perdana *et al.*, 2021). Because data are recorded on a decentralised system that participants cannot control, it ensures that no one owns the system (Upadhyay, 2020). Blockchain data records are referred to as blocks, and these are connected in a chain using the crypto-analytic hash function. The hash function

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used to validate the transactions on blocks prevents alterations to recorded data (Wang *et al.*, 2019a). The ability of a block to remain unchanged and unaltered is referred to as immutability. The decentralisation and immutability properties of the technology can revolutionise business operations because these allow the sharing of agreed information that cannot be altered by partner organisations in supply chains (Gurtu and Johny, 2019; Kshetri, 2021). These characteristics of the technology can extend its application to building trusting relationships between the organisations in supply chains (Queiroz and Wamba, 2019).

Further, the smart contract feature of blockchain technology is a computer protocol that facilitates the verification and enforcement of the negotiated terms of a contract without the need for third-party intervention (Upadhyay, 2020). The protocols of a smart contract can validate various transactions, such as payment processing or asset verification (Cole *et al.*, 2019). By ensuring that all participants are obeying the rules, smart contracts instil confidence among supply chain members. Moreover, the recent development of a permissioned blockchain that limits data access to participants who have an invitation or the permission to join the network has offered much-needed data privacy to supply chain members (Nandi *et al.*, 2020; Wong *et al.*, 2020b). Besides, implementing blockchain technology in supply chains leads to improved efficiency in forecasting demand, managing inventory, tracing the product origin, and managing the supply chain finance process (Hald and Kinra, 2019). Hence, organisations are increasingly seeking ways to adopt this technology in supply chains (Perdana *et al.*, 2021).

Most well-known blockchain technology applications in supply chains are for the traceability of products ranging from essential food items to luxury diamonds, which is aimed at promoting consumer confidence (Gurtu and Johny, 2019). Similarly, blockchain-based supply chains can detect counterfeits in product categories ranging from consumer products of less public concern to medicines, a serious public health concern that endangers lives (Gaur, 2020). In the transport and logistics industry, using blockchain technology to digitise and transfer key trade documents, such as the bill of lading and customs documents, can improve process efficiency and increase global trade by 15% through minimising the barriers to trade (DHL, 2019).

Despite the benefits of blockchain technology when implemented in supply chains, its implementation is confined to the proof-of-concept stage (Cole *et al.*, 2019), with limited mainstream adoption in supply chains. In a global survey, 28% of executives rated a low level of understanding of this technology as a major barrier to its implementation (Deloitte, 2019). Moreover, practitioners with some understanding indicated that the lack of knowledge on implementation factors hinders their technology uptake (Gaur, 2020). Saberi *et al.* (2019) and Kouhizadeh *et al.* (2021) highlighted that the successful implementation of this technology begins with identifying related challenges. Therefore, to promote blockchain diffusion in supply chains, it is necessary to ascertain the value expected to be created and the implementation strategies required to materialise its value. Hence, a significant research area is an identification, prioritisation, and development of strategies for implementing blockchain technology.

Academic literature on blockchain implementation in supply chains has started appearing from 2015 with many conference papers at the start followed by few journal articles (Wang *et al.*, 2019a). Hald and Kinra (2019), Saberi *et al.* (2019), and Tokkozhina *et al.* (2022) identified blockchain technology implementation challenges through literature synthesis and highlighted the need for empirical research to examine these challenges. Accordingly, Queiroz and Wamba (2019), Wang *et al.* (2019a, b), Wong *et al.* (2020b), and Kouhizadeh *et al.* (2021) investigated the blockchain implementation challenges in India, Europe, Indonesia, Malaysia, and United States. These studies have identified complexity, lack of financial resources, lack of management support, trust, and privacy as the blockchain implementation challenges. These studies use data collected from the logistics practitioners and academics who are familiar with the technology but lack experience in implementing it. Their lack of experience raises concern about their ability to evaluate the implementation of this technology. Also, the empirical research examining real cases to investigate blockchain implementation challenges is limited warranting future research. Our study is different from various perspectives, including the scope, the methodology, the survey sample and the analysis. Particularly, this study collects the responses from the multiple stakeholders who are not only knowledgeable but also involved in the blockchain implementation. We address the objective through analytics hierarchy process (AHP)-based case study using both qualitative and quantitative data collected from various stakeholders, such as consultants, developers, and clients, who are experienced in implementing blockchain technology. The case study approach used in this study is considered appropriate as it elaborates the understanding of challenges influencing blockchain technology implementation in supply chains in Indian context (Shah and Corley, 2006; Ketokivi and Choi, 2014). Moreover, conducting a case study is regarded as a suitable method to explore the complex phenomena surrounding the implementation of disruptive blockchain technology (Yin, 2003).

The present study contributes to the literature in two ways. First, this is the first such study to prioritise challenges in implementing blockchain technology in supply chains. Prioritising the identified challenges would assist in developing strategies that promote the implementation of blockchain technology. Second, the study compares the perspectives of multiple stakeholders who have adequate experience in implementing this technology. Such comparisons are critical for understanding and addressing the differences between stakeholder preferences as they join the consortium and collaborate for implementing blockchain technology.

The remainder of the paper is organised as follows. We propose a conceptual framework in section 2 through a review of the literature on technology implementation in supply chains. We discuss the research methodology to identify critical challenges in section 3. We present the study results and related analysis in section 4 and discuss these results and their implications in section 5 and 6 respectively. We conclude the paper in section 7 by discussing the limitations of this study and future research areas.

2. Background

2.1 Blockchain technology

Based on the developments and their applications, the evolution of blockchain technology can be divided into three phases. In Phase 1, blockchain is mainly used as a cryptocurrency in applications related to currency transfer, remittance, and digital payments.

In Phase 2, businesses have realised decentralized ledger an underlying principle of blockchain technology can be separated from the cryptocurrency application and used for inter-organisational collaboration. The development of decentralised applications (DApp) is considered as the major aspect of blockchain evolution in Phase 2.

Advancement in Phase 3 of blockchain technology evolution can be seen in automating the validation process of data recording through the internet of Things (IoT) ecosystem. Integration of IoT into blockchain creates a “de facto standardized Ledger of Everything” that brings the highest degree of accountability with no more human errors and missed transactions (Pournader *et al.*, 2020). Overall, blockchain technology has evolved from being used as a digital currency application towards a wider decentralised application with the ability of automation in transaction validation.

2.2 Literature on blockchain in supply chains

Limited academic literature available on blockchain technology in supply chains can be summarised into two categories. First category of papers examines the application of blockchain technology in supply chain domains, while the second category identifies the drivers and challenges of blockchain implementation in supply chains. We discuss these two categories of papers in the following sections.

2.2.1 Blockchain application in supply chain domains. The current application of blockchain technology in supply chains falls within three broad supply chain domains such as sourcing (buy), logistics, and finance A summary of these studies is provided in (see Table 1) and discussed below.

Buy (sourcing) function referred to as procurement plays an important role in identifying and managing the intra- and inter-organisational issues which impact supply chain resilience. The use of blockchain technology to trace the product origins assists in making sure the products are from conflict-free sources and thus promoting trust among the supply chain members (Kshetri, 2021). Moreover, the distributor ledger concept behind the blockchain technology is much like a stock ledger with the information on the purchase orders, inventory levels, goods received, shipping manifests, and invoices that can be accessed by all the supply chain members instantaneously promoting data visibility among the members (Cole *et al.*, 2019). Overall, the availability of accurate demand forecast information also assists in managing resources effectively and reduces inventory carrying costs which facilitate the implementation of process improvement tools such as lean and six-sigma in supply chains (Kamble *et al.*, 2019).

Logistics assists in the management and coordination of freight transport, storage, inventory management, materials handling, and information processing activities. Greater dependency on logistics services for the distribution of products from sourcing to consumption through production in global supply chains has made the logistics industry to play a critical role in efficient supply chains (Kamble *et al.*, 2019). For seamless information flows between logistics service providers and supply chain members, the resources used for the distribution of products such as vehicles and handling equipment should be integrated with technologies such as GPS, sensors, IoT devices, or automatic image-recognition software that provides the live information to blockchain distributed database (Vivaldini, 2021). Once such integration has been achieved, the permanent nature of blockchain will ensure that data cannot be modified at any time in the future. Moreover, the technology also enhances the customer experience by enabling them to trace and track the product live (Wang *et al.*, 2019a).

Supply chain finance became crucial after the global financial crisis due to the less credit availability and higher borrowing costs. To optimise financial flows in supply chains, organisations are aligning financial flows with product and information flows through technology. Smart contracts of blockchain technology facilitate supply chain finance through matching and verifying the recorded data against the agreement and trigger payment which

Supply chain function	Role of blockchain technology	Source
Buy	Blockchain technology helps the organizations in accurate demand forecasts, manage resources effectively and reduce inventory carrying costs because of its ability to create records of activities	Cole *et al.* (2019), Kamble *et al.* (2019), Caldarelli *et al.* (2021)
Logistics	Blockchain technology assists in tracking and monitoring cargo along the supply chain. In adverse condition, this technology can help to efficiently pinpoint the source and diagnose the root cause of a serious problem	Hald and Kinra (2019), Kamble *et al.* (2019), Wang *et al.* (2019a), Vivaldini (2021)
Finance	Smart contracts of blockchain technology assist in automatically triggering payments after validation of the pre-set terms	Babich and Hilary (2020), Chang *et al.*, (2012), Wang *et al.* (2019a), Upadhyay (2020)

Table 1.
Role of blockchain technology in supply chain function

may or may not be in bitcoin or another cryptocurrency (Babich and Hilary, 2020). It can autonomously trigger other transactions when key milestones are met, such as goods being issued (creating a shipment), pickup confirmed (activating a sensor), or proof of delivery (issuing an invoice). The automation of initiating purchase orders or invoices without the use of spreadsheets or manual interference speed up the transactions and minimises the costs and time associated with intermediation (Cole *et al.*, 2019).

In spite of the benefits, blockchain technology adoption in supply chains is relatively slow and very much limited to pilot studies (Kouhizadeh *et al.*, 2021). Identifying and addressing the challenges that impede blockchain implementation became an important topic for investigation (Caldarelli *et al.*, 2021). Following provides the literature on drivers and challenges of blockchain implementation in supply chains.

2.2.2 Drivers and challenges of blockchain implementation in supply chains. Literature on blockchain implementation in supply chains can be classified into two streams. First stream of literature focuses on investigating the factors driving the implementation of blockchain technology in supply chain (see for example: Kamble *et al.*, 2019; Queiroz and Wamba, 2019; Wong *et al.*, 2020a). Kamble *et al.* (2019) identified the perceived usefulness of the technology and attitude of the users as the factors affecting the intention to implement blockchain technology among supply chains operating in India. Meanwhile, Queiroz and Wamba (2019) study highlighted distinct blockchain adoption behaviours between India-based and USA-based professionals. Wong *et al.* (2020a) identified facilitating conditions, technology readiness of the firm, and technology affinity as the factors influencing the managerial intention to implement blockchain technology among the SMEs in Malaysia. In the context of Brazil, Queiroz *et al.* (2021) recognised effort expectancy, facilitating conditions, trust and social influence as the factors impacting the intention to implement blockchain technology in supply chains.

Second stream of literature emphasises on examining the challenges impacting the blockchain implementation in supply chains. Casey and Wong (2017) highlighted the interoperability between different blockchains and the complexity of the rules and regulations that govern the implementation as the challenges impacting the blockchain implementation in supply chains. Through interviewing supply chain experts from multiple countries, Wang *et al.* (2019b) reported that complexity of the technology, high cost of implementation, lack of clear governance rules, and interoperability between two or more different blockchains and compatibility with other existing systems as the challenges of blockchain implementation. Wong *et al.* (2020b) in the context of Malaysia identified the pressure from competition in the market, complexity, financial resources, and relative sustainable advantage impact the implementation of blockchain technology. Meanwhile, Kouhizadeh *et al.* (2021) recognised lack of management commitment and support, lack of knowledge and expertise, lack of cooperation, coordination and information disclosure between supply chain members, lack of policies and industry involvement as the barriers. More recently, Caldarelli *et al.* (2021) identified scalability, implementation costs, and lack of standards as the challenges of blockchain implementation in apparel supply chains.

3. Blockchain implementation challenges: a conceptual framework

To understand the implementation of blockchain technology in supply chains, it is important to examine the factors influencing implementation decision-making, which is the objective of this study. Different technology adoption models and theories, such as the technology acceptance model, the theory of planned behaviour, the theory of reasoned action, the unified theory of acceptance and use of technology, the diffusion of innovation (DOI) theory, and the technological, organisational and environmental (TOE) model are used to understand factors facilitating the implementation of the technology (e.g. Chong and Ooi, 2008; Lin, 2014).

However, apart from the TOE framework and the DOI theory, all the other theories are individual-level theories that examine individual attitudes towards technology implementation. Therefore, they are not appropriate for examining technology implementation at the organisational level (Bradford *et al.*, 2014).

In the supply chain context, the TOE framework has been applied to study the implementation of various internet-based supply chains management technologies, such as e-business, e-commerce, information and communications technology, enterprise resource planning (ERP), electronic data interchange (EDI), radio frequency identification (RFID) and cloud computing (Low *et al.*, 2011; Chan *et al.*, 2012). More recently, researchers have used the TOE framework to examine the factors impacting blockchain technology adoption (Saberi *et al.*, 2019; Caldarelli *et al.*, 2021; Kouhizadeh *et al.*, 2021). In line with the previous studies, the TOE framework is used as an underlying theory in this study.

The TOE framework presents the technology, the organisation, and the external environment as the three factors that influence firms' decision-making of adopting and implementing innovations. Traditional TOE models have focused at the organisational level and excluded inter-organisational relationship aspects such as the position of the firm in supply chains, trust amongst the supply chain partners, and collaboration between the firms (Chan *et al.*, 2012). Chong and Ooi (2008) have identified the inter-organisational relationship as a crucial factor influencing the technology adoption between organisations. Table 2 presents the literature using the TOE framework to investigate technology adoptions in supply chains. In the context of blockchain technology in supply chains, challenges related to interorganisational aspects need to be addressed for successful technology implementation (Saberi *et al.*, 2019). The theory elaboration approach considered in this study allows to add more variables to the existing framework (Ketokivi and Choi, 2014). Similar to Chong and Ooi (2008), Huang *et al.* (2008), Chan *et al.* (2012), and Kouhizadeh *et al.* (2021) this study considers the technology, organisational, external environment and interorganisational categories as the challenge categories of blockchain technology implementation in the supply chains.

3.1 Technology challenge category

A review of the recent adoption models reveals that the Roger's (1995) DOI theory is used to identify the technology-related factors affecting the innovation adoption rate. In our study, DOI is used to provide a theoretical explanation of the technological challenges of the TOE

Source	Context	Technology	Organizational	External environment	Intra-organizational
Chong and Ooi (2008)	RosettaNet standards	☑			☑
Huang *et al.* (2008)	EDI adoption	☑	☑	☑	☑
Low *et al.* (2011)	Cloud computing	☑	☑	☑	
Chan *et al.* (2012)	e-collaboration	☑	☑	☑	☑
Lin (2014)	e-SCM	☑	☑	☑	
Saberi *et al.* (2019)	Blockchain adoption	☑	☑	☑	
Caldarelli *et al.* (2021)	Blockchain adoption	☑	☑	☑	☑
Kouhizadeh *et al.* (2021)	Blockchain adoption	☑	☑	☑	☑

Table 2. Literature used TOE framework to examine technology adoption in supply chains

framework (Baker, 2011). The DOI theory defines compatibility, complexity, relative advantage, trialability, and observability as the factors affecting technological implementation (Rogers, 1995). In the context of blockchain technology, current advancements will not be able to replace the existing systems, and therefore, a blockchain-based system should be compatible with the existing legacy system (Lielacher, 2018). The technical interfaces used to connect the two systems add complexity to the implementation process. Moreover, the lack of earlier full-scale adoption of the technology in supply chains obstructs the firm's ability to ensure its successful implementation and will impede it in realising the relative advantages offered by the technology in comparison with the conventional centralised database structure. Besides, flexibility to trial the technology in the supply chain process will play an important role in its implementation.

3.2 Organisational challenge category

Organisational context in this study refers to several factors, such as top-management support, technical know-how, financial resources, and firm size, which facilitate technology adoption in organisations (Tornatzky and Fleischer, 1990). In particular, organisations with a high degree of centralisation of power with the top management are likely to make adoption decisions irrespective of resistance from lower-level managers and employees. Regarding the organisation size, large organisations can invest in resources that facilitate implementation. However, the agility and the flexibility of smaller organisations facilitate their adoption of innovations (Wang *et al.*, 2019a). Further, because organisational resources, such as financial resources and technical expertise, influence decisions on technology implementation, it is important to understand their role in the implementation process. In particular, the newness of blockchain technology and the lack of readily available, off-the-shelf software may result in greater costs for organisations (Lielacher, 2018).

3.3 External environment challenge category

External environment factors such as the industry structure, the security provided by the technology service provider, and the regulatory environment may become constraints or provide opportunities for technology implementation in supply chains (Huang *et al.*, 2008; Bradford *et al.*, 2014). The lack of government regulations regarding the recording of transactions on the blockchain has bypassed the inefficiencies likely to result from following such regulations. Despite the lack of government standards to guide blockchain implementation, organisations are carefully seeking industry use cases to understand the industry characteristics influencing blockchain implementation. Moreover, the presence of external technology providers with more than 50% mining power to validate new transactions on blockchain raises a security concern regarding the data recorded on blockchain (Lielacher, 2018).

3.4 Interorganisational relationships challenge category

An interorganisational relationship is a complex construct with many dimensions, such as the partner's power, information sharing, privacy, and trust. According to Chong and Ooi (2008), partner power is an organisation's ability to exert influence on another company to act in a prescribed manner. Supply chain members who trust each other will achieve the benefits of technology implementation. Thus, blockchain technology implementation depends on the degree of trust between business partners (Saberi *et al.*, 2019). Information sharing is crucial to a successfully integrated supply chain. Despite its importance, firms do not have the confidence to share information with the members of their supply chains because their competitors may obtain this information, which would affect the firms' business (Chan *et al.*, 2012). Hence, the privacy that this technology offers plays an important role in its diffusion in supply chains. Based on this discussion, we propose a conceptual framework of the challenges in implementing blockchain technology in supply chains (see Figure 1).

4. Research methodology

Using quantitative methods to analyse a case assists in theory elaboration by providing rich insights into the context (Kaplan and Duchon, 1988). In this study, to identify the critical challenges from the proposed framework, case study methodology is adopted, and AHP is used to analyse the quantitative data of the interviews. In the context of technology adoption, AHP has been widely used to analyse the data. For example, the method was used to identify the challenges influencing the decision-making regarding technology adoption (Bigdeli *et al.*, 2013), to investigate market success and failure factors (Adhiarna *et al.*, 2013; Park *et al.*, 2017), and to select technology providers (Chang *et al.*, 2012).

4.1 Analytic hierarchy process: a brief overview

AHP is a multi-criteria decision-making approach that systematically analyses the complex situation and organises into components of a hierarchical structure (Saaty, 1990). In this study, AHP analysis is conducted in three stages. The first stage involves the identification of critical challenge categories and the challenges of the implementation of blockchain technology and structuring them in hierarchical levels. In the second stage, data is collected through pairwise comparison of the challenges in terms of their importance to a challenge category in the next higher level. Through a comparison of challenges, several preference (square) matrices are generated. For a set of n challenges in a matrix, $(n^2 - n)/2$ judgements are needed, and the remaining judgements are reciprocals ($a_{ji} = 1/a_{ij}$). We explain the data collection procedure in detail in Section 4.3. Finally, in stage 3 unique and normalised vectors of the criticality of challenges are computed. The overall criticality of the challenges is determined by aggregating the weights throughout the hierarchy.

Once the criticality is determined, it is important to check the consistency of judgements elicited from the managers. Consistency ratio (CR) is used to measure the extent to which an established preference is retained. A CR $\leq$ 0.1 is recommended as acceptable (Saaty, 1990). If CR > 0.1, it is suggested that the managers need to re-evaluate their judgements. Overall, the use of AHP to analyse the data satisfies the credibility and dependability criteria of the qualitative research proposed by Shah and Corley (2006) (refer to Table 3). In this study, Expert Choice® software is used to calculate the priority weights of challenges and challenge categories.

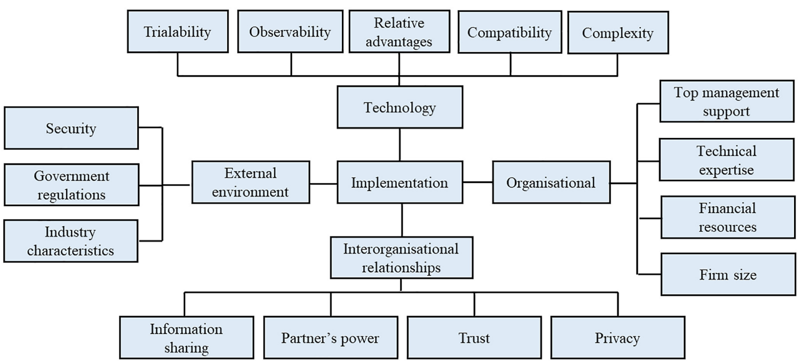

Figure 1. Conceptual model of challenges of blockchain implementation in supply chains

Trustworthiness criteria	Methods for meeting trustworthiness criteria	Research phase
Credibility	• Selection of leading firms in the field of blockchain technology implementation as a case study and researchers' experiences in technology adoptions in supply chain assists in providing credibility	Case selection
	• Use of qualitative arguments along with quantitative AHP data collected during interview provides triangulation	Data collection
	• Computed priority weights and verbatim interviews transcripts supporting the priority weights are sent to the participants for feedback	Data analysis
Transferability	• Detailed description of research setting facilitates in validating the interview protocol	Case selection
	• Hierarchical model developed in this study based on theoretical framework assists in developing semi-structured interview questionnaire	Research design
Dependability	• Interview protocol developed in this study can be used in future research in similar settings	Data collection
	• Purposive sampling assists in collecting data from participants who are rich in information	Case selection
	• The consistency ratio (CR) of AHP refers to the degree to which decision-makers adhere to the rank order specified and also measures the distortion in data	Data analysis
Confirmability	• Hierarchical model of first order challenge categories and second order challenges used to collect the data assists in meticulous data management	Research design
	• Findings from AHP are further discussed with participants to make sure the correct interpretations of the quantitative assessments are captured during the interview process	Data analysis

Table 3. Trustworthiness criteria of research

4.2 Case study

We adopt a multi-case approach that employs a combination of methods, including data collection through semi-structured interviews with developers, consultants, and clients and a review of internal and publicly disclosed documents and websites. The use of data from multiple stakeholders yields rich insights into the phenomena under investigation through the comparison of data from different cases (Shah and Corley, 2006).

In this study, to select the cases that have experience in blockchain implementation, we adopt a two-stage approach. First, from the list of the Top IT Consulting Firms for 2018 in India (Goodfirms, 2018), we distributed questionnaires and the participation criteria to the 50 top consultant and software developing organisations out of which 10 expressed their interest. Out of these 10 firms, finally, six firms who have been involved in blockchain implementation participated in the study. Based on the respondents' role in technology implementation, we clustered the organisations into two groups, one with three developers and the other with three consultants. Second, to identify their clients, we reviewed the publicly disclosed documents of the respondent consultant and developer organisations. Based on this review, we contacted four clients who have implemented blockchain technology in their Indian operations in the supply chain context and two showed their willingness to participate in the study. Finally, we identified a total of eight respondents, namely, three developers, three consultants, and two clients, as the respondents for this study. As all these cases are involved in blockchain implementation and provide in-depth insights to address the study objectives, the number of cases does not have any impact on the study findings (Gammelgaard, 2017; Mirkovski *et al.*, 2019). These selected cases clustered into different stakeholder groups assist in conducting cross-case analysis that provides crucial information on collaboration among these firms to promote blockchain implementation.

A sample size of eight respondents is deemed to be adequate, given that studies that use the AHP technique are usually conducted with fewer responses from senior executives who are knowledgeable on the issue under investigation. For instance, Abdulrahman *et al.* (2014) interviewed five experts to ascertain priorities regarding the reverse logistics factors, Sangka *et al.* (2019) interviewed ten respondents to identify the managerial competencies of third-party logistics providers, and Rahman *et al.* (2019) used data from five respondents to examine the challenges faced by multinational third-party logistics providers. In our study, we selected respondents who are familiar with the functionalities of blockchain technology and are experienced in the implementation of this technology as well as other technologies, such as IoT, RFID, and ERP. The selection of leading firms in the field with experience in the implementation of blockchain technology as a case study organisations and researchers' experiences in technology implementations in supply chain assists in meeting the credibility criterion of the qualitative research (see Table 3). For confidentiality reasons, all firms are identified using pseudonyms.

4.2.1 Case stakeholder - developers. To maintain the anonymity of the respondents, the three developer companies included in this study are identified as Developer A1, Developer A2 and Developer A3. Developer A1 is India's oldest (established in the year 1968) and largest IT service, consulting, and business solutions company that has more than 400,000 employees globally. Since it is the largest and oldest technology provider, Developer A1 has the potential to attract most of its existing clients to its blockchain platforms. Developer A2 is a US-based organisation and more than 70% of its 350,000 employees are located outside that country, including 130,000 employees in India. It is one of the first few organisations worldwide to have developed blockchain solutions and is known for providing the infrastructure required for blockchain technology. Developer A3 is a relatively new firm established in 2000 and offers blockchain solutions to large multinational corporations headquartered in India. All the respondents of the developer companies are in a senior executive position in the firm with an average of 15 years of experience and are involved in blockchain implementation at client's facilities for more than 3 years (see Table 4).

4.2.2 Case stakeholder: consultancy firms. The three consultancy firms considered in this study are identified as Consultant B1, Consultant B2 and Consultant B3 to maintain respondent anonymity. Consultant B1, established in 1845, is the oldest financial and advisory service consultancy company, and it started offering blockchain consulting services to financial institutions in 2016. In the study context, Consultant B1 offers blockchain services to Client C2 and their trading partners, whereas Consultant B2 and Consultant B3 started offering their blockchain services to several industries in 2017. Unlike Consultant B1 and Consultant B2 who mostly offer only consultancy services, Consultant B3 also offers software solutions and is currently recognised as India's second-largest IT provider. All the respondents have experience of over 13 years in offering consultancy services to businesses across multiple industries ranging from financial to IT services (see Table 4).

4.2.3 Case stakeholder: client organisations. For confidentiality reasons, the client firms are identified as Client C1 and Client C2. Client C1, established in 1907, is Asia's first private steel company with fully integrated operations from mining to the manufacturing and marketing of finished products. Client C1 has implemented blockchain technology in collaboration with SAP, and Developer A2 to trace the life cycle of steel bars in its supply chain. Client C2 is a Fortune 500 company and India's largest bank with operations in more than 36 countries. It is among the initial founding members of the "BankChain platform" for implementing blockchain solutions in Indian banks. Currently, Client C2 uses blockchain for recording and sharing customer information, authenticating contracts, making cross-border payments, and financing trading/supply chain organisations. Respondents from the client organisations are

Table 4.
Profile of case study companies and respondents

Case study profile						Respondent profile			
Case organization	Headquarter location	Established year	Countries operating	Employees globally	Products/Services offered	Education	Respondent position	IT experience	Blockchain experience
Developer									
A1	India	1968	44 countries	>400,000	IT service, consulting, and business solutions	Under graduation	Project manager	17 years	4 years
A2	United States	1911	170 countries	>350,000	Cloud computing, Artificial intelligence, commerce, data and analytics, Internet of Things (IoT), Blockchain, IT infrastructure, mobile, and security	Under graduation	Team leader	12 years	3 years
A3	UK	2000	11 countries	>1,000	Cloud computing, Artificial intelligence, Internet of Things (IoT), Blockchain, GST and VAT solutions	Post-graduation	Manager	16 years	5 years
Consultant									
B1	UK	1845	150 countries	>250,000	financial and advisory service	Post-graduation	Leader	13 years	5 years
B2	Ireland	1989	120 countries	>492,000	Strategy, consulting, digital, technology and operations	Under graduation	Manager	18 years	3 years
B3	India	1981	46 countries	>236,000	IT service, consulting, and outsourcing solutions	Under graduation	Project manager	14 years	3 years
Client									
C1	India	1907	26 countries	>80,500	Ferrous and Non-Ferrous raw material	Post-graduation	Operations manager	21 years	2 years
C2	India	1806	36 countries	>257,000	Bank	Post-graduation	IT department manager	16 years	3 years

senior executives with over 16 years of experience and have worked on blockchain implementation project for over two years. Over the years, respondents are involved in projects implementing RFID, ERP, and IoT systems in organisations and their supply chains.

In the study context, there are several instances when Consultant B2 and Developer A2 have formed a consortium to offer blockchain services to organisations across several industries. Consultant B1 analysed Client C2's business goals and identified the applicability of blockchain technology to this client's existing business ecosystem. These interrelationships among the case study organisations facilitate the collection of insights into not only each technology implementation but also their interactions.

4.3 Data collection

During the interview, respondents were briefed about the study context of blockchain technology implementation in supply chains. Consultants and developers were asked to address the interview questions with the blockchain implementation at client's supply chain in mind; whereas, respondents from client organisations answered the questions in relation to the blockchain implementation in their supply chains. A three-part questionnaire is used to conduct semi-structured interview. Part A contains questions (in the AHP format) designed to capture the respondents' opinions on the pairwise comparison of criticality of the challenges and challenge categories. A 9-point rating scales linguistically described as equally, slightly, moderately, strongly and extremely critical corresponding to the values of 1, 3, 5, 7 and 9, respectively is used to capture the degree of criticality of a challenge or challenge-category. Since the respondents were not familiar with the AHP data collection procedure, we provided them a clear explanation, through an example, about the scale and the assignment of criticality scores while making pairwise comparisons between any two challenges. Questions in Part B captures the respondents' assessments of the effort required to manage the blockchain implementation challenges at clients' facilities through a scale that ranges from 1 for "least effort required" to 9 for "most effort required". In addition, respondents were asked to provide justifications for the ratings given while answering Part A and Part B of the questionnaire. Appendices 1 and 2 provides direct quotations of the relevant justifications given by the respondents during the interview. Lastly, Part C contains general questions about the company and the respondent's background. The duration of the interviews ranged from 90 to 120 min with a short break in between. All the interview transcripts were sent to the participants for feedback, and follow-up conversations with them assisted in providing credibility to the qualitative study. Overall, the set of specific actions taken into consideration while designing this study assists in meeting the credibility, transferability, dependability and conformability criteria that bring rigour to qualitative research (see Table 3).

5. Results and analysis

The results are summarised in Tables 5 and 6. The CR values presented in these tables of each respondent category are within the acceptable limit (i.e. $\leq$0.1), thus demonstrating that the respondents' opinions are consistent.

5.1 Identification of critical challenges

The analysis results show that all the developers indicate that organisation (weight = 0.455) is the most critical challenge category with technical expertise (weight = 0.370) as a critical challenge that needs to be addressed. The technology (weight = 0.404) challenge category is next, and in it, complexity (weight = 0.376) is a critical challenge. The less critical challenge category, external environment (weight = 0.073), has security (weight = 0.659) as a critical

Challenge categories	Developers	Consultants	Clients	Challenge	Developers	Consultants	Clients
CR value	0.082	0.089	0.084				
Technology	0.404	0.574	0.518	CR value	0.091	0.085	0.067
				Relative advantages	0.109	0.169	0.113
				Compatibility	0.262	0.262	0.189
				Complexity	0.376	0.382	0.391
				Trialability	0.118	0.076	0.185
				Observability	0.135	0.111	0.123
Organisational	0.455	0.254	0.330	CR value	0.067	0.086	0.091
				Top management support	0.345	0.361	0.326
				Technical expertise	0.370	0.426	0.308
				Financial resources	0.185	0.161	0.269
				Firm size	0.100	0.053	0.097
External environment	0.073	0.115	0.103	CR value	0.040	0.068	0.040
				Security	0.659	0.584	0.455
				Government regulations	0.156	0.184	0.455
				Industry characteristics	0.185	0.232	0.091
Inter organisational relationship	0.065	0.056	0.048	CR value	0.042	0.096	0.095
				Information sharing	0.231	0.308	0.229
				Partner's power	0.471	0.365	0.474
				Trust	0.212	0.254	0.233
				Privacy	0.087	0.073	0.064

Table 5.
Relative weights of challenge-categories and challenges of consultants, developers, and clients

challenge. Partner's power (weight = 0.471) is a critical challenge under the least critical challenge category, interorganisational relationships (weight = 0.065).

All the consultants indicate that the technology challenge category (weight = 0.574) is more critical than the organisational (weight = 0.254), external environment (weight = 0.115), and interorganisational relationships (weight = 0.056) challenge categories. According to them, the most important challenge in each challenge category is as follows: complexity (weight = 0.382) under the technology challenge category; technical expertise (weight = 0.426) in the organisational challenge category; security (weight = 0.584) in the external environment challenge category; and partner's power (weight = 0.365) under the interorganisational relationship challenge category (see Table 5).

By contrast, all clients indicate that technology is the most critical challenge category (weight = 0.518) with complexity (weight = 0.391) as the most critical challenge. It is followed by the organisational challenge category (weight = 0.330) with top-management support (weight = 0.326) as the most critical challenge; the external environment category (weight = 0.103) with security (weight = 0.455) and government regulation (weight = 0.455) as the most critical challenges; and the interorganisational relationship challenge category (weight = 0.048) with partner's power (weight = 0.474) as the most critical challenge.

	Developers				Consultants				Clients		
	A1	A2	A3	Overall	B1	B2	B3	Overall	C1	C2	Overall
Relative advantages	0.012	0.018	0.064	0.029	0.051	0.070	0.056	0.097	0.029	0.070	0.058
Compatibility	0.059	0.071	0.126	0.070	0.020	0.302	0.227	0.150	0.119	0.262	0.098
Complexity	0.121	0.042	0.150	0.101	0.151	0.183	0.144	0.219	0.167	0.114	0.203
Trialability	0.023	0.015	0.040	0.032	0.031	0.035	0.026	0.044	0.031	0.043	0.096
Observability	0.011	0.009	0.030	0.036	0.017	0.032	0.031	0.064	0.016	0.025	0.063
Top management support	0.150	0.475	0.158	0.198	0.368	0.083	0.198	0.092	0.144	0.034	0.108
Technical expertise	0.033	0.167	0.086	0.212	0.065	0.089	0.057	0.108	0.057	0.168	0.102
Financial resources	0.386	0.035	0.086	0.106	0.130	0.021	0.025	0.041	0.211	0.096	0.089
Firm size	0.060	0.044	0.019	0.057	0.031	0.008	0.013	0.013	0.096	0.017	0.032
Security	0.011	0.062	0.115	0.052	0.038	0.074	0.103	0.067	0.029	0.084	0.047
Government regulations	0.018	0.009	0.049	0.012	0.004	0.030	0.042	0.021	0.013	0.036	0.047
Industry characteristics	0.072	0.006	0.013	0.015	0.010	0.012	0.017	0.027	0.006	0.009	0.009
Information sharing	0.010	0.021	0.016	0.018	0.027	0.018	0.025	0.017	0.023	0.012	0.011
Partner's power	0.003	0.018	0.021	0.037	0.006	0.011	0.022	0.021	0.012	0.023	0.023
Trust	0.025	0.007	0.012	0.017	0.024	0.029	0.010	0.014	0.040	0.005	0.011
Privacy	0.005	0.002	0.016	0.007	0.027	0.002	0.003	0.004	0.008	0.002	0.003

Table 6.
Overall priority weights of blockchain implementation challenges at client's facilities perceived by consultants, developers, and clients

Overall, developers indicate that technical expertise (weight = 0.212), top-management support (weight = 0.198), and financial resources (weight = 0.106) are the top three critical challenges. Examples of the justifications for the ratings provided by the respondents can be seen in Appendix 1. For example: developer A1 rated financial resources as critical and stated:

> Our clients express that it is not easy for their organisation to consider the blockchain technology because of the initial costs associated with the technology and lack of awareness on operational costs of running the technology.

By contrast, consultants consider complexity (weight = 0.219), compatibility (weight = 0.150) and technical expertise (weight = 0.108) the top three critical challenges. While clients indicate that complexity (weight = 0.203), top-management support (weight = 0.108) and technical expertise (weight = 0.102) are the top three critical challenges. For example: criticality given to the compatibility challenge is justified by B2 as follows:

> When our clients adopt blockchain technology in full-scale to trace the products it is important to integrate with the ERP systems of all the supply chain members.

In most cases, the opinions of the respondents are consistent with the overall judgement. Some exceptions are observed: for instance, Consultant B1 emphasises top-management support (weight = 0.368) and financial resources (weight = 0.130) from the organisational challenge category, whereas Consultant B2 and Consultant B3 prioritise compatibility and complexity from the technology challenge category as critical challenges (see Table 6).

5.2 Level of effort required to overcome the challenges

Effort refers to the degree of engagement with tasks by employing resources that are physical and cognitive in nature (Westbrook and Braver, 2015; Gouda and Saranga, 2018). In this study, the term effort represents the quantity of resources such as time, money, and human resources needed to engage with the tasks and address the blockchain implementation challenges. The perceived effort required to manage the challenges is indicated through a scale with values ranging from 1 for “least effort required” to 9 for “highest effort required”. Respondents were asked to address the interview questions on effort required to implement blockchain technology at client’s supply chain by keeping in mind all three factors time, money, and human resources simultaneously. To understand the judgements of the respondent groups, the weights of the effort required are computed and presented in Table 7. An analysis of the developers’ judgements indicates that they identify challenges related to industry characteristics, information sharing, and compatibility which have equal weight (0.088) as the challenges that require the most effort. Conversely, they identify security (weight = 0.030), technical expertise (weight = 0.034) and trust (weight = 0.037) as the challenges that require least effort. In most cases, the respondents’ opinions are consistent. There are some exceptions, such as Developer A3 emphasising trust (weight = 0.045) as the challenge that requires great effort and Developer A2 indicating that trust (weight = 0.023) requires less effort to be managed (see Table 7). Appendix 2 presents examples on the reasons for the rating of effort required to address the challenges. For example, developer A1 stated:

> Compatibility of blockchain with the existing systems and IOT devices for data transfer is possible through the applications such as enterprise application adapters.

The results obtained on analysing all the consultants’ judgements indicate that they consider that challenges related to complexity (weight = 0.114); financial resources (weight = 0.100); and compatibility, observability, and government regulations which have equal weight

Table 7. Effort required by developers, consultants, and clients to address the blockchain implementation challenges at client's facilities

	Developers				Consultants				Client		
	A1	A2	A3	Overall	B1	B2	B3	Overall	C1	C2	Overall
Relative advantages	0.050	0.046	0.045	0.047	0.071	0.057	0.056	0.061	0.034	0.065	0.050
Compatibility	0.090	0.092	0.082	0.088	0.086	0.092	0.083	0.087	0.069	0.054	0.061
Complexity	0.070	0.069	0.073	0.071	0.129	0.103	0.111	0.114	0.103	0.076	0.089
Trialability	0.050	0.046	0.055	0.051	0.043	0.057	0.042	0.048	0.034	0.054	0.045
Observability	0.070	0.080	0.073	0.074	0.086	0.092	0.083	0.087	0.046	0.054	0.050
Top management support	0.070	0.069	0.073	0.071	0.057	0.057	0.069	0.061	0.092	0.076	0.084
Technical expertise	0.040	0.023	0.036	0.034	0.043	0.046	0.042	0.044	0.092	0.087	0.089
Financial resources	0.080	0.092	0.082	0.084	0.100	0.092	0.111	0.100	0.080	0.065	0.073
Firm size	0.060	0.046	0.055	0.054	0.057	0.069	0.056	0.061	0.057	0.087	0.073
Security	0.030	0.034	0.027	0.030	0.043	0.046	0.042	0.044	0.069	0.076	0.073
Government regulations	0.060	0.046	0.045	0.051	0.086	0.080	0.097	0.087	0.046	0.033	0.039
Industry characteristics	0.080	0.103	0.082	0.088	0.057	0.069	0.056	0.061	0.034	0.033	0.034
Information sharing	0.090	0.092	0.082	0.088	0.043	0.046	0.056	0.048	0.046	0.065	0.056
Partner's power	0.060	0.080	0.064	0.067	0.043	0.046	0.042	0.044	0.034	0.033	0.034
Trust	0.040	0.023	0.045	0.037	0.043	0.034	0.042	0.039	0.069	0.043	0.056
Privacy	0.060	0.057	0.082	0.067	0.014	0.011	0.014	0.013	0.092	0.098	0.095

(0.087) require increased effort. However, they indicate that privacy (weight = 0.013); trust (weight = 0.039); and security, partner's power and technical expertise (all with weight = 0.044) are the challenges that require less effort. At the individual level, there are some differences in opinions, such as Consultant B2's (weight = 0.069) perception that the effort required to address the challenge related to industry characteristics is high compared with the perceptions of Consultant B1 (weight = 0.057) and Consultant B3 (weight = 0.056).

The results obtained on analysing all the clients' judgements indicate that privacy (weight = 0.095), technical expertise (weight = 0.089) and complexity (weight = 0.089) are the challenges they view as requiring more effort to address. Conversely, they consider that government regulations (weight = 0.039), industry characteristics (weight = 0.034) and partner's power (weight = 0.034) are the challenges that require less effort. Among the clients, there are some similarities and differences in opinion. One such difference is that Client C2 (weight = 0.087) considers that a strong effort is required to address the firm size challenge, whereas Client C1 (weight = 0.057) views it as requiring relatively less effort.

5.3 Classification of challenges based on the criticality–effort matrix

Next, we perform a criticality–effort matrix analysis using a 2 × 2 format. "Implement immediately", "plan to execute", "seek assistance", and "no action required for now" are the four quadrants of the matrix. The challenges in the "implement immediately" quadrant are critical for implementing blockchain technology and require less effort. The "plan to execute" quadrant challenges are critical but require great effort to address. By contrast, the challenges in the "seek assistance" quadrant are not critical and require less effort; therefore, these challenges can be addressed by seeking external assistance or outsourcing. However, the challenges in the "no action required for now" quadrant are less critical to blockchain implementation and require more effort to address than other challenges. Hence, these challenges should be addressed last, that is, no action is required at the initial stage. In this study, based on the perceptions of the developer, consultant, and client groups we draw three matrices (see Figure 2).

According to the developers' perspective, the challenges of technical expertise, firm size, and security belong to the "implement immediately" quadrant. Top-management support, financial resources, complexity, compatibility, and partner's power are the challenges in the "plan to execute" quadrant. The consultants perceive technical expertise and security as the critical challenges that require less effort (these belong to the "implement immediately" quadrant). The challenges related to complexity, compatibility, relative advantages, observability, and top-management support are grouped under the quadrant "plan to execute". From the clients' perspective, the challenges of trialability, relative advantages, and observability belong to the "implement immediately" quadrant. Top-management support, technical expertise, financial resources, complexity, and compatibility are the challenges in the quadrant "plan to execute" (see Figure 2).

6. Discussion and implications

6.1 Discussion

The analysis results indicate similarities and differences in the perceptions of stakeholder groups regarding the criticality of the challenges and the effort required to address these challenges. These differences in perceptions result in variations in the criticality–effort matrix and highlight the need for adopting different strategies to ensure successful technology implementation.

6.1.1 The "implement immediately" quadrant. The consultants and the developers consider the lack of technical expertise a crucial challenge that must be addressed for

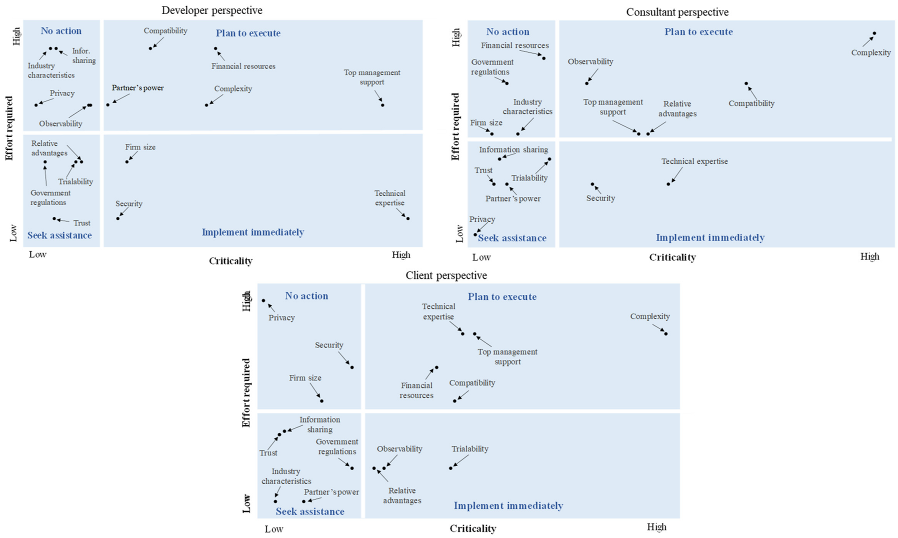

Figure 2.
Criticality-effort matrix for the implementation of blockchain technology at the client's supply chains

successful implementation. Despite India having the second largest pool of blockchain experts, employee productivity is relatively low. Highly skilled employees who have the required technological knowledge and the ability to work in various industries are particularly crucial for implementing blockchain among supply chain members. During the interview, consultant B2 highlighted:

> Technically skilled professionals are critical. Salaries and demand for blockchain technology professionals are very high. So, it is difficult to attract and retain people with blockchain technology skills.

Meanwhile, the manager of the client C1 expressed:

> It is not easy to convince current employees to undergo training to use blockchain technology in their processes.

However, all the respondents believe it would be much easier to find skilled employees in the near future because educational institutes in India, such as the Indian Institute of Technology, have started offering blockchain-based courses.

The developers and the consultants view security as a critical challenge that requires less effort, resulting in its position in the “implement immediately” quadrant. Despite the recent technological advances, most of the consultants consider that selfish mining is still a concern. with a new business opportunity to offer auditing services that detect selfish mining during the data recording and validating processes. As revealed in the interview with Consultant B3:

> We are offering services to audit the mining practice and protect the confidentiality, integrity, and availability of the system and its information to promote our client's confidence.

Moreover, the vast majority of blockchain security breaches are related to human errors during the data validation process. The interview with Developer A2 highlights:

> Hyperledger Fabric and smart contracts that we developed can be integrated with the IoT/sensors and smart tags to capture and record data automatically thus eliminating human errors.

As the consultants and developers have started offering new services to address the security issues associated with blockchain technology, it is perceived that the effort required by client to address the blockchain implementation challenge is less. In comparison to consultancies and developers, the client organisations placed the challenges of trialability, relative advantages and observability of the technology challenge category under the "implement immediately" quadrant.

6.1.2 The "plan to execute" quadrant. All the stakeholders consider that the challenges related to top-management support, complexity, and compatibility of the technology with existing systems are critical and require more effort, and hence, these are grouped under the "plan to execute" quadrant. As in the case of all the other e-SCM technological implementations, such as RFID and ERP systems, the results of this study indicate that top-management support is crucial for blockchain implementation (Cole *et al.*, 2019). However, it is the dependence on a skilled workforce for the successful implementation of the technology that results in top management to refrain from providing support. Client C2 interview indicates:

> The lack of a knowledgeable and skilled workforce to implement the technology has demotivated us from its implementation.

Moreover, insufficient understanding of how technology fits with the organisation's policy and benefits offered by the technology results in a low-level of support. Especially, as this technology is still evolving and changing continually, top management needs to offer different forms of support for different aspects. For example, Developer A2 emphasised the need for the Client's top management to support employees undergoing the change management process. Given that 25% of organisations worldwide are replacing existing legacy systems with blockchain solutions (Deloitte, 2019), top-management support is critical.

Although blockchain technology is replacing the existing systems in some applications, a high proportion of blockchain applications are still stacked on the existing systems. For instance, this technology can be used to interlink the ERP systems of organisations in the supply chain at a low cost (Cole *et al.*, 2019). Therefore, its compatibility with existing systems and interoperability with existing software is crucial for the successful implementation of this technology. Moreover, integration with the existing system implies that the blockchain technology should be compatible with the existing business practices. However, it is clear from the interviews that significant changes are required to the business process for the successful implementation of the technology. To address the compatibility issues and to implement blockchain technology as a solution to fragmented infrastructure, effort required. In particular, considering the increasing number of players in the constantly expanding blockchain industry and the different network members that interact with each other, addressing the compatibility challenge requires careful planning by the developers, consultants, and clients and their supply chain members in the consortia formed to implement this technology. Client C1interview highlights:

> Our supply chains are complex and constantly expanding requiring multiple systems from various organisations to be compatible.

Stakeholder groups we interviewed indicated that the complexity associated with the technology, organisational structure, and external environment of the client are crucial aspects that need to be addressed for the successful implementation of blockchain technology. Specifically, blockchain functionality is a complex idea that requires transactions to be verified by using complex cryptographic algorithms. Regarding organisational structure, Consultant B1 interview indicates:

> The structure of our client is so complex, with duplications in roles across several departments, it made it challenging for us to implement blockchain technology.

Meanwhile, Consultant B2 highlights that its complexity makes it difficult for its end users who are external to the organisation to appreciate the benefits that this technology offers, which affects its uptake in supply chain. To remove the complexity in implementing and running blockchain networks at their clients, Developer A1 and Developer A3 are working on creating templates, or in other words, blockchain-as-a-service. Although the development of these services requires more resources and careful planning, these will motivate more organisations to consider using blockchain technology.

6.1.3 The "seek assistance" quadrant. All the stakeholders interviewed in the study perceive trust as a common challenge that belongs to the quadrant "seek assistance". During the interview, Consultant B1 highlighted the relationship between technology and trust:

> This technology is a democratisation of trust. However, it is abstract, understanding it requires technical knowledge. Many of the related processes are not transparent, which makes it difficult for our clients to realise its benefits and thus results in trust issues.

Therefore, consultants and developers are developing ecosystems to promote trust regarding technology implementation among their clients. Meanwhile, client organisations should seek consensus among the supply chain members to build trust.

According to the clients and the consultants, the challenges of partner's power and information sharing under the interorganisational challenge category belong to the "seek assistance" quadrant. Consultant B2 highlighted:

> Successful implementation of blockchain technology in supply chains depends upon the influencing capability of the dominating player.

Over the past year, Consultant B2 has worked closely with large retailers who have influenced all their supply chain members towards blockchain implementation so that they can trace the origin of the products they are selling. Meanwhile, Client C1 requires all its supply chain members to use blockchain technology to trace the life cycle of steel bars.

Globally, the lack of regulation is considered a critical barrier to blockchain adoption (Deloitte, 2019). However, this study's results indicate that this challenge is less critical in the Indian context. According to Developer A2:

> Blockchain implementation in India is not influenced by government regulations. But, the recognition of blockchain by the Indian government will provide confidence to organisations that intend to adopt the technology.

This is evident in the case of the blockchain implementation by Client C2 who has persuaded private banks to consider blockchain technology. Moreover, government support initiatives, such as providing training and incentives and facilitating research and development have enabled the adoption of technologies such as RFID in supply chains (Cole *et al.*, 2019). In the study context, the Indian government's plan of preparing a national blockchain framework will facilitate the wider deployment of this technology (NITI Aayog, 2020).

The successful deployment of blockchain technology in supply chains depends on the relative advantages it offers, that is, organisations' ability to perceive the greater benefits of this new technology compared with previous technologies (Lielacher, 2018). In the study context, the participating consultants and developers believe that the lack of evidence on relative advantages is not a critical challenge that influences the technology implementation and it requires the active disclosure by firms that have successfully implemented the technology. Consultant B1 and Consultant B2 have highlighted in their interviews that they are successful in offering blockchain solutions across several industries and have published white papers illustrating the increased benefits offered by the technology compared with earlier technologies. In addition, client organisations believe that they must understand the relative advantages offered by the technology, and hence, they rely on their consultants' white papers at this stage.

6.1.4 The "no action required for now" quadrant. There are no challenges common to all stakeholders in the quadrant "no action required for now". Among all these challenges, the consultants and the developers perceive that the characteristics of industry affect blockchain implementation. Since its introduction, blockchain technology has been implemented in the financial industry. In 2018, the financial industry accounted for 45% of the global blockchain expenditure (IDC, 2019). More recently, it has been implemented in the technology, media, telecommunication, and non-food manufacturing sectors (Deloitte, 2019). Further expansion to other industries requires efforts from all the stakeholder groups on educating managers about the benefits the technology offers, and this approach will assist in meeting the projected blockchain expenditure of US$ 12.4 billion by 2023 (IDC, 2019). Moreover, most of the interview respondents rated the privacy challenge as less critical because they believe the development of permissioned blockchain with limited data access to participants will address this challenge. However, significant effort and careful planning are required to customise blockchain to assign rights to respondents to review only permissible parts.

6.2 Implications

6.2.1 Practical implications. By performing criticality–effort matrix analysis, this study offers several managerial implications. First, it provides strategies to developers for bringing about advancements in blockchain technology that would improve supply chain efficiency when implemented. This study identifies the lack of technical expertise to promote technology development as a major challenge concerning developers. Therefore, developers need to focus on retaining skilled people through employee recognition programs. However, it is a major challenge in the Indian context because the IT industry accounts for a significant extent of the brain drain issue that the country experiences.

Second, this study's findings would assist consultants in developing plans to facilitate the implementation of blockchain technology in their clients' supply chains. The consultants identified the challenges related to the workforce as employees who either have no understanding of the technology or have no cross-industry work experience. Consultants can only acquire cross-industry skills over time with experience. Thus, consultancies need to develop an internal digital skills program to boost the technological skills of their employees. The other challenge that needs to be immediately addressed is security issues related to data mining in the blockchain. This challenge provides consultants with an opportunity to develop services to audit the mining practice and protect the confidentiality, integrity, and availability of the system and its information.

Third, the findings of this study would facilitate organisations to develop ways for the implementation of blockchain technology in supply chains. The study results indicate that trialability, observability, and the relative advantages of the technology facilitate organisations to opt for technology implementation in supply chains. For successful blockchain implementation, organisations should form consortia with the other firms offering similar business services. Joining consortia is critical because it yields cost savings and accelerates learning among the stakeholders (Deloitte, 2019).

Lastly, the study findings offer policy implications. This study identifies that the lack of regulation does not influence technology uptake. However, when government organisations implement technology it motivates the others in the industry towards technology implementation. Therefore, government organisations should take the lead in technology implementation in supply chains. In the context of developed nations, regulation plays an important role in their technology uptake, which can be observed in the case of earlier technologies, such as RFID. Hence, developing a regulatory framework would assist in the technology uptake in developed economies. Although blockchain implementation in India is not governed by any regulations, the Indian government has proposed a skill development initiative to supply the much-needed skilled workforce trained on blockchain technology. The availability of such a skilled workforce would enable India to become the next Silicon Valley.

6.2.2 Theoretical implications. The study contributes to existing research in three ways. Blockchain technology offers several benefits to emerging economies such as India where transparency is an issue (Queiroz and Wamba, 2019). Despite the benefits offered by the technology, its adoption depends on how the implementation challenges are addressed (Kouhizadeh *et al.*, 2021). The current literature on blockchain technology in supply chains has highlighted the need for research that investigates the blockchain implementation challenges through examining the real cases who have implemented the technology (Caldarelli *et al.*, 2021; Kshetri, 2021). This is the first to identify and prioritise the challenges from the perspectives of multiple stakeholder groups involved in blockchain technology implementation. The use of insights from diverse stakeholder groups provides crucial insights into a well-researched concept such as the challenges of technology implementation (Gammelgaard, 2017). By investigating the challenges that developers, consultants, and client organisations need to address, this study provides a holistic understanding and facilitates coordination among these stakeholder groups for successful blockchain implementation.

The second implication of the study is to theory. The selection of the TOE theory as an underpinning theory addresses the need identified by Hald and Kinra (2019) for research to adapt to organisational theory to explore the implementation of blockchain technology in supply chains. Unlike the implementation of technology in an organisation which is influenced by technology characteristics and organisational context, technology implementation in the supply chain is complex where the focal firm and its relationship with other firms determine the implementation (Kouhizadeh *et al.*, 2021). To examine the impact of relationships among supply chain members on the implementation of blockchain technology, this study extends the TOE framework by incorporating the interorganisational relationships challenge category to examine supply chain relationships. The use of interorganisational relationships challenge category to extend theory classifies this study as the theory elaboration approach of case study analysis (Ketokivi and Choi, 2014).

The third implication of the study is examining the blockchain implementation challenges in developing countries. In the literature industry characteristics, trust, information sharing, and privacy among the supply chain members are identified as the critical challenges that needs to be addressed for the successful implementation of blockchain technology in supply chains (Kshetri, 2021; Wang *et al.*, 2019b; Queiroz and Wamba, 2019; Kouhizadeh *et al.*, 2021). Whereas, our study findings indicate that these challenges are less critical in the context Indian supply chains. Rather findings of our study highlight complexity, compatibility, top management support, and technical expertise as the critical challenges. Among these critical challenges consultants and developers believe technical expertise is considered as the challenge that requires less effort to be addressed. Meanwhile, in India motivating top management to adopt new technologies that has long-term benefits and minimising the complexity associated with the informal structure in organisations requires significant effort. Thus, from theoretical perspective researchers need to focus on the challenges related to technological and organisational categories while investigating the blockchain implementation in the context of developing countries rather than the challenges related to external environment and interorganisational relationships.

7. Limitations and future research

Despite the significance of its results, this study has some limitations. The major limitation is the study context. The results were obtained by focusing on the Indian context and therefore may not be applicable to other developing nation contexts. In the future, more research is needed in other developing countries. In addition, developed countries, such as the United States and Western European nations, are expected to account for 39.7% and 24.4% respectively of the global blockchain expenditure by 2023 (Leader insights, 2019), and thus, researchers need to empirically investigate the technology implementation challenges in the developed nation context.

Given the newness, very few firms in India have implemented blockchain technology. Thus, in this study the sample size of the respondents with experience in implementing blockchain technology is limited. Broader implementation of technology in the future will assist to conduct study with a larger client sample and their supply chain members. The other limitation related to the study sample is respondent groups. This study offered a comparative analysis of the criticality of blockchain implementation challenges from the perspectives of developers, consultants, and client organisations that are a part of different consortia involved in blockchain implementation. However, such consortia are increasingly being formed by firms offering similar solutions to gain cost advantages and accelerate blockchain learning. Therefore, to provide a holistic understanding of blockchain implementation, future research needs to consider the views of all the consortia members, including those of competitors or other industry members, to identify other critical challenges.

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Appendix 1
Examples of interview evidence on rating the challenge criticality

Challenge criticality	Evidence from the interview	Case organisation
Compatibility	When our clients adopt blockchain technology in full-scale to trace the products it is important to integrate with the ERP systems of all the supply chain members	B2
	Our supply chains are complex and constantly expanding requiring multiple systems from various organisations to be compatible	C1
Complexity	The structure of our client is so complex, with duplications in roles across several departments, it made it challenging for us to implement blockchain technology	B1
Top management support	Rapid changes in technology has created confusion to a concept already considered as disruptive distracting our clients away from the technology implementation	B2
	The lack of a knowledgeable and skilled workforce to implement the technology has demotivated us from its implementation	C2
Technical expertise	Technically skilled professionals are critical. Salaries and demand for blockchain technology professionals are very high. So, it is difficult to attract and retain people with blockchain technology skills	B2
	It is not easy to convince current employees to undergo training to use blockchain technology in their processes	C1

(*continued*)

Challenge criticality	Evidence from the interview	Case organisation
Financial resources	Our clients express that it is not easy for their organisation to consider the blockchain technology because of the initial costs associated with the technology and lack of awareness on operational costs of running the technology	A1
	We invest in technologies or any other infrastructure based on the benefits offered over the lifetime. In this case it is very hard for us to anticipate the benefits against costs which has demotivated us from investing in the technology	C2
Security	Advancements in technology is no longer a security concern, it is lack of rules among our client's supply chain partners	A2
Trust	This technology is a democratisation of trust. However, it is abstract, understanding it requires technical knowledge. Many of the related processes are not transparent, which makes it difficult for our clients to realise its benefits and thus results in trust issues	B1
Privacy	We used blockchain technology to provide visibility of our products in the supply chain. In doing so, we feel we lost oversight on who is accessing our data resulting in privacy related concerns	C1

Appendix 2
Examples of interview evidence on rating the effort required

Effort required	Evidence from the interview	Case organisation
Compatibility	Compatibility of blockchain with the existing systems and IOT devices for data transfer is possible through the applications such as enterprise application adapters	A1
	Using Open API architecture offers the interoperability between different blockchain systems	B1
Complexity	Using consistent terminology for communication with the supply chain members will bring common understanding among the members and addresses the complexity in understanding the technology	B3
Top management support	Successful blockchain adoption in our supply chain depends on changes to the process. This requires a great effort to get approval from all the supply chain members	C1
Security	We are offering services to audit the mining practice and protect the confidentiality, integrity, and availability of the system and its information to promote our client's confidence	B3
	Hyperledger Fabric and smart contracts that we developed can be integrated with the IoT/sensors and smart tags to capture and record data automatically thus eliminating human errors	A2

(*continued*)

Effort required	Evidence from the interview	Case organisation
Government regulation	Blockchain implementation in India is not influenced by government regulations. But, the recognition of blockchain by the Indian government will provide confidence to organisations that intend to adopt the technology	A2
	Using the existing Indian government schemes, such as Make in India makes it easier to promote the adoption of blockchain technology among firms operating in India	B3
Partner's power	Successful implementation of blockchain technology in supply chains depends upon the influencing capability of the dominating player	B2
Privacy	The introduction of private blockchain where members with key can access the information stored on blockchain has offered the privacy to our clients	A1

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