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# Barriers to blockchain technology adoption in supply chains: the case of India

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## Abstract
In the era of digitalization, Blockchain is an evolving technology that has the potential to change the shape of numerous industries. Blockchain is considered the transforming technology that has the ability to change the conventional supply chain network by providing additional transparency of transactions in terms of information and physical goods. Additionally, the implementation of blockchain technology in the supply chain is required to accomplish the objectives of industry 4.0. However, there has to date been a scarcity of blockchain implementations due to the numerous barriers associated with it. Therefore, the primary aim of this research is to identify and investigate the major barriers to implementing blockchain technology in supply chains. We identified ten significant barriers to adopting blockchain technology through a literature review and expert opinions. Additionally, the finalized barriers were categorized into an influential and influenced group using the DEMATEL method. The findings of this study show that 'influential group' barriers require more attention from the supply chain partners to mitigate these barriers. The primary influential barriers are 'Lack of information sharing,' 'Trust management issues,' and 'Lack of upgraded technologies', and these barriers require immediate attention from supply chain stakeholders wishing to use blockchain. These findings contribute to improving managerial decisions and digital strategies regarding blockchain within organisations, and how implementation can effectively be achieved.

**Keywords** Barriers · Blockchain Technology · DEMATEL · Supply Chain · Sustainability

## 1 Introduction

Supply Chains (SC) are becoming more complex due to globalization, environmental legislation, and increased government requirements, and increased compliance requirements. These SC transformations challenge SC partners and compel them to integrate the emerging tools and technologies to gain competitive advantages. The Blockchain is one of the relatively new and increasingly popular technologies that is integrated with SC operations. Due to this, it is receiving significant attention from different SC stakeholders and academia. Blockchain can improve SC operations through increasing end-to-end visibility. Blockchain Technology (BT) has drawn a lot of attention and has made significant progress in fraud prevention and data security (Demirkan et al. 2020a, b; Francisco and Swanson 2018).

Moreover, this technology could mitigate other SC complexities such as data loss, transparency, veracity, and reliable communication. BT is considered to be a tool that can re-establish the confidence of the SC partners by

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offering a platform for sharing credible and safe information. Therefore, BT is seen as a potentially significant technology trend that will impact business and society in the upcoming years (Khan et al. 2019).

The emergence of BT as a general-purpose technology has disrupted organizations' functioning and is endorsed by some governments for revealing the information and transactions that involve verification and trust (Yli-Huumo et al. 2016). The transactional data is saved in separate nodes on the Blockchain and only added after the consensus is achieved among the nodes. The primary features of the BT comprise the decentralization of decision making, immutability of data, reliability, distributed processing, fewer transaction fees, transmission speed, automaticity, irreversibility, and transparency with pseudonymity (Treiblmaier 2018; Iansiti and Lakhani 2017). These features lead to higher-level concepts such as data origin, increased security, enhanced trust, privacy, authenticity, integrity, availability, consensus, and accountability, allowing substantial managerial implications (Neisse et al. 2017; Treiblmaier 2018; Liang et al. 2017). These implications are valuable for SC management.

Managing BT's supply chain activities can be path-breaking (Venkatesh et al. 2020). Contemporary supply chain managers are trying to reduce duplication and increase efficiency (Upadhyay 2020). With the usage of BT, SC will potentially increase efficiencies, saving the stakeholders' time and cost. Complex and diverse SCs can be tracked with relatively more accuracy and efficiency by capturing the decisive data in the Blockchain, from the sourcing of raw material to the manufacturer to the consumer (Xu et al. 2019; Upadhyay et al. 2021a, b).

The literature indicates that using Blockchain in the SC will enhance the visibility and efficiency of operations, improve trustworthiness, eliminate unwanted SC intermediaries, and increase consumer confidence (Saurabh and Dey 2021). While the BT offers several advantages for the dynamic and volatile SC, its effective application in the SC confronts several barriers. For example, studied BT literature and observed a scarcity of research on BT deployment. There are still unsolved limitations and problems associated with BT, which necessitate more investigation and analysis. These barriers become even more crucial in growing and developing economies such as India. For example, inadequate IT infrastructure, low technological expertise, and a distributed supply chain network all contribute to the potential and limits of BT deployment. The presence of these barriers needs to be tackled for the successful implementation of Blockchain. Therefore, this research addresses these barriers associated with adopting Blockchain in supply chain management. Precisely, this research has the following objectives:

(i) To identify the barrier to BT implementation in supply chain management
(ii) To develop knowledge of the interrelationships among these barriers
(iii) Provide recommendations for the adoption of BT

Our specific motivation in designing and conducting this study was to identify BT barriers and the causal relationships between them, so as to allow decision makers at government policy and company levels to efficiently and effectively take actions to overcome such barriers, and allow BT to flourish. While some previous studies have identified barriers, the causal structure of such barriers has not previously been identified as we have now done: the present study provides sound guidance for which barriers influence other 'influenced' barriers, hence giving practitioners an understanding of where they should focus their efforts in implementing blockchain.

We conducted a literature review to identify significant barriers to achieving the above research objectives, as identifying the significant barrier helps adopt BT in the supply chain. However, the identified barriers are substantial and hence it is not practically feasible to mitigate them all simultaneously. Consequently, to successfully implement the BT in the supply chain, we need to develop a causal relationship map to provide for systematic mitigation of these barriers. In addition, once the cause and effect relationships between apparent barriers are known, organizations can utilize their resources in a more optimized manner related to the mitigation of these barriers. Identification of this causal structure of BT implementation barriers is a unique contribution of this study, especially in a developing economy from where we gathered our data, being India.

The remaining sections of this paper are structured as follows: Section 2 provides the background of the study and review of the relevant literature, section 3 provides the details of the research methodology applied in the study; section 4 deals with data analysis and result; section 5 gives the discussion about the findings; finally, section 6 delivers the conclusion, limitation and future scope of the study.

## 2 Background of the study

In the era of industry 4.0, BT is getting considerable attention among industry professionals and academicians. This technology has numerous benefits and applications across industries, from goods producers to service providers. Integrating SC is beneficial for efficient operations and reducing uncertainties. Blockchain deployment enhances the SC transaction by increasing transparency, security, traceability, and flexibility using smart contracts (Kosba et al. 2016). In supply chain management, there are five essential strategic priorities:

low cost, high processing speed, risk control, sustainability, and flexibility. These objectives of the SC can be achieved or enhanced to a certain degree through the implementation of BT. The specific characteristics of Blockchain, such as real-time exchange of information, cybersecurity, visibility, consistency, traceability, and transparency, are the primary reason behind the blockchain integration of SC. Aslam et al. (2021) studied the requirement of blockchain adoption and its impact on operational performance, demonstrating that operational performance positively links supply chain management practices.

Risius and Spohrer (2017) mentioned that "BT is a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors. This is functionally similar to a distributed ledger that is consensually kept, updated, and validated by all the transactions within a network by the parties involved. In such a network, BT enforces transparency and guarantees eventual, system-wide consensus on the validity of an entire history of transactions". This definition claim that BT works as "a digital logbook of transactions", which provide the most secure, consistent, safe, decentralized peer to peer sharing of information.

Existing studies in the SC perspective regarding blockchain applications are categorized into four major types: "conceptual", "descriptive", "predictive," and "prescriptive" research. For instance, Cole et al. (2019) studied BT and identified the potential areas of BT contribution to performance from a SC perspective. Further, they also highlighted the scope for future research, from which we derived motivation for this study, of shining a light on BT barriers and their interrelationships. Wang et al. (2020) proposed blockchain-based system architecture and found that BT can decrease the complexity of the management of SC.

Mohanta et al. (2019) identified privacy and security as the major challenges in implementing Blockchain using a literature review. Lu (2019) reviewed BT and identified the significant components of Blockchain, blockchain-enabled data management, blockchain-enabled security, BT-based IoT, and primary applications of Blockchain. Further, they also describe potential trends in BT and associated challenges. Helo and Hao (2019) reviewed BT and outlined potential immutable distributed ledgers in SC operations. Finally, Reyna et al. (2018) investigate the blockchain-enabled IoT challenges and examine how BT can advance IoT performance.

Zhang and Chen (2020) conduct a literature survey on IoTs, Blockchain, business analytics, and Industry 4.0 technologies. They considered Blockchain as a novel idea and most of the studies have been conducted in the last two to three years. From an academic perspective, Hassani et al. (2018) investigated the implementation of BT in banking and observed a substantial negative effect of Blockchain on banking because of less research and development. In cybersecurity and accounting, Demirkan et al. (2020a, b) studied the blockchain framework and observed that for financial security, cybersecurity and financial misconduct monitoring, and financial accounting, Blockchain would be used. BT is clearly demonstrated from the literature to be of potentially significant benefit to organisations and SC's efficiency, yet is still immature and needing to overcome barriers to change and perceived risks that always come with new technologies (Samson et al. 2022).

Lu (2018) observed that Blockchain gives us an enormous potential to construct data security and confidence for automation and knowledge development on the IoT. Based on blockchain-related insights, they claim that Blockchain could play a vital role in the planet's sustainable development. In addition, the numerous applications of BT, such as Internet of Things (IoT), smart contracts, healthcare, Industry 4.0, and digital assets, were established. Finally, Viriyasitavat and Hoonsopon (2019) describe Blockchain and evaluate its functionality and business processes. Moreover, this study recommended that the design of business processes can also address the problems of time inconsistency and consensus bias.

Blockchain is also implemented in the construction industry; for instance, Perera et al. (2020) examined the BT implementation in construction and mentioned that the conservative essence of this industry in digitalization and its resistance to adapt reduces the incorporation of Blockchain in this industry. They found that Blockchain has much potential in this industry. Viriyasitavat et al. (2019) recognize new research areas, challenges, and potential applications in incorporating Blockchain into the development of business process management through a literature review. Viriyasitavat et al. (2020) explore that Blockchain could be used to pass and authenticate the trust of businesses and partners and presents a system of business process management to assist in a timely, reliable, and economic evaluation. In a sense, IoT and Blockchain, describe the many problems of the business method. Many business process challenges are also identified for IoT and blockchain adoptions.

Some studies have attempted to create lists of BT barriers: Li et al. (2021) perform a literature survey of Blockchain applications and provide some research direction. Further, they also identified the major challenges, opportunities, and barriers to adopting industrial Blockchain. Lim et al. (2021) conducted the literature survey to explore the research area of the Blockchain in the context of supply chain management. The finding shows an increasing concern in using Blockchain for SC operations. Finally, Kamble et al. (2021) provided a decision support framework for policymakers to forecast the probability of a successful blockchain implementation by an organization using machine learning techniques.

Sanka et al. (2021) conduct literature surveys to assess the breakthrough in Blockchain and provides the major challenges for adoption, its applications, and future research direction. Saurabh and Dey (2021) focused on the grapewine SC and identified some significant drivers of implementing blockchain technologies. They found that disintermediation, traceability, expense, faith, enforcement, and alignment and control can affect the adoption-intention decision processes of SC actors. Finally, Agrawal et al. (2021) propose a blockchain-enabled traceability structure for traceability in the SC of multi-tier textiles and garments.

This review of literature determined that most studies, using a range of methodologies, pointed to the conceptual and in some instances practical benefits of BT, with only early stage research yet published on the details and nuances of BT drivers and barriers. Of those who list such drivers and barriers, we note that priorities of such are rarely published to date, and we also note that it is likely (but not yet empirically verified) that some barriers and more important than others, and that some are likely to be the (primary) drivers and influencers of (secondary) others. Clear knowledge of this will help to effect better and faster take-up of BT, hence research that contributes to this unanswered question is deemed to be valuable from both conceptual and practical bases. In short, our primary research question is: what are the primary cause and effect relationships between blockchain adoption barriers, that allows for identification of 'influencing' and 'influenced' barrier elements? We have chosen to focus on BT barriers rather than drivers, because the drivers are already relatively well demonstrated and indeed are somewhat obvious, at least in conceptual terms.

## 3 Research methodology

The present study's main aim is to identify the primary barriers to adopting BT in supply chain management and to evaluate the causal interrelationship between them. The significant barriers were identified through a literature survey and further evaluated using the grey Delphi method to fulfill these objectives. Additionally, the causal relationship between these barriers was determined through the DEMATEL method. Several methods exist to explore the causal relationship among the barriers, such as Interpretive Structural Modelling (ISM),

Total Interpretive Structural Modelling (TISM), and Decision Making Trial and Evaluation Laboratory DEMATEL (Khan and Haleem 2021). However, these methods have some limitations, for example, the ISM method can provide the causal interrelationship among the barriers, but it cannot measure relationship strength (Mathivathanan et al. 2021).

On the other hand, TISM is an extension of the ISM and has the same limitation, while DEMATEL does not have such limitations. Therefore, DEMATEL is a well-suited method to explore the causal interrelationship among the barriers to blockchain adoption (Khan et al. 2019). The proposed framework for this study is presented in Fig. 1.

This study is conducted in the context of developing countries, and experts are selected from India. This study utilises the two methods, grey Delphi and DEMETAL. Ten experts are participated in the grey Delphi method for the finalisation of the barriers and five experts among them participated in the DEMATEL analysis. The experts' details are provided in Table 1.

### 3.1 Grey delphi

Dalkey and Helmer (1963) developed the Delphi technique. It is a well-known survey approach for reaching consensus by integrating the opinions of experts on a particular problem. The Grey Delphi approach combines the Delphi and the theory of grey sets to overcome the limitation of the conventional Delphi method. The following are the steps of the grey Delphi:

**Step 1:** Identification of barriers

Reviewing relevant literature has identified a list of barriers associated with blockchain adoption in SC. These identified barriers serve as the basis for the questionnaire used to collect data from experts.

**Step 2:** Collection of responses through linguistic scale

Experts are expected to respond to the questionnaire using the corresponding scale using the linguistic scale. Table 2 provides the linguistic scale and its equivalent grey number.

**Step 3:** Establishing the grey numbers

According to Table 2, the collected responses are converted to corresponding grey values. This grey number is employed in subsequent processes. Suppose the evaluation panel is comprised of k experts. The evaluation of the factor $\otimes G_i$ can be obtained as follows:

$$\otimes G_i = \frac{(\otimes G_i^1 + \otimes G_i^2 + \cdots + \otimes G_i^h + \cdots + \otimes G_i^k)}{k} \tag{1}$$

Where $\otimes G_i$ is the overall assessment of barrier significance and $\otimes G_i^h$ denotes that h$^{th}$ expert's evaluation of barrier I of BT adoption in SC.

**Step 4:** Whitening of the grey numbers

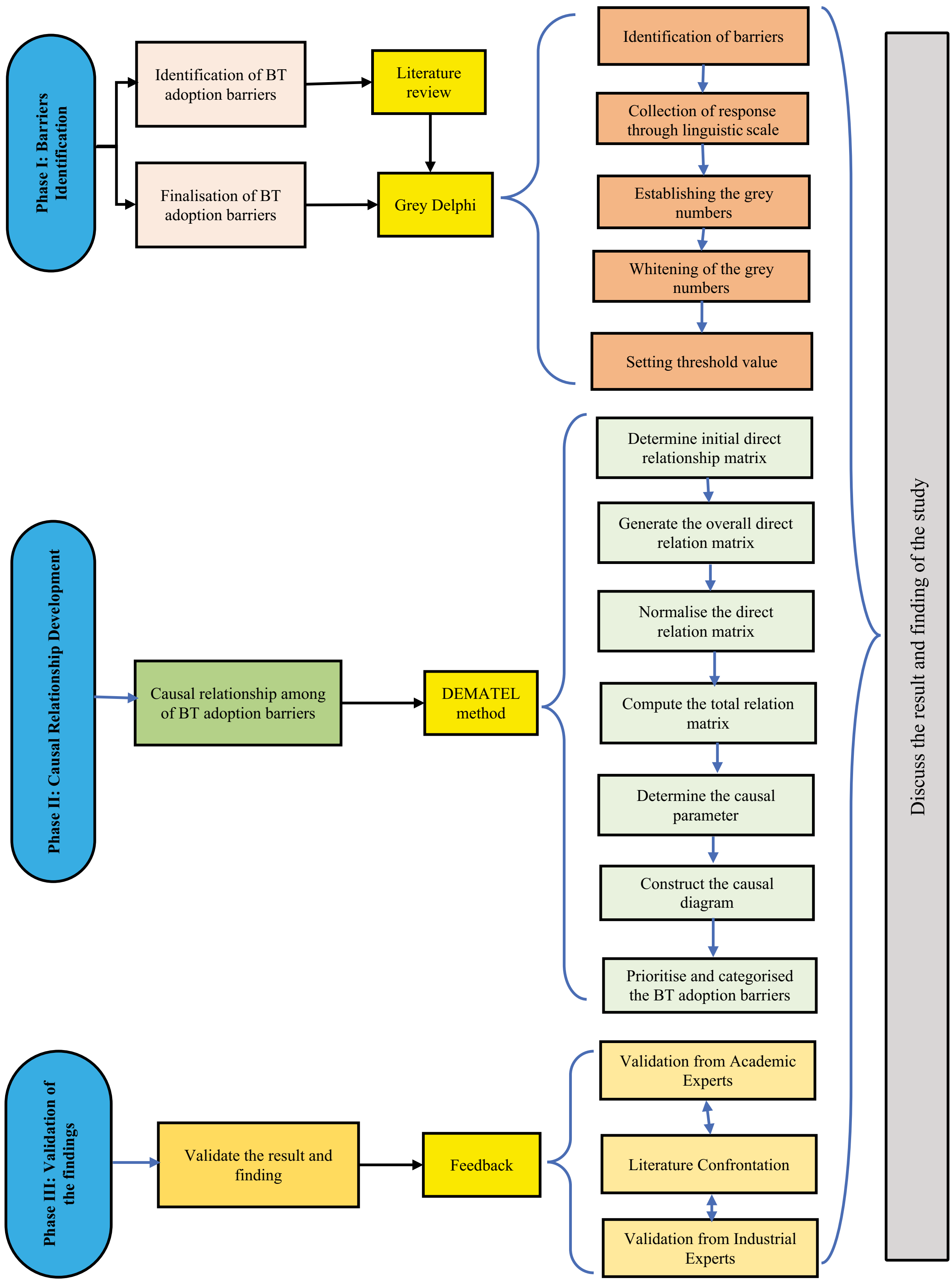



**Fig. 1** A proposed research framework for this study

**Table 1** Descriptive data about expert panelists

| S No | Designation | Work Experience in years | Country | Education | Gender | Working Area | Participated in Grey Delphi | Participated in DEMATEL |
|---|---|---|---|---|---|---|---|---|
| 1. | Professor | 32 | India | Doctorate | Male | Data Driven Supply Chain; Industry 4.0 | Yes | Yes |
| 2. | Professor | 15 | India | Doctorate | Female | Technology Transfer, Blockchain | Yes | No |
| 3. | Supply Chain Manager | 16 | India | Master of Technology | Male | Supply Chain Management; Industry 4.0 | Yes | Yes |
| 4. | Procurement Manager | 14 | India | Master of Business Administration | Male | Supplier selection, Procurement | Yes | No |
| 5. | Logistics Managers | 15 | India | Bachelor of Technology | Male | Smart logistics management; | Yes | Yes |
| 6. | Process Designer | 14 | India | Doctorate | Female | Technology integration and system design | Yes | No |
| 7. | Operations Managers | 18 | India | Master of technology | Male | Production and operations | Yes | No |
| | Blockchain designer | 12 | India | Master of Sciences | Male | Blockchain design and coding | Yes | Yes |
| 9. | Supply Chain Manager | 13 | India | Master of business Administration | Male | Supply chain management | Yes | No |
| 10. | Warehouse Manager | 18 | India | Master of Engineering | Female | Technology integration in warehouse and Smart warehousing | Yes | Yes |

The general interval grey number $\otimes G_i == [\underline{G}, \overline{G}] = [G' \in G | \underline{G} \leq G' \leq \underline{G}]$, considers the $\tilde{\otimes}$ as its whitenisation value. When the distribution of, $\tilde{\otimes}$ is uncertain/unkown, whitenisation may be accomplished using Eq. (2).

$$\tilde{\otimes} = \alpha.\underline{G} + (1 - \alpha).\overline{G}, = [0, 1] \tag{2}$$

The commonly used value of $\alpha$ is 0.5, $\tilde{\otimes}$ is known as 'whitenization', whose value equals the weighted mean (Liu and Forrest 2010).

**Step 5:** Setting threshold value

The selection/rejection of barriers concludes the grey Delphi procedure. The relevance of the factor is established by comparing the total score to a threshold value(λ). The rationale underlying the barrier selection procedure is if $\tilde{\otimes} \geq \lambda$,, then the factor is selected; else, it is rejected.

## 3.2 DEMATEL

DEMATEL was proposed to establish the causal interrelationship among the factors in 1976. Since then, it is widely used in various application areas such as supply chain management, traceability, smart city, healthcare, consumer behavior, and many more (Haleem et al. 2019; Medalla et al. 2021). The steps of the DEMATEL technique are presented as follows:

**Step I:** Develop the direct influence matrix

The influence of one barrier over others is determined using the experts through a questionnaire. In this study, an expert panel is formed who provided their responses to develop the direct influence matrix. For example, the influence of a barrier' i' over 'j,' by $k^{th}$ expert, have expressed through the 0-4 scale (0 -no influence and 4-very high influence), as shown in Table 3.

**Table 2** Linguistic scale and their associated grey number

| Linguistic scale | Very low important (VL) | Low important (L) | Medium important (M) | High important (H) | Very high important (VH) |
|---|---|---|---|---|---|
| Grey number | [0,1] | [1,2] | [2,3] | [3,4] | [4,5] |

**Table 3** Linguistic Scale for influential score

| Scale | Interpretation |
|---|---|
| 0 | No influence |
| 1 | Very low influence |
| 2 | Medium influence |
| 3 | High influence |
| 4 | Very high influence |

In this matrix, $x_{ij}$ implies the influence of barrier $i$ over barrier $j$ and the diagonal element is 0. For each respondent, an n×n matrix is acquired as $X^h = [x_{ij}{}^h]$ where h represents the h$^{th}$ experts ($1 \leq h \leq k$). In this manner, k number of matrices is get from k experts as $X^1, X^2, X^3 \ldots. X^k$.

**Step II:** Develop the overall direct-relation matrix using the input from $H$ experts, the average matrix $A = [a_{ij}]$ is obtained using Eq. (3)

$$a_{ij} = \frac{\sum_{h=1}^{k} x_{ij}^{h}}{k} \tag{3}$$

**Step III:** Create a normalized initial direct-relation matrix using the Eqs. (4) and (5)

$$D = A \cdot S \tag{4}$$

$$WhereS = \frac{1}{max_{1 \leq i \leq n} \sum_{j=1}^{n} a_{ij}} \tag{5}$$

**Step IV:** Develop the total relation matrix "T" using Eq. (6)

$$T = D \cdot (I - D)^{-1} \tag{6}$$

Where, "I" represents identity matrix

**Step V:** Calculate the causal parameters with Eqs. (7) and (8):

$$R_i = \sum_{j=1}^{n} t_{ij} \, for \, all \, i \tag{7}$$

$$C_j = \sum_{i=1}^{n} t_{ij} \, for \, all \, j \tag{8}$$

Where $R_i$ signifies the row-wise summation and $C_j$ implies the column-wise summation.

**Step VI:** Prominence and effect score is calculated from Eqs. (9) and (10):

$$P_i = R_i + C \tag{9}$$

$$E_i = R_i - C_i \tag{10}$$

The prominence score (Pi) implies that net influence barrier $i$ adds to the system and the effect score ($E_i$) shows the net effect of barriers on the system. If the effect score ($E_i = R_i - C_i$) is more than zero, barrier $i$ produces a net cause otherwise it is a net receiver. Prominence and effect score is utilized to develop the causal diagram by plotting the prominence score on x-axis and effect score on y-axis.

# 4 Results

## 4.1 Identification of the barriers of blockchain technology adoption in SC

Barriers to the BT implementation of the SC were identified through the literature review. The Scopus database is selected to identify the relevant articles because it is the largest scientific literature database. Afterward, we searched the keywords' supply chain management and 'Blockchain', 'blockchain technology, 'obstacles,' 'challenges' and 'barriers' in the Scopus database. The combination of these keywords are searched in TITLE-ABS-KEY field. The relevant literature is finalized by an initial review of the abstract and title of the article. Afterward, a comprehensive literature review is conducted, and thirteen barriers are identified for the blockchain implementation in the SC; these finalized barriers with their relevant references are shown in Table 4.

Based on this preliminary identification of barriers, a questionnaire was created to collect input from experts. These experts were requested to provide feedback on the applicability of these barriers in the context of emerging nations. In accordance with the grey Delphi method's procedures, experts' responses are gathered through questionnaires. Table 5 displays these results on the linguistic scale.

After receiving responses from an expert panel, we have translated the linguistic value to a grey number using Table 2. Finally, Table 6 displays the resulting grey matrix.

Moreover, the overall grey weight is determined using Eq. (1). Finally, using Eq. (2), the overall grey weight (crisp number) is whitened. These crisp data are utilized to select or reject the barriers for further analysis. If the crisp value is greater than 3.5, the barriers are included in the study; otherwise, they are excluded. Table 7 displays the overall grey and crisp weight and the decision.

In this manner, ten barriers are found relevant for adopting BT in the context of emerging economies. Further, the finalized barriers to blockchain adoption are presented in Table 8.

## 4.2 DEMATEL analysis

The finalized barriers to adopting BT for the management of SC are presented in Table 9. First, the Initial Direct

**Table 4** Barriers of blockchain technologies implementation in the supply chain

| S. No | Code | Barriers | References |
|---|---|---|---|
| 1. | **IBT1** | Blockchain adoption framework complexity | Balasubramanian et al. (2021), Stranieri et al. (2021), Vadgama and Tasca (2021) |
| 2. | **IBT2** | Scalability issue | Boutkhoum et al. (2021), Khan et al. (2022) |
| 3. | **IBT3** | Ineffective organizational policies | Mendling et al. (2017), Saberi et al. (2018) |
| 4. | **IBT4** | Communication gap among SC partners | Upadhyay et al. (2021a, b), Bragadeesh and Umamakeswari (2020) |
| 5. | **IBT5** | Data security protocol | Wamba and Queiroz (2020) |
| 6. | **IBT6** | Data Security and privacy | Lone and Naaz (2021), Mougayar (2016) |
| 7. | **IBT7** | High investment cost | Rana et al. (2021), Teodorescu and Korchagina (2021), Saberi et al. (2018) |
| 8. | **IBT8** | Trust management issue | Bader et al. (2021), Upadhyay et al. (2021a, b), Andoni et al. (2019) |
| 9. | **IBT9** | Online platform cost | Kumar and Prakash (2019) |
| 10. | **IBT10** | Lack of information sharing | Bader et al. (2021), Lim et al. (2021), Sengupta et al. (2019) |
| 11. | **IBT11** | Lack of technical recourse | Falcone et al. (2020), Kurpjuweit et al. (2019), Mougayar (2016) |
| 12. | **IBT12** | Lack of upgraded technologies | Tandon et al. (2020), Ferdous et al. (2019), Mangla et al. (2017) |
| 13. | **IBT13** | Lack of adequate knowledge about Blockchain | Benzidia et al. (2021), Falcone et al. (2020), Cole et al. (2019) |

Relationship Matrix (IDRM) is obtained from the expert panel. Five experts in the present study have expertise in supply chain management, technology adoption, and Blockchain. After getting the IDRM, the overall direct relationship matrix is developed with the help of Eq. (1) and shown in Table 5.

This IDRM is transformed into a Normalised Relationship Matrix (NRM) using Eqs. (2) and (3). The obtained NRM is demonstrated in Table 10.

The obtained NRM is transformed into a total relationship matrix (T) applying Eq. (4), which is presented in Table 11.

The threshold value has been computed to identify the significant relationship among the barriers. This threshold value is determined by adding the "average of the T matrix" and the "standard deviation of the T matrix." This threshold value supports this structure's differentiation and the causal map's development. If the values in the T matrix (see Table 11) are more than the threshold value, then the causal map is deemed to be drawn. This cause and effect map not only aids in determining the importance of one barrier over another but also allows minor effects to be filtered out of the causal effect map. The causal map of the blockchain technology adoption barriers is created and shown in Fig. 2 is constructed using the T matrix presented in Table 11. Figure 2 depicts the causal relationships between the barriers of blockchain technologies adoption. The nodes signify the barriers, and the arrow shows the direction of relationships along with the relationship weight. The relationship weight is provided over the directional arrow. The higher weights signify the strong relationship between the barriers. Further, it also shows the cause-and-effect barriers with two different colours.

In the total relationship matrix *T*, the row-wise summation (R) and column-wise summation (C) is performed using Eqs. (5) and (6) and shown in Table 12. Further, the prominence and effect scores are determined with the help of Eqs. (7) and (8), respectively.

**Table 5** Experts' assessment of barriers to BT implications

| IBT | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **IBT1** | M | H | H | VH | VH | VH | VH | M | H | H |
| **IBT2** | H | H | L | L | H | M | M | M | M | M |
| **IBT3** | H | H | VH | H | VH | VH | VH | VH | VH | VH |
| **IBT4** | VH | M | H | M | H | H | VH | H | VH | H |
| **IBT5** | M | L | H | H | M | L | VH | M | M | M |
| **IBT6** | H | H | M | H | H | M | VH | VH | H | VH |
| **IBT7** | H | H | VH | VH | H | VH | H | VH | M | H |
| **IBT8** | M | H | M | H | H | H | VH | VH | H | VH |
| **IBT9** | M | M | M | M | H | H | VH | H | L | M |
| **IBT10** | VH | VH | M | H | VH | VH | VH | VH | VH | H |
| **IBT11** | VH | H | M | VH | VH | M | H | M | M | H |
| **IBT12** | M | VH | H | H | VH | VH | VH | M | VH | VH |
| **IBT13** | M | VH | VH | M | VH | M | H | VH | H | VH |

**Table 6** Transformed Grey matrix

| ICFs | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **ICF1** | [2,3] | [3,4] | [3,4] | [4,5] | [4,5] | [4,5] | [4,5] | [2,3] | [3,4] | [3,4] |
| **ICF2** | [3,4] | [3,4] | [1,2] | [1,2] | [3,4] | [2,3] | [2,3] | [2,3] | [2,3] | [2,3] |
| **ICF3** | [3,4] | [3,4] | [4,5] | [3,4] | [4,5] | [4,5] | [4,5] | [4,5] | [4,5] | [4,5] |
| **ICF4** | [4,5] | [2,3] | [3,4] | [2,3] | [3,4] | [3,4] | [4,5] | [3,4] | [4,5] | [3,4] |
| **ICF5** | [2,3] | [1,2] | [3,4] | [3,4] | [2,3] | [1,2] | [4,5] | [2,3] | [2,3] | [2,3] |
| **ICF6** | [3,4] | [3,4] | [2,3] | [3,4] | [3,4] | [2,3] | [4,5] | [4,5] | [3,4] | [4,5] |
| **ICF7** | [3,4] | [3,4] | [4,5] | [4,5] | [3,4] | [4,5] | [3,4] | [4,5] | [2,3] | [3,4] |
| **ICF8** | [2,3] | [3,4] | [2,3] | [3,4] | [3,4] | [3,4] | [4,5] | [4,5] | [3,4] | [4,5] |
| **ICF9** | [2,3] | [2,3] | [2,3] | [2,3] | [3,4] | [3,4] | [4,5] | [3,4] | [1,2] | [2,3] |
| **ICF10** | [4,5] | [4,5] | [2,3] | [3,4] | [4,5] | [4,5] | [4,5] | [4,5] | [4,5] | [3,4] |
| **ICF11** | [4,5] | [3,4] | [4,5] | [4,5] | [4,5] | [2,3] | [3,4] | [4,5] | [2,3] | [3,4] |
| **ICF12** | [2,3] | [4,5] | [3,4] | [3,4] | [4,5] | [4,5] | [4,5] | [2,3] | [4,5] | [4,5] |
| **ICF13** | [2,3] | [4,5] | [4,5] | [2,3] | [4,5] | [2,3] | [3,4] | [4,5] | [3,4] | [4,5] |

As per the prominence and net effect score, the causal relationship map is constructed and illustrated in Fig. 3.

The importance order of each barrier is obtained through the DEMATEL method. The critical order of the barrier is 'Lack of information sharing' ≻ 'Trust management issue' ≻ 'Lack of upgraded technologies' ≻ 'Ineffective organizational policies' ≻ 'Communication gap among SC partners' ≻ 'Lack of technical recourse' ≻ 'Data Security and privacy' ≻ 'Lack of adequate knowledge about blockchain' ≻ 'Blockchain adoption framework complexity' ≻ 'high investment cost'. The important order of each barrier is shown in Fig. 4.

Further, the identified barriers are classified into "influential barriers" and "influenced barriers." The 'influential barriers' consist of five barriers: ' Lack of information sharing', 'Trust management issue' and 'Lack of upgraded technologies', 'Communication gap among SC partners' and 'high investment cost.' These barriers require more focus, which influences the other significant barriers. The most influential barrier is the 'Lack of information sharing' that would be a major concern of the SC partners. The SC partners are unwilling to share their information with other parties because they believe this crucial information can be misused. To overcome this barrier, there is a requirement to establish trust among the SC stakeholders. The next influencing barriers, ' Trust management issue,' are mitigated through cooperation and understanding of the need of current business scenarios. The implementation of the Blockchain itself increases the trust among the SC partners. The third influencing barrier is the 'Lack of upgraded technologies' that require high investment and extensive support from the top management. Without technological advancement and sufficient technical capability, Blockchain cannot be implemented at the SC level. Therefore, it is recommended that top management could put enough resources into implementing the Blockchain technological capability for long-term success. The next influencing barrier is the 'Communication gap among SC partners' that could be mitigated through effective communication with SC partners. The next influencing barrier is 'high investment cost', which could be a major concern, particularly for small enterprises. Our results show that in a developing country like India, some SC partners are not ready to invest in the high-cost advanced technologies like Blockchain. To motivate them to implement the Blockchain, there is a crucial requirement to create awareness about the benefits of BT. Since the investment requirement is viewed as a significant barrier, enhanced focus on business case creation and overall value determination should be a managerial focus.

The influenced group barrier includes the 'ineffective organizational policies', 'lack of technical recourse', 'data security and privacy, 'lack of adequate knowledge about blockchain', and 'lack of a framework for blockchain'. These influenced factors can be expected to be readily

**Table 7** Results of the grey Delphi method

| Initial Barriers | Overall Grey Weigh | Crisp Weight | Decision | Rename |
|---|---|---|---|---|
| **ICF1** | [3.2,4.2] | 3.7 | Select | BBT1 |
| **ICF2** | [2.1,3.1] | 2.6 | Reject | NA |
| **ICF3** | [3.7,4.7] | 4.2 | Select | BBT2 |
| **ICF4** | [3.1,4.1] | 3.6 | Select | BBT3 |
| **ICF5** | [2.2,3.2] | 2.7 | Reject | NA |
| **ICF6** | [3.1,4.1] | 3.6 | Select | BBT4 |
| **ICF7** | [3.3,4.3] | 3.8 | Select | BBT5 |
| **ICF8** | [3.1,4.1] | 3.6 | Select | BBT6 |
| **ICF9** | [2.4,3.4] | 2.9 | Reject | NA |
| **ICF10** | [3.6,4.6] | 4.1 | Select | BBT7 |
| **ICF11** | [3.3,4.3] | 3.8 | Select | BBT8 |
| **ICF12** | [3.4,4.4] | 3.9 | Select | BBT9 |
| **ICF13** | [3.2,4.2] | 3.7 | Select | BBT10 |

**Table 8** Finalised barriers of blockchain technologies with description

| S. No | Code | Barriers | Description |
|---|---|---|---|
| | **BBT1** | Blockchain adoption framework complexity | The structure for applying it is insufficient because BT is still in its initial stage in the context of SC. |
| | **BBT2** | Ineffective organizational policies | Adopting BT necessitates the establishment of new organizational standards to reflect shifting roles, responsibilities, and expertise. |
| | **BBT3** | Communication gap among SC partners | BT implementation is hampered by a lack of effective communication among SC stakeholders |
| | **BBT4** | Data Security and privacy | Cyber-attacks may result in the unauthorized access and dissemination of sensitive data |
| | **BBT5** | High investment cost | Adopting BT requires an organization to invest in new infrastructure for data collecting and processing, which is costly |
| | **BBT6** | Trust management issue | The SC partners are not willing to share the information due to a lack of trust |
| | **BBT7** | Lack of information sharing | Numerous businesses consider their data a competitive advantage and are reluctant to reveal critical information. |
| | **BBT8** | Lack of technical recourse | The Lack of technical skills in BT is a key barrier to its adoption for SC. |
| | **BBT9** | Lack of upgraded technologies | The absence of standardized tools, methods, and performance measurements complicates BT implementation in SC |
| | **BBT10** | Lack of adequate knowledge about Blockchain | Implementing BT in SC is difficult due to the theory and application for BT in different sectors. |

able to be mitigated, once the influencer barrier factors are effectively overcome. For example where the barriers related to trust, communication, technological knowledge and willing information sharing are mitigated, our results show that organisational policy barriers, lack of knowledge barriers, and technical barriers such as perceived security/ privacy barriers should be consequentially mitigated with more ease and effectiveness. Our study has thus demonstrated the causal relationships between barrier factors to BT implementation and these findings can have potential utility for professional purposes in a practical sense.

Our specific findings about barriers to BT implementation are not able to be directly benchmarked against most other such studies, because most others were conducted in developing countries, or across a mix of countries, whereas ours were specific to the developing nation of India. For example, the insights coming from Fig. 2 show that in India, lack of upgraded technologies is a barrier that is influenced by numerous other influencer barriers, and we acknowledge that this situation might be different in other, more developed economies.

## 5 Discussion and implications

### 5.1 International comparisons

It is reasonable to expect that barriers to BT adoption, and indeed drivers of the same might vary across industries and countries, because of the different settings, motivational factors and incentives (Cole et al. 2019), and capabilities within supply chains across such industries, sectors and countries. For example, emphasis in Balasubramanian et al. (2021) was placed on government directed policies and business readiness in Dubai, whereas in our data from

**Table 9** Initial relationship matrix

| Barriers | BBT1 | BBT2 | BBT3 | BBT4 | BBT5 | BBT6 | BBT7 | BBT8 | BBT9 | BBT10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **BBT1** | 0 | 3.75 | 2.25 | 3.125 | 1.625 | 2.125 | 3.625 | 1.125 | 0 | 2.125 |
| **BBT2** | 2.875 | 0 | 2.5 | 1.125 | 1.5 | 2.25 | 3.5 | 3.125 | 1.625 | 2.375 |
| **BBT3** | 0.375 | 2.625 | 0 | 3.125 | 1.125 | 3.875 | 3.125 | 0 | 1.125 | 0 |
| **BBT4** | 0.125 | 1.125 | 2.125 | 0 | 1.375 | 3.125 | 3.75 | 1.125 | 2.75 | 1.125 |
| **BBT5** | 1.125 | 0 | 1.125 | 1.125 | 0 | 2.625 | 1.875 | 0.75 | 1.5 | 0 |
| **BBT6** | 0.125 | 2.125 | 3.125 | 2.375 | 1.125 | 0 | 3.625 | 0 | 3.125 | 1 |
| **BBT7** | 1.125 | 2.125 | 1.25 | 0.125 | 0.125 | 3.375 | 0 | 1.125 | 4 | 2.25 |
| **BBT8** | 0.125 | 3.125 | 1.125 | 3.25 | 1.75 | 2.125 | 1.125 | 0 | 3.625 | 2.125 |
| **BBT9** | 0.125 | 1.75 | 2.125 | 1.125 | 2.625 | 1.125 | 2.125 | 3.25 | 0 | 3.125 |
| **BBT10** | 1.75 | 1.125 | 1.125 | 0.625 | 2.75 | 3.125 | 1.125 | 2.125 | 2.125 | 0 |

**Table 10** Normalised relationship matrix

| Barriers | BBT1 | BBT2 | BBT3 | BBT4 | BBT5 | BBT6 | BBT7 | BBT8 | BBT9 | BBT10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **BBT1** | 0 | 0.1571 | 0.0942 | 0.1309 | 0.0681 | 0.0890 | 0.1518 | 0.0471 | 0.0000 | 0.0890 |
| **BBT2** | 0.1204 | 0 | 0.1047 | 0.0471 | 0.0628 | 0.0942 | 0.1466 | 0.1309 | 0.0681 | 0.0995 |
| **BBT3** | 0.0157 | 0.1099 | 0 | 0.1309 | 0.0471 | 0.1623 | 0.1309 | 0.0000 | 0.0471 | 0.0000 |
| **BBT4** | 0.0052 | 0.0471 | 0.0890 | 0 | 0.0576 | 0.1309 | 0.1571 | 0.0471 | 0.1152 | 0.0471 |
| **BBT5** | 0.0471 | 0.0000 | 0.0471 | 0.0471 | 0 | 0.1099 | 0.0785 | 0.0314 | 0.0628 | 0.0000 |
| **BBT6** | 0.0052 | 0.0890 | 0.1309 | 0.0995 | 0.0471 | 0 | 0.1518 | 0.0000 | 0.1309 | 0.0419 |
| **BBT7** | 0.0471 | 0.0890 | 0.0524 | 0.0052 | 0.0052 | 0.1414 | 0 | 0.0471 | 0.1675 | 0.0942 |
| **BBT8** | 0.0052 | 0.1309 | 0.0471 | 0.1361 | 0.0733 | 0.0890 | 0.0471 | 0 | 0.1518 | 0.0890 |
| **BBT9** | 0.0052 | 0.0733 | 0.0890 | 0.0471 | 0.1099 | 0.0471 | 0.0890 | 0.1361 | 0 | 0.1309 |
| **BBT10** | 0.0733 | 0.0471 | 0.0471 | 0.0262 | 0.1152 | 0.1309 | 0.0471 | 0.0890 | 0.0890 | 0 |

India, where information technologies are relatively well developed in rapidly developing and competitive markets, key factors were more at the organisational level of information sharing, trust, information technological and capability, and organisational capabilities.

An example of differences in industry context and its impact on blockchain barriers comes from Kurpjuweit et al. (2019), who examined BT in the additive manufacturing field in particular, determining that lack of technical expertise was the major barrier, as well as blockchain-skilled specialists and governance mechanisms being absent, as compared with our findings in the context of Indian industry in general, where these factors were much less prominent, compared with information sharing and trust challenges. From the studies that we reviewed, it is reasonable to conclude that context matters, because the regulatory situation, the business sophistication and internal business readiness, as well as the style of relationships between supply chain partners does vary across sectors and countries.

We note that while some contextual differences exist across countries and industries, that overlapping similarities can be reasonably expected, such as in the reported results from, who comment on the need for a culture of collaboration, which, if not present, could be a common barrier, wherever the industry and country.

This research identifies significant barriers to implementing BT in the SC, and the relationships between these barriers. The identified barriers should be mitigated for the successful adoption of BT in supply chain management. These causal relationships among the barriers helps the SC managers and policy planners to mitigate these barriers by knowing those that influence others. This research suggests that we can impact and control the influenced group barriers by controlling the influential group barriers, hence providing the knowledge that makes overcoming such barriers more effective. This research also provides the advantages and requirements of the BT that encourage SC stakeholders to implement the BT in their respective SC. The causal relationship among the barriers helps the managers to prepare the action plan and tactics more effectively.

### 5.2 Implications for government and industry

Policy implications come from our study for both government / regulators, and for businesses. For government, that sets the contextual conditions for new technology adoption, several strategies are possible to contribute to reduction in the height of barriers, such as fostering trust in industry, for example through convening roundtables for industry groups,

**Table 11** Total relationship matrix

| Barriers | BBT1 | BBT2 | BBT3 | BBT4 | BBT5 | BBT6 | BBT7 | BBT8 | BBT9 | BBT10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **BBT1** | 0.0996 | 0.3425 | 0.2876 | 0.2906 | 0.2164 | 0.3592 | 0.4153 | 0.1933 | 0.2521 | 0.2500 |
| **BBT2** | 0.2082 | 0.2199 | 0.3039 | 0.2342 | 0.2254 | 0.3724 | 0.4158 | 0.2754 | 0.3230 | 0.2725 |
| **BBT3** | 0.0879 | 0.2559 | 0.1639 | 0.2520 | 0.1613 | 0.3598 | 0.3438 | 0.1163 | 0.2458 | 0.1351 |
| **BBT4** | 0.0791 | 0.2105 | 0.2485 | 0.1401 | 0.1827 | 0.3426 | 0.3658 | 0.1678 | 0.3171 | 0.1870 |
| **BBT5** | 0.0867 | 0.1090 | 0.1513 | 0.1374 | 0.0789 | 0.2397 | 0.2176 | 0.1027 | 0.1895 | 0.0895 |
| **BBT6** | 0.0832 | 0.2471 | 0.2864 | 0.2304 | 0.1743 | 0.2293 | 0.3667 | 0.1306 | 0.3263 | 0.1832 |
| **BBT7** | 0.1197 | 0.2477 | 0.2157 | 0.1488 | 0.1428 | 0.3390 | 0.2191 | 0.1752 | 0.3491 | 0.2327 |
| **BBT8** | 0.0930 | 0.2980 | 0.2324 | 0.2814 | 0.2218 | 0.3289 | 0.2980 | 0.1492 | 0.3667 | 0.2433 |
| **BBT9** | 0.0876 | 0.2369 | 0.2468 | 0.1945 | 0.2410 | 0.2796 | 0.3048 | 0.2550 | 0.2151 | 0.2627 |
| **BBT10** | 0.1392 | 0.2043 | 0.2045 | 0.1694 | 0.2339 | 0.3284 | 0.2600 | 0.1992 | 0.2754 | 0.1327 |

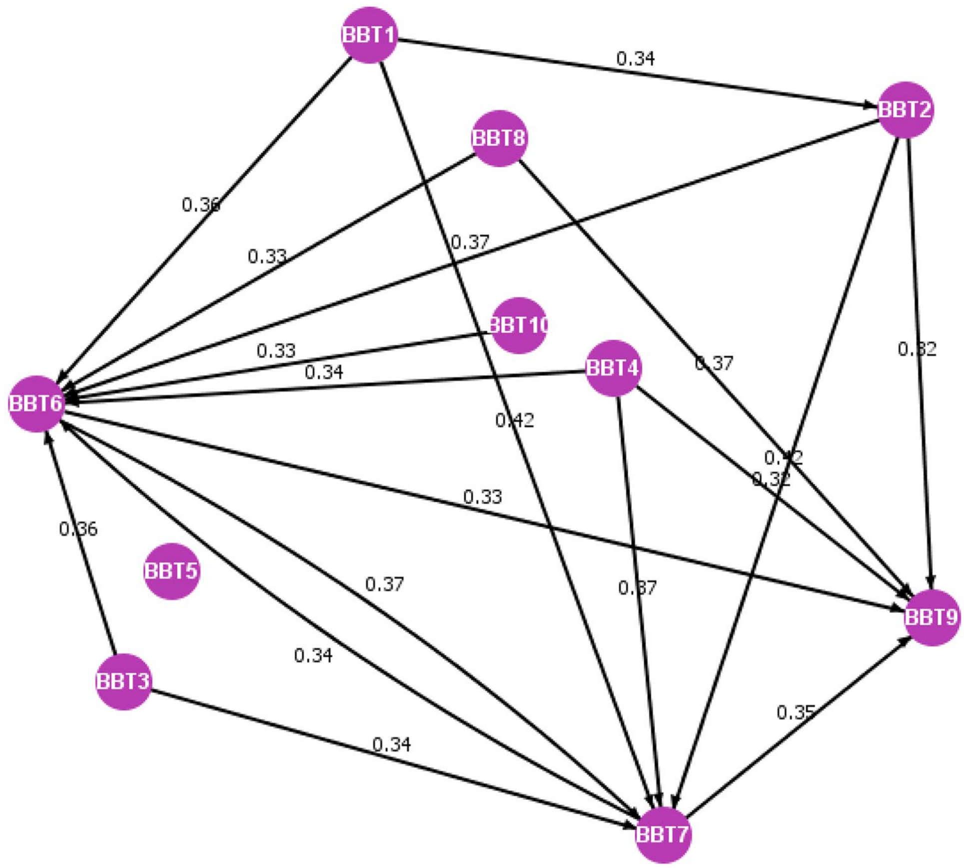



**Fig. 2** Network relationship Map for the barriers to blockchain technology adoption

and providing BT education programs and improved information infrastructure. Government also has a role to play in overseeing data security standards.

For executives in businesses, overcoming the primary barriers such as lack of preparedness to share information and to trust counterparties can be mitigated by placing additional effort into relationship building, aligning incentives and co-investing in BT. Third party technologies and training can be used to source expertise and hence overcome that barrier. With that knowledge will come increased confidence in such new technologies such as BT, and a collective view within supply chains that BT can be used to develop win-win outcomes, through data and knowledge sharing. For some businesses that may have a tradition of keeping information 'secret', they may benefit from a formal business case evaluation of BT, that clearly articulates net benefits and provides the impetus to make a step change in their information policies and culture. While every business and every supply relationship is to some extent unique, the findings of this study provide a solid context of the barrier factors that can be checked by policy makers and business leaders, in order to anticipate and assist in mitigating potential implementation blockages and problems.

**Table 12** Cause and effect of barriers to the adoption of BT

| Barriers | R | C | R+C | R-C | Cause/ Effect |
|---|---|---|---|---|---|
| **BBT1** | 2.7066 | 1.0841 | 3.7908 | 1.6225 | Cause |
| **BBT2** | 2.8506 | 2.3718 | 5.2224 | 0.4788 | Cause |
| **BBT3** | 2.1219 | 2.3410 | 4.4629 | -0.2192 | Effect |
| **BBT4** | 2.2411 | 2.0788 | 4.3200 | 0.1623 | Cause |
| **BBT5** | 1.4023 | 1.8787 | 3.2810 | -0.4763 | Effect |
| **BBT6** | 2.2576 | 3.1789 | 5.4364 | -0.9213 | Effect |
| **BBT7** | 2.1899 | 3.2069 | 5.3967 | -1.0170 | Effect |
| **BBT8** | 2.5128 | 1.7647 | 4.2776 | 0.7481 | Cause |
| **BBT9** | 2.3239 | 2.8600 | 5.1839 | -0.5361 | Effect |
| **BBT10** | 2.1470 | 1.9888 | 4.1358 | 0.1582 | Cause |

Fig. 3 Causal relationships among barriers of BT adoption in the supply chain

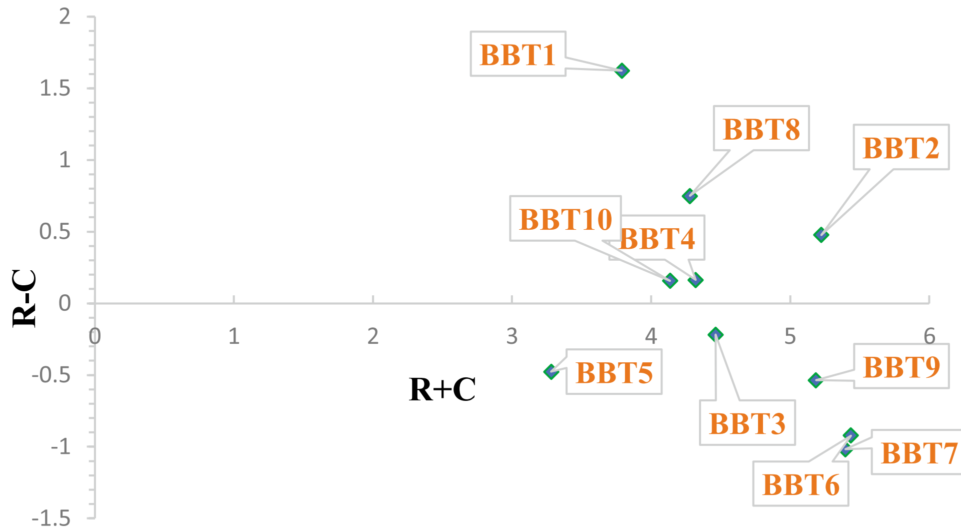
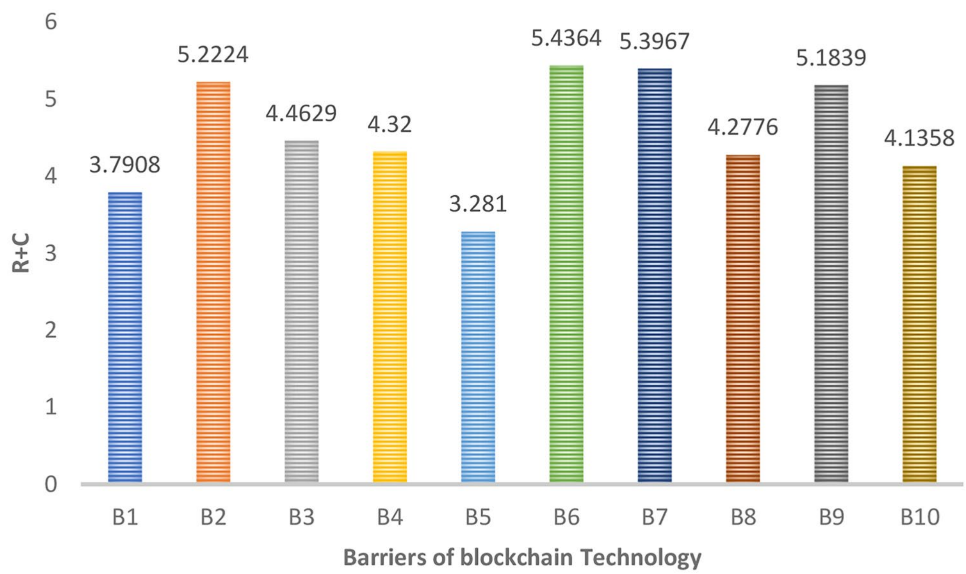



Fig. 4 Ranking of the barriers to BT implementation in the supply chain




## 6 Conclusion, limitation, and suggestions for future research

This study's objective was to identify and assess the causal relationship among the barriers to adopting BT in the SC. The literature review recognized ten primary barriers to blockchain adoption in the SC to accomplish this objective. These significant barriers to adopting BT were confirmed and analytically finalized by the grey Delphi method. After that, the causal interrelationship between them was developed using the DEMATEL method. The adopted methodology also categorized the identified barriers into an influential and influenced group. The influential group contains five barriers, and the remaining five were classified into the influenced group. Managerial implications were drawn from these findings, based on this cause-effect knowledge as generated.

The study has certain limitations, such as the barriers being finalized through a literature survey and expert opinions. Thus, there is always a possibility of overlooking some potential barriers in the article's selection and review. Further, the evaluation is based on expert feedback, which could be biased, despite the study design efforts to minimise such bias. These shortcomings can be eased by broadening the literature review process so that certain relevant barriers can also be captured. We propose that interviews with industry practitioners who have implemented BT, and the construction of both quantitative (survey) based research, and qualitative case studies will build on this present study to further validate and refine our collective understanding of BT barriers. Given the business and supply chain potential of BT, such further refinement of knowledge about blockchain barriers is much warranted. This study is based on expert views from a developing nation, India, where barriers might be expected to different than in other regions such as developed nations in Europe and USA, hence we suggest that studies that explicitly compare barriers across these regions will be useful in future. In addition, such comparative and benchmarking studies will lead to learning across regions and economy classifications, that will also add to collective knowledge and expertise. Further studies should also include case studies of how such barriers were overcome or mitigated at the individual firm or supply chain level.

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## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.



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