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## Article

# A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology

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## GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

# A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology

Gurudutt Nayak<sup>1,2\*</sup> and Amol S. Dhaigude<sup>1</sup>

**Abstract:** This paper proposes a conceptual model of sustainable supply chain management (SSCM) in small and medium enterprises (SME) using blockchain technology (BT). With growing focus on sustainable business process, research on SSCM is gaining prominence. BT, being a disruptive technology, has potential to impact the SSCM. Using the extant literature, the antecedents of SSCM using BT have been identified. Multiple-criteria decision-making has been deployed to develop the conceptual model. Various managerial and theoretical implications along with scope for future research have been discussed.

**Subjects:** Supply Chain Management; Small and Medium Enterprises; Technology Adoption; Multi-Criteria Decision Making; Sustainability

**Keywords:** sustainable supply chain management; blockchain technology; triple bottom line; sustainability; supply chain performance; conceptual model

**Jel Classification:** M150; M110; M100

### 1. Introduction

Sustainable supply chain management (SSCM) has gained substantial attention from both researchers and practitioners (Carter & Liane Easton, 2011; Carter & Rogers, 2008; Li, Pan, Kim, Linn, & Chiang,

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### PUBLIC INTEREST STATEMENT

This paper identifies critical success factors that play an important role in adopting sustainable supply chain management using blockchain technology. We use MCDM approach to examine the interrelationships among these critical success factors based on inputs obtained from nine industry experts and two academicians. The findings demonstrate that “Culture”, “Competition” and “Financial Constraints” form the foundation of the model while “Government Support”, “Supplier Acceptance” and External Stakeholders” are dependent and do not influence any critical success factors. In addition, ICT forms the crucial link among the factors and has significant impact on the adoption of sustainable supply chain management using blockchain technology.

2015; Perez-Sanchez, Barton, & Bower, 2003; Roy, Schoenherr, & Charan, 2018) over the period. SSCM answers the call for sustainable development by regulators, corporations, and consumers, given that it focusses on a triple bottom-line, namely environmental, social and economic performance (Golobic & Smith, 2013). SSCM is increasingly being seen as a means to empower firms and gain “competitive position” in the marketplace (Khodakarami, Shabani, Saen, & Azadi, 2015). However, transforming from traditional supply chain management (SCM) to SSCM in SME creates a significant pressure on organizations to modify their existing supply chains to meet sustainability needs (Schrettle, Hinz, Scherrer-Rathje, & Friedli, 2014). Sustainability theory directs organizations to incorporate various types of practices including return of product to producer at the end-of-life; eco-friendly handling of returns (Zhu, Sarkis, & Geng, 2005); diffusing environmental-friendly strategies at each level of the supply chain (Rostamzadeh, Govindan, Esmaili, & Sabaghi, 2015); and ensuring transparency, fair compensation and value for human life (Wolf, 2014).

Practitioners and academicians worldwide are struggling with the design and development of a sustainable supply chain. As the nature of the supply chain is complex consisting of multi-echelon, physically separated entities trying to maximize their own gains, implementing SSCM in SME becomes all the more challenging. This complexity is further fueled by uncertainties due to factors such as globalization, varied regulatory policies, irrational human behavior, cultural influences, etc. (Ivanov, Dolgui, & Sokolov, 2018). Inefficient transactions, deception, pilferage, and underperforming supply chains lead to trust deficiency and call for a transparent system, capable of providing real-time information-sharing along with verifiability.

In the current state, supply chains are dependent on systems such as enterprise resource planning (ERP) that stores all the information at one central place for most of the time. This ERP or allied systems have their own shortcomings. Moreover, the lack of trust among the supply chain members complicates things even further. Single point failure is another shortcoming of this centralized system making it susceptible to attack, corruption and hacking (Dong et al., 2017). In the realm of SSCM, there is a strategic importance to the validation and verification, which is that processes, products, and events within the supply chain should match certain sustainability criteria and certifications (Grimm, Hofstetter, & Sarkis, 2016). So, the key question is whether the current supply chain information systems can support the information required for the timely provenance of goods and services in a secure manner which is clear and robust enough to trust. The solution to this complex problem lies in enhancing supply chain transparency, safety, resilience, and process veracity. The answer to this problem may be blockchain technology (BT).

BT is an emerging technology that is disrupting the marketplace and expanding business horizons. BT uses a decentralized “trustless” database that permits for high volume transactions and process disintermediation, as also decentralization between contracting members (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). Blockchain has all the properties that can enable disparate supply chain members to coordinate their actions to achieve a collective goal. For example, global logistical giant, Maersk, was able to save billions of dollars after partnering with IBM for its maritime container management through blockchain. In case of SSCM, transparency and validity of the sustainable practices can be enhanced using BT. For example, tracing possible social and ecological conditions that might pose safety, health or environmental apprehensions is a significant application area for BT (Adams, Kewell, & Parry, 2018). However, BT, like any other disruptive technology, is facing adoption issues in supply chain networks in SME especially on the technological, behavioral, policy-oriented and organizational fronts (Crosby et al., 2016; Lemieux & Lemieux, 2016; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). These issues need to be explored further as they impact both practice and study. In this paper, we strive to model the CSF required to implement BT in SSCM. More specifically, this study tries to answer following two questions:

RQ1: What are the CSFs for adopting sustainable supply chain management in SME using blockchain technology?

RQ2: How these CSFs are interlinked with each other?

We use interpretative structural modelling (ISM) and the Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (MICMAC) method to model the CSF and capture their interrelations. Systematic literature review and discussion with industry experts are conducted to identify the CSF required to implement BT in SSCM. Structured questionnaire and cross-sectional survey design are adopted to collect data. Results indicate that the "top management" support factor is driven by competition, culture and financial constraints. Top management further influences the Infrastructure, and Planning & Execution team, which in turn influence ICT. Results also show that Supplier acceptance, External shareholders and Government support are most influenced by other factors. MICMAC analysis shows that ICT is the most crucial factor, whereas factors such as Government support, Supplier acceptance, Customer acceptance, External stakeholders and People are the dependent factors.

This study makes a few significant contributions to the SSCM and technology adoption literature. To the best of our knowledge, this is the first study of its kind to model the CSF required to implement BT in SSCM. This study explores the changing roles of the supply chain members and their complex interrelationships that occur while implementing BT in SSCM. These findings will open new frontiers of debate for both academicians and practitioners, for example, issues such as decrease in opportunistic behavior of supply chain members, trust-less environment of transactions, regulatory support for smart contracts, social responsibility of BT, etc.

The rest of the paper is divided into six sections: Section 2 presents literature review. Section 3 details the methodology adopted, and data collection and analysis. Section 4 presents discussions and managerial implications. Section 5 summarizes the findings, lists the limitations of the study and provides direction for future research.

## 2. Literature review

### 2.1. Sustainable supply chain management

Supply chain is defined as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flow of products, services, finances, and/or information from a source to a customer" (Mentzer et al., 2001, p. 4). On a conceptual level, supply chain Management (SCM) is nothing but managing these flows to create value for the partnering firms and the ultimate customer. Mentzer et al., (2001, p. 18) in their seminal paper define SCM as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". SCM is one of the core value-adding activities of the business, which has attracted attention of industry practitioners and scholars. SCM literature is enriched with research threads, such as supply chain integration (e.g., Flynn, Huo, & Zhao, 2010; Gunasekaran & Ngai, 2004), supply chain coordination (e.g., Cachon & Lariviere, 2005; Kanda & Deshmukh, 2008) agile supply chain (e.g. Prater, Biehl, & Smith, 2001; Swafford, Ghosh, & Murthy, 2006), supply chain performance (e.g. Beamon, 1999; Gunasekaran, Patel, & McGaughey, 2004), design of supply chain (Sharma, Ingalls, Jones, & Khanchi, 2013), etc. The increasing trend on sustainability has shifted attention on SSCM.

SSCM can be defined as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria" (Seuring & Müller, 2008, p. 1700). SSCM is a critical junction on which merges the triple bottom-line namely, environmental, social and economic performance (Golicic & Smith, 2013). Academic debate on SSCM is limited and therefore the subject requires further research attention (Ansari & Kant, 2017; Brandenburg, Govindan,

Sarkis, & Seuring, 2014; Carter & Rogers, 2008). Researchers have explored SSCM prominently in a manufacturing context compared to the services arena (Hassini, Surti, & Searcy, 2012). Food-based and automobile-based SSCM are relatively explored in detail. SSCM literature has been extensively studied using an interdisciplinary and mix method approach, for example, case studies, conceptual/theoretical modelling, survey-based and interview-based (e.g., Dubey et al., 2017; Svensson, 2007) studies. The impact of SSCM on supply chain performance shows mixed results. One strand of literature argues that SSCM leads to economic gains as it increases energy efficiency, enhances goodwill and brand value, results in cost-cutting, etc. (Ageron, Gunasekaran, & Spalanzani, 2012; Ahi & Searcy, 2013; Golicic & Smith, 2013; Green, Zelbst, Meacham, & Bhadauria, 2012; Wang & Sarkis, 2013; Zailani, Jeyaraman, Vengadasan, & Premkumar, 2012). However, another strand of literature opines that SSCM is difficult to design and implement and it creates significant pressure on the supply chain members to alter their behavior, leading to not so positive impacts on the overall supply chain in SME (e.g., Pagell & Shevchenko, 2014; Zhu, Sarkis, & Lai, 2007). The complexity of SCM is gradually increasing and factors such as globalization, cyber-attacks, opportunistic behavior of partners are making SSCM implementation in SME even more difficult. Table 1 summarizes the key papers on SSCM.

## 2.2. Blockchain technology

BT is the new buzzword in technology. In fact, it is BT that is the power behind the digital cryptocurrency, Bitcoin (Nakamoto, 2008). Bitcoin is just one use of BT, the technology is also disrupting business operations including supply chain practices (Tian, 2016). BT is a disseminated database of records or joint public/private ledgers of all digital events that have been performed and shared amid participating members (Crosby et al., 2016) of BT. The distributed ledger technology is the foundation of BT. The original copies and value are moved as the chain extends, unlike the Internet where information and multiple copies traverse the network. In BT, value is captured by recording the transactions in a shared ledger and these are secured by transparent and auditable time-stamped decentralized information (English, Auer, & Domingue, 2016).

It is interesting to note that in the decentralized ledger system, users can be anonymous (public network) or visible (private network, say a supply chain network). The public and private networks have one key difference and that is access to the ledger. In a public network, each user has a copy of the ledger and participates in the conforming transactions independently whereas in case of a private network, participants require permissions to keep the copy of the ledger and participate in the confirming transactions.

In BT, an agent makes a new transaction which is to be included in the blockchain. The new transaction is broadcast to all the members for verification. When majority of the members or nodes approve the new transaction, it is added as a new block. This approval is based on some pre-specified rules (Smart contract) and cannot be changed without the consent of all people in the network. The smart contract, one of the key features of BT, empowers the agents to conduct an authenticated transaction without the involvement of any third-party. A smart contract is naturally a software program that supplies rules and policies for negotiating terms and actions among agents. It automatically authenticates whether the contractual terms are met and accomplishes various transactions (Delmolino, Arnett, Kosba, Miller, & Shi, 2016). Once the new block is added, its record is saved at multiple nodes (disintegrated approach) to create a trust chain and to enhance security. Decentralization makes the system immune to backups. Moreover, BT guarantees transparency without causing any behavioral changes among the participant agents, thereby leading to greater trust in the overall network. This is the key driving factor for improving supply chain performance. How BT will change SCM is uncertain and needs further research (Saber, Kouhizadeh, et al., 2018a) attention. BT will be very effective for designing, organizing, and planning the general management and operations of supply chains. According to Baker and Steiner (2015), four new entities namely, registrars, standards organizations, certifiers and actors will play major roles in SSCM using BT.

Every product will have a digital blockchain presence that will aid all the actors to access product portfolios and their transactions history. A digital identifier will link the physical product to its



**Table 1. Summary of the key SSCM papers**

Sr. No.	Authors	Year of publication	Journal Name	Key findings
1	Murphy, Poist & Braunschwig	1994	Transportation journal	One of the first studies to assess the adverse effect of transportation industry on environment; It advocates the 3 'R's namely recycling, reducing and reusing to minimize adverse effect.
2	Linton, Klassen & Jayaraman	2007	Journal of Operations Management	Provides the background and how sustainability can be integrated with operations management, paving way for future research prospects.
3	Seuring & Müller	2008	Journal of cleaner production	The first systematic literature to propose conceptual framework for SSCM literature. This paper indicates that researchers have focused only on green aspects and failed to integrate the social aspects of sustainability while indulging in SSCM initiatives.
4	Carter & Rogers	2008	International journal of physical distribution & logistics management	The triple bottom-line performance was introduced in the logistics literature within the framework of SSCM; Enhanced the theory of SCM.
5	Krause, Vachon & Klassen	2009	Journal of supply chain management	Highlighted the strategic roles of supply chain partners, especially in the purchasing domain, to coordinate the SSCM initiatives in the short- and long-term. Cost trade-offs and the need to communicate about SSCM practices are also clearly outlined.
6	Pagell & Wu	2009	Journal of supply chain management	Created a model to build an SSCM by benchmarking with top 10 SSCM firms. The behavioral changes to be adopted while continuing the best practices in traditional SCM is also strongly recommended.
7	Wolf	2011	Journal of Business Ethics	Provided a model for SSCM integration using the German manufacturing sector as the base; also focused on the strategic importance of the customer and supplier buy in for SSCM practices.
8	Wu & Pagell	2011	Journal of operations management	Explored the trade-offs between the short-run and long-run sustainability goals and offered solutions to balance them.
9	Seuring	2013	Decision support systems	This paper highlights the research methodologies adopted in SSCM research and recommends the need for conducting empirical research. It also highlights the lack of attention to the social side of SSCM.
10	Pagell & Shevchenko	2014	Journal of supply chain management	Critiqued the traditional backward approach SSCM of neglecting the trade-offs and innovations. Five strategies were suggested to effectively implement SSCM.

(Continued)

**Table 1. (Continued)**

Sr. No.	Authors	Year of publication	Journal Name	Key findings
11	Silvestre	2015	International Journal of Production Economics	Studied SSCM in a developing country setting using the case study approach and argued that SSCM depends on organizations' trajectory and time; also focused on institutional voids in developed countries and the slow learning curve.
12	Dubey et al.	2017	Journal of cleaner production	Carried out systematic literature review and identified 12 drivers of SSCM. These drivers were modelled using TISM and MICMAC to establish the relationship between them.

Source: Developed by authors

online identity (Abeyratne & Monfared, 2016). Using smart contracts, agents would be able to modify events like ownership of the product, value-added services, certifications, quantity, quality, locations, etc. (Abeyratne & Monfared, 2016). BT will help the upstream and downstream flows of material and information in a reliable and transparent manner and this will have compounding positive outcomes, such as higher level of customization, reduced cost of surveillance, and holistic management practices to serve the ultimate customer (Tian, 2016). And finally, the sustainability initiatives will effectively be implemented across the entire supply chain using BT to achieve the economic, environmental and social performance, i.e., the triple bottom-line targets.

Tracking probable environmental and social situations that might create an environmental, social, safety or health hazard is a crucial application of BT (Adams et al., 2018). The economic benefits are easier to observe and there are several instances that prove that BT is helpful in increasing the wealth of the partnering firms (e.g., Lemieux, 2016; Mettler, 2016; Underwood, 2016). In terms of sustainable performance, BT can ensure compliance with human rights, and fair, safe work practices by curbing malpractices. For example, a clear record of product history helps purchaser confidence that goods being obtained are from ethical sources. In terms of environmental concerns, the adoption of BT in SSCM can do wonders. It can bring down product recall and even if there is a recall, it can be smoothly managed. Efficient energy systems such as Echchain and ElectricChain will help to reduce greenhouse gas emissions (futurethinkers, 2017). The authentication of the environmental-friendly product can be done at any level and in real-time. This will give the buyers confidence and increases their willingness to pay. Moreover, the recycling initiatives, which are treated as a black box, can be used effectively. Environment-conscious consumers can also track movement and source of goods, thus build goodwill for the brand following sustainability practices. There are several other things that can be added to the list, such as emission trading schemes, supply chain governance, carbon tax trading, etc., all of which will help to achieve environmental performance.

Even though the advantages of using BT in SSCM have been extensively listed, its adoption in SME is relatively slow in actual practice. Being a disruptive technology, people have apprehensions about BT's use in SSCM. Supply chain members need to understand and plan for these challenges. Based on published literature, we have identified the following CSF for BT in SSCM. The feedback of experts was also considered while preparing the final list of CSF. These factors are listed in Table 2.



**Table 2. CSF for SSCM implementation**

CSF	Conceptualization	Source
Top Management support	Top Management is the apex body, comprising of the board of directors responsible for formulating the mission and vision of the organization. The members are the strategic decision-makers and are primarily responsible for designing and implementing the sustainability culture in the organization.	Diabat, Kannan, and Mathiyazhagan (2014); Faisal (2012); Gopalakrishnan, Yusuf, Musa, Abubakar, and Ambursa (2012); Jabbour and de Sousa Jabbour (2016); Luthra, Garg, and Haleem (2015); Wolf (2011)
Infrastructure	The tangible and intangible assets owned and controlled by the supply chain partnering firms to ensure smooth coordination of sustainable initiatives, for e.g. storage facility, access to green processes etc.	Chaabane, Ramudhin, and Paquet (2012); Ferreira, Jabbour, and de Sousa Jabbour (2017); Saberi, Kouhizadeh, et al., (2018b)
Financial Constraints	The availability of funds and the ability to raise funds for carrying out SSCM activities. This area covers the efficient deployment of funds and also devising criteria/matrix to calculate the impact of SSCM on performance.	Al Zaabi, Al Dhaheer, and Diabat (2013); Grimm, Hofstetter, and Sarkis (2014); Chkanikova and Mont (2015)
Planning & Execution	Planning & Execution fulfills activities related to planning the SSCM process. It also involves training key stakeholders and designing programs for streamlined execution.	Barney (1986); de Sousa Jabbour, de Oliveira Frascareli, and Jabbour (2015); Diabat et al. (2014); Ghadimi, Wang, and Lim (2019); Saberi, Kouhizadeh, et al., (2018a)
Culture	Culture is a complex set of beliefs, values, symbols and assumptions that outlines how a firm undertakes its business.	Gopalakrishnan et al. (2012); Stiller and Gold (2014); Wolf (2011)
Information communication and Technology (ICT)	The use of advanced information technology concepts such as BT to ensure data security and provide the necessary support in technology adoption for the SSCM initiative.	Faisal (2012); Luthra et al. (2015); Wittstruck and Teuteberg (2012a)
Customer Acceptance	Responsible to ensure that the sustainability philosophy permeates down the hierarchy; also provides the necessary support to all the downstream customers up to the ultimate consumer. The customer's involvement starting from awareness to the actively demanding stage for sustainable products/services is observed here.	Beske and Seuring (2014); Wittstruck and Teuteberg (2012b);
Supplier Acceptance	Responsible to ensure that the sustainability philosophy permeates down to the supplier; also provides the necessary support to all the upstream suppliers up to the original raw material producer. The supplier's involvement starting from awareness to actively demanding stage for sustainable products/services is observed here.	Dubey, Gunasekaran, and Childe (2015); Jabbour and de Sousa Jabbour (2016); Chen et al. (2017)
Government Support	The regulatory bodies framing the policies and laws that have direct or indirect impact on the SSCM initiatives.	Rossi, Colicchia, Cozzolino, and Christopher (2013); Beske and Seuring (2014); Chkanikova and Mont (2015);
Competition	The set of firms that cater to the same customer segments and produce similar products or services. This factor has a compounding effect on the SSCM and is strategic in nature.	Grimm et al. (2014); Wittstruck and Teuteberg (2012b);

(Continued)

**Table 2. (Continued)**

CSF	Conceptualization	Source
External Stakeholders	The external stakeholders consisting of the industry and institutions which are not directly impacted and benefited economically by the SSCM processes.	Bai and Sarkis (2014); Busse, Schleper, Weilenmann, and Wagner (2017); Chkanikova and Mont (2015); Grimm et al. (2014); Yawar and Seuring (2017)
People	All the employees who play a significant role in the SSCM processes.	Al Zaabi et al. (2013); Meixell and Luoma (2015); Wolf (2011)

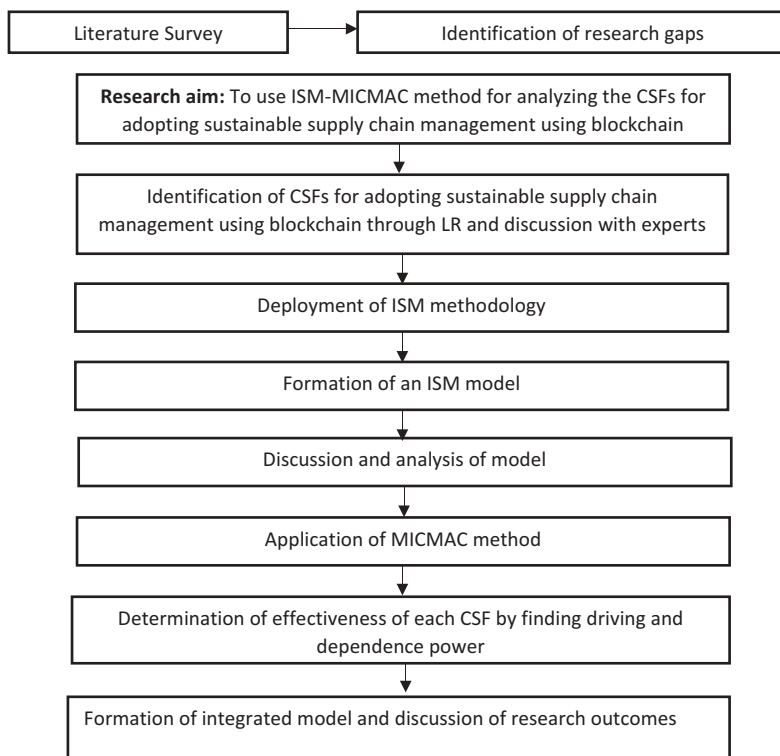
Source: Developed by authors

### 3. ISM – micmac methodology and model development

Over the last three decades, Interpretive Structural modelling (ISM) has evolved as a tool to identify interrelation or interaction among various factors identified in a study. ISM lends order and provides direction to the complex relationships that exist between different factors or elements (Sage, 1977). The overall system structure is outlined in a directed graph as an output. This graph demonstrates a hierarchy among factors considering their driving power among the system. ISM has been used extensively in the area of operations management and supply chain where it is used to model the interrelationships between various enablers to provide an understanding of risks in global supply chains (Gorane & Kant, 2013; Mandal & Deshmukh, 1994; Nishat Faisal, Banwet, & Shankar, 2006). Thakkar, Kanda, and Deshmukh (2007), in their study of the Indian automotive SMEs, use ISM to study the buyer-supplier relationships while Jadhav, Mantha, and Rane (2014) use ISM in their study on sustainable lean implementation. While ISM helps in outlining relationships among various factors, MICMAC is used to display the relative position of these factors in a two-dimensional plane considering the driving force and the dependence of the factors (Mandal & Deshmukh, 1994). Figure 1 graphically portrays the methodology used for this study.

**Figure 1. Research methodology.**

Source: Developed by authors.



### 3.1. Steps in ISM

The first step involves identifying different factors or enablers, relevant to the problem, through a survey or by an extensive literature review, or both. Once these factors are identified, the next step is to establish the contextual relationships that form between them. The contextual relationships are identified by making a pair-wise comparison between the factors and responses obtained from domain experts. Based on the pair-wise comparison, a structural self-interaction matrix (SSIM) is developed. Next, transitivity among the relationships is checked and then converted to a reachability matrix using 0s and 1s.

Once the reachability matrix is generated, it is further divided into multiple levels based on the dependence and the driving power of the factors. Next, a directed graph is generated which indicates the one-way or two-way relationships between the factors, outlining the hierarchy among them. The lowest level refers to higher influence while the highest level indicates those factors that hardly have an influence in the system.

### 3.2. Data collection

A structured questionnaire is designed and administered in a face-to-face meeting with nine industry experts and two academicians. All the experts possess more than 15 years of experience in SSCM and have exposure to emerging technologies. Seven out of the nine industry experts are working in leading private organizations, while two belong to the public sector. The industry experts represent top management including five chief operating officers, two presidents (Supply Chain), one vice president (operations) and one director (procurement). The two academicians are currently serving as Professors in the SCM and Information Technology area. The mean age of all experts is 48.4 years and the gender distribution ratio of male to female is 73:27.

### 3.3. Results and findings

#### 3.3.1. Structural self-interaction matrix (SSIM)

The structural self-interaction matrix (SSIM) is generated based on the opinions of experts and is related to the interrelationship between the factors. To measure the interrelationship and represent the relationship between factor  $i$  and factor  $j$ , four symbols X, O, B and D are used. These symbols denote, “No relation”, “Opposite”, “Both way” and “Direct” among the factors.

X: factor  $i$  and factor  $j$  has no relation

O: factor  $j$  will help achieve factor  $i$

B: factor  $i$  and factor  $j$  will help achieve each other

D: factor  $i$  will help achieve factor  $j$

#### 3.3.2. Reachability matrix

The SSIM is then converted into a binary matrix using 0s and 1s to replace X, O, B and D; and the initial reachability matrix is created by converting the SSIM, following the rules below (Warfield, 1974):

The reachability matrix entry is 0 for both  $(I,j)$  and  $(j,i)$  if the  $(i,j)$  entry of the SSIM is X.

The reachability matrix entry is 1 for both  $(I,j)$  and  $(j,i)$  if the  $(i,j)$  entry of the SSIM is B.

The reachability matrix entry is 0 for both  $(I,j)$  and 1 for  $(j,i)$  if the  $(i,j)$  entry of the SSIM is O.

The reachability matrix entry is 1 for both  $(I,j)$  and  $(j,i)$  if the  $(i,j)$  entry of the SSIM is D.

Table 3 presents the initial reachability matrix.

**Table 3. Initial reachability matrix**

	TM	PE	PL	GS	INF	ICT	FC	COMP	CA	SA	ES	CLT
TM	1	1	1	0	1	1	0	0	0	0	1	0
PE	1	1	1	1	0	1	0	0	1	1	0	0
PL	0	0	1	1	0	0	0	0	1	1	1	0
GS	0	0	0	1	0	0	0	0	1	1	1	0
INF	0	0	0	1	1	1	0	1	0	0	0	0
ICT	0	0	1	1	0	1	0	1	1	1	0	0
FC	1	1	0	0	1	0	1	0	0	0	0	1
COMP	1	0	0	0	0	0	0	1	0	1	1	0
CA	0	0	1	0	0	0	0	0	1	0	0	0
SA	0	0	0	1	0	0	0	0	0	0	0	0
ES	0	0	0	1	0	0	0	0	0	1	0	0
CLT	1	0	0	0	0	0	0	0	0	0	0	1

Once the initial reachability matrix is generated, it is checked for the transitivity rule and is updated till full transitivity is applied. Transitivity calculation is done manually; each of the relations is verified and 0 is replaced by 1 whenever the transitive property is satisfied.

The final reachability matrix is then generated by considering the transitivity (Table 3). The transitivity checking is done by checking if factor *i* influence factor *j* and factor *j* influences factor *k*; if yes, then factor *i* should influence factor *k*. The final reachability matrix (after incorporating transitivity) is presented in Table 4.

### 3.3.3. Level partition

The final reachability matrix helps us to identify the “reachability set” and the “antecedent set” for each factor. The reachability set consists of the factor under consideration and the other factors, which it may help achieve, while the antecedent set has this factor and the other factors, which may help achieving it. Also, to generate levels for all factors, an intersection set is derived.

The top-level factor(s) in ISM hierarchy is the one for which the reachability set and intersection set are the same. This is because this factor(s) would not be able to help the other factors above its level. The partition made in the first iteration is presented in Table 5. Once the top-level factor(s) are identified, they are taken off from the list and the same process is repeated to identify the factor(s) for the next level. These iterations are conducted till levels for each factor are identified.

Table 6 outlines all the level partitions. These levels are then used to generate the digraph, which outlines the interrelationships or causality.

### 3.3.4. Formation of ISM-based model

The ISM model generated helps in developing the hierarchy of factors that are considered for this study. In the event of a causal relationship between factor *j* and factor *I*, it is represented by a directed edge. This directed graph or Di-graph provides insights into the interrelationships between these factors from a systemic perspective. The hierarchy of factors along with the direction of relations is depicted in Figure 2.

The hierarchical order from top to bottom demonstrates the increasing driving power while arrows indicate influence of one factor on another in the system. The results show that Top Management is driven by Competition, Culture and Financial constraints in SSCM using BT. Top management influences Infrastructure and the Planning and Execution team while both these factors influence ICT. It can also be noted that Supplier acceptance, External Shareholders and Government support are listed on top and are influenced by other factors.

### 3.3.5. MICMAC analysis

The ISM model considers the binary digits, i.e., 0 or 1 to represent the link between the factors. The binary digit 0 is used to signify no relationship among the factors while the binary digit 1 is used to indicate that a relationship exists between the factors. However, the ISM model does not demonstrate the strength of the relationship. The relationship among factors could be indicated as very strong, strong, weak or very weak. Also, there may be no relationship among the factors.

In this study, MICMAC analysis is used to list and analyze the factors in relation to their driving and dependence power in the system, thereby addressing the strength of the relationship. Also, the inclusion of 10-point scale helps in better capturing the strength of relations. In an MICMAC analysis, the scores are converted into a number between 0 and 1. Based on the scores, the factors are grouped under four quadrants namely “Dependent”, “Autonomous”, “Independent” and “Linkage”. All factors with low-driving power and high-dependence power are categorized under “Dependent” while factors with less driving and dependence power are grouped under “Autonomous”. Factors with high driving and dependence power are considered under “Linkage,” and “Independent” factors are the ones with high driving and less dependence power. The linkage

**Table 4. Final reachability matrix**

	TM	PE	PL	GS	INF	ICT	FC	COMP	CA	SA	ES	CLT
TM	1	1	1	1*	1	1	0	0	1*	1*	1	0
PE	1	1	1	1	0	1	0	0	1	1	0	0
PL	0	0	1	1	0	0	0	0	1	1	1	0
GS	0	0	0	1	0	0	0	0	1	1	1	0
INF	0	0	0	1	1	1	0	1	1*	1*	1*	0
ICT	0	0	1	1	0	1	0	1	1	1	1*	0
FC	1	1	1*	1*	1	1*	1	0	1*	1*	1*	1
COMP	1	1*	1*	0	1*	1*	0	1	0	1	1	0
CA	0	0	1	1*	0	0	0	0	1	1*	1*	0
SA	0	0	0	1	0	0	0	0	1*	1*	1*	0
ES	0	0	0	1	0	0	0	0	1*	1	1*	0
CLT	1	1*	1*	0	1*	1*	0	0	0	0	1*	1

Note: \*Based on transitivity checks



**Table 5. Level partition in iteration 1**

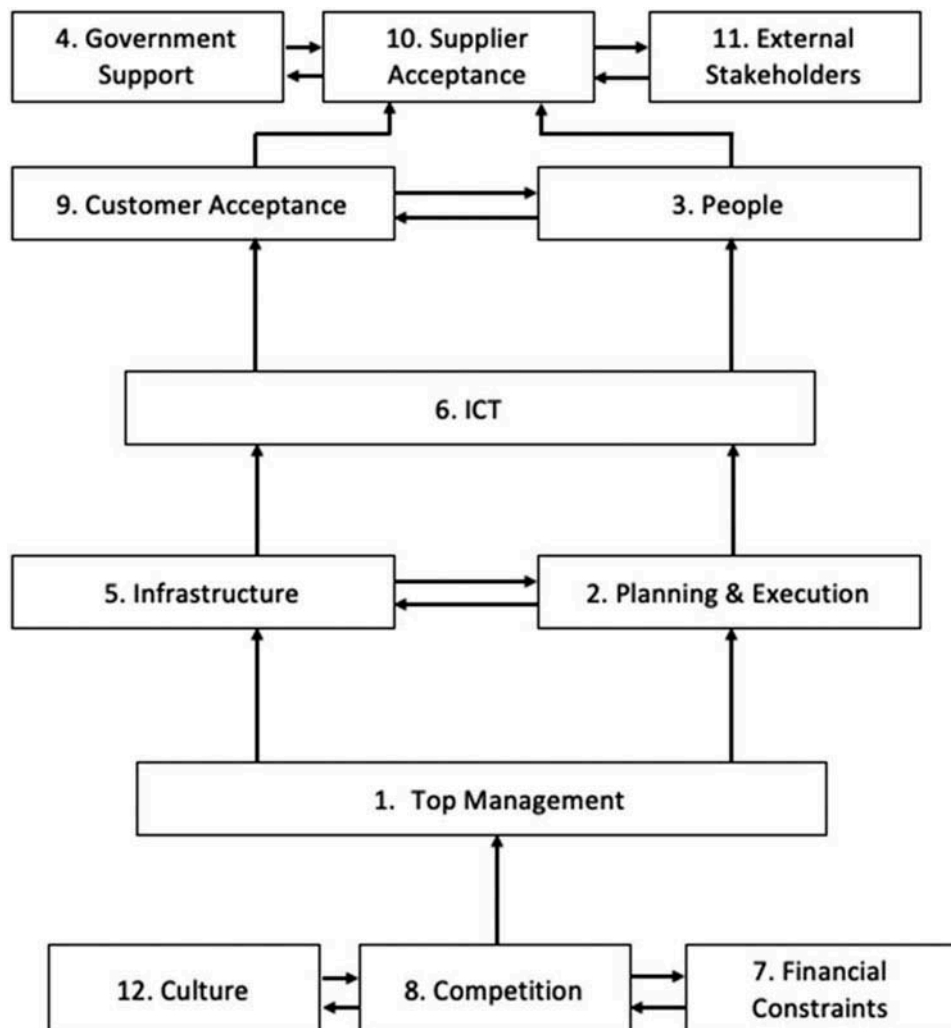
Components	Reachability Set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,9,10,11	1,2,7,8,12	1,2	
2	1,2,3,4,6,9,10	1,2,7,8,12	1,2	
3	3,4,9,10,11	1,2,3,6,7,8,9,12	3,9	
4	4,9,10,11	1,2,3,4,5,6,7,9,10,11,12	4,9,10,11	I
5	4,5,6,8,9,10,11	1,5,7,8,12	5,8	
6	3,4,6,8,9,10,11	1,2,5,6,7,8,12	6,8	
7	1,2,3,4,5,6,7,9,10,11,12	7	7	
8	1,2,3,5,6,8,10,11	5,6,8	5,6,8	
9	3,4,9,10,11	1,2,3,4,5,6,7,9,10,11	3,4,9,10,11	
10	4,9,10,11	1,2,3,4,5,6,7,8,9,10,11	4,9,10,11	I
11	4,9,10,11	1,3,4,5,6,7,8,9,10,11,12	4,9,10,11	I
12	1,2,3,5,6,11,12	7,12	12	

**Table 6. The complete partition**

Components	Reachability Set	Antecedent set	Intersection set	Level
4	4,9,10,11	1,2,3,4,5,6,7,9,10,11,12	4,9,10,11	I
10	4,9,10,11	1,2,3,4,5,6,7,8,9,10,11	4,9,10,11	I
11	4,9,10,11	1,3,4,5,6,7,8,9,10,11,12	4,9,10,11	I
3	3	1,2,3,6,7,8,12	3	II
9	3,9	1,2,3,5,6,7,9	3,9	II
6	6,8	1,2,5,6,7,8,12	6,8	III
2	1,2	1,2,7,8,12	1,2	IV
5	5,8	1,5,7,8,12	5,8	IV
1	1	1,7,8,12	1	V
7	7	7	7	VI
8	8	8	8	VI
12	12	7,12	12	VI

**Figure 2. The ISM model outlining hierarchy of components.**

Source: Developed by authors.



factors are the most crucial factors based on their dependence and driving power. Table 7 outlines the reachability matrix considering the driving power and dependence.

Figure 3 outlines the MICMAC analysis. The results show that with high dependence and driving power, “ICT” is the most crucial factor in the process of SSCM using BT. Factors such as Government Support, Supplier Acceptance, Customer Acceptance, External Stakeholders and People are grouped under Dependent as they demonstrate high dependence and low-driving power and are driven mostly by Independent factors namely, Financial Constraints, Culture, Competition, Infrastructure, Top Management and Planning & Execution, demonstrating low-dependence and high-driving power. None of the factors demonstrate low dependence and driving power and hence, the Autonomous quadrant is empty.

#### 4. Discussion and implications

This study focusses on identifying and modelling the CSF of SSCM using BT. The CSF are identified based on a detailed literature review and then presented to a group of experts belonging to different sections of the supply chain. Their recommendations are used to create a final list of factors. From the ISM model, it can be observed that “Competition”, “Culture” and “Financial

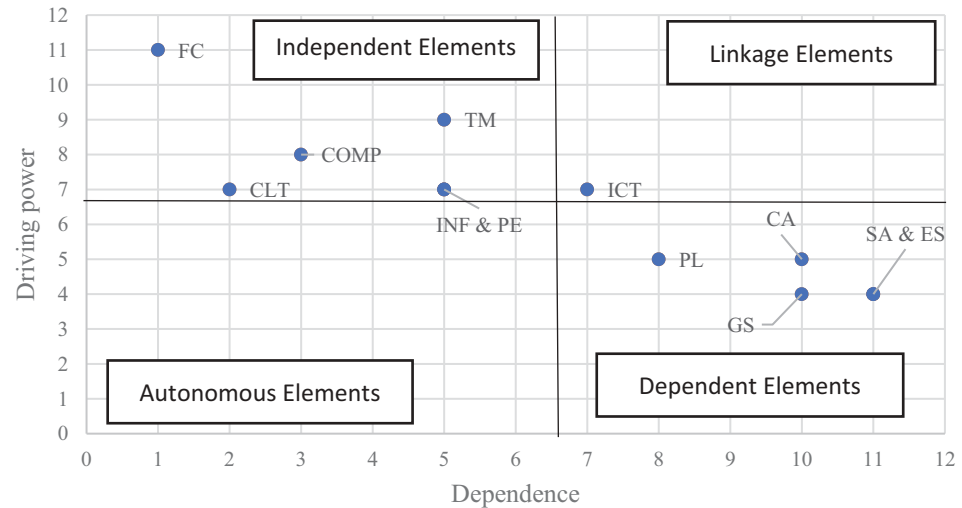
**Table 7. Reachability matrix with driving power and dependence**

	TM	PE	PL	GS	INF	ICT	FC	COMP	CA	SA	ES	CLT	Driving power
TM	1	1	1	1	1	1	0	0	1	1	1	0	9
PE	1	1	1	1	0	1	0	0	1	1	0	0	7
PL	0	0	1	1	0	0	0	0	1	1	1	0	5
GS	0	0	0	1	0	0	0	0	1	1	1	0	4
INF	0	0	0	1	1	1	0	1	1	1	1	0	7
ICT	0	0	1	1	0	1	0	1	1	1	1	0	7
FC	1	1	1	1	1	1	1	0	1	1	1	1	11
COMP	1	1	1	0	1	1	0	1	0	1	1	0	8
CA	0	0	1	1	0	0	0	0	1	1	1	0	5
SA	0	0	0	1	0	0	0	0	1	1	1	0	4
ES	0	0	0	1	0	0	0	0	1	1	1	0	4
CLT	1	1	1	0	1	1	0	0	0	0	1	1	7
Dependence	5	5	8	10	5	7	1	3	10	11	11	2	

Source: Developed by authors.

**Figure 3. CSF clusters.**

Source: Developed by authors.



Constraints” are the drivers for SSCM using BT. Wolf (2011) demonstrates that competitive pressure acts as barrier in SSCM while Al Zaabi et al. (2013) highlight how cost increases with sustainable activities. Grimm et al. (2014) demonstrate how cultural and language differences cause challenges in adopting SSCM processes.

Based on the experts’ responses, it is seen that “Top Management” influences “Infrastructure” and “Planning & Execution” while “Government Support”, along with “Supplier Acceptance” and “External Stakeholders” form the lowest level of influence. With increasing pressure on integrating sustainable actions by various stakeholders, coupled with a highly competitive environment, it is evident that organizations must adopt SSCM in SME using BT to achieve competitive advantage.

From the above, the following insights can be summarized:

- Top Management plays a crucial role in adopting SSCM in SME using BT; clearing barriers during implementation; and creating an environment of trust among partners. The vision and mission defined by the top management provides guidelines to the planning and execution team, which is given the responsibility to undertake the deployment process.
- The MICMAC analysis provides evidence that good infrastructure supports the planning & execution team to achieve these objectives. The government should undertake steps to create an ecosystem for SME that aids supply chains to compete globally in the sustainability arena. Investing in recycling units, pooling resources, and technological support could be some ways to achieve this end.
- For supply chains to become sustainable, culture among the partnering firms plays a significant role, along with financial constraints and competition. Traditional supply chains are hit by self-optimizing behavior by various entities, resulting in poor performance. Lack of transparency and traceability are the key parameters that need to be addressed. This could be done by adopting BT, thereby creating an environment of trust and harmony.
- Adopting ICT provides an added advantage as it provides crucial information in real-time. It provides support to various people in the supply chain, enabling them to achieve the outlined objectives. ICT could also be used to connect with upstream and downstream players for efficient flow of information, thereby gaining their acceptance to be a part of the system. The MICMAC analysis also demonstrates that ICT forms the crucial link between the CSF. The government may initiate actions to promote adoption of ICT by providing state-of-the-art infrastructure to SME.

By identifying interrelationships between the various CSF, a supply chain system would be able to coordinate with other partners and stakeholders to increase the overall sustainable performance (Meng, Tischhauser, Wang, Wang, & Han, 2018). This study provides several inputs to the academia and industry. The first major contribution is in identifying CSF that could play a decisive role in the successful adoption of SSCM practices using BT. To the best of our knowledge, this is the first study of its kind to address this upcoming trend given that BT is gaining popularity due to the security aspects and transparency it provides to the system (Saberi, Kouhizadeh, et al., 2018b). The second contribution is exploring the interdependencies between these CSF and providing clarity on the impact that one CSF has on other, unlike the typical MCDM approach, which considers these CSF independently. This provides the practitioner a better direction while undertaking BT in SSCM. Thirdly, this paper also extends the academic debate of “trust” issues in a typical SCM environment and provides rich ground for advancing behavioral operations theories. Lastly, this study is the first study of its kind to explore the adoption of SSCM practices with BT in a developing nation context. This is particularly important as the developing nations provide support to developed nations in the manufacturing and allied activities as original equipment manufacturers (OEM) or outsourcing partners, thereby making a strong case for adopting SSCM practices using BT. This provides a holistic approach towards reducing the adverse effects of SCM activities throughout the supply chain. Also, this study provides insights to the regulators, law makers and watchdogs to devise laws and policies that could promote SSCM practices using BT.

This paper provides initial thoughts and insights about adoption of BT for SSCM in SME and how it may help SC players, policymakers, regulators, organizations, etc., to use BT as a valid and efficient tool within for SSCM. There are several benefits of BT in SSCM (e.g., access to confidential data access, security protocols, better communications among all key players, etc.), as well as a set of opportunities (e.g., improving performance outcomes, creation of smart devices, etc.) and challenges in the near future (e.g., readiness of SC players, lack of adequate regulations, loss of private data and identity, etc.). However, there are few challenges in adoption of BT in SSCM. Firstly, BT by itself is not suitable for large data storage, even though there are different ways to work around it. Secondly, there are challenges for adoption of cryptocurrencies especially the regulation. It should be made clear that cryptocurrency is not a must for blockchain value creation. Thirdly, the costs aspects of the BT need to be considered. BT requires heavy investments in infrastructure and software. Who is going to spearhead it and how? Is the investment made outweighs the benefits? Fourth, the resistance to change may be another major hurdle. Lot of SC players might be threatened with the transparency of BT. How managers are going to implement this change? Last but not the least, how does the end consumers perceives the SSC initiatives and how much he/she values it? As BT is emerging technology, the clarity on these issues will come over time.

### **5. Conclusion, limitations and scope for future research**

BT is emerging as a disruptive innovation in the technology space, changing the business landscapes and finding adoption in various processes including SSCM practices. This paper identifies and models CSF for SSCM in SME using BT. Through an extensive literature review, coupled with discussions with industry experts, we identified and modelled 12 CSF using ISM. The model generated provides clarity on the interrelationships between these CSF. From the model, it can be observed that “Culture”, “Competition” and “Financial Constraints” serve as the foundation factors while “Government Support”, “Supplier Acceptance” and “External shareholders” form the dependent ones. The MICMAC analysis further categorizes these CSF based on the driving power and dependence. The results demonstrate that six factors namely, “Financial constraints”, “Top Management support”, “Competition”, “Culture”, “Infrastructure” and “Planning & Execution” are classified as independent based on the decreasing order of driving power. “ICT” is the only linkage factor and is the most crucial CSF among the others. “People”, “Customer Acceptance”, “Government Support”, “Supplier Acceptance” and “External Stakeholder” are grouped as dependent based on their decreasing order of driving power. The Autonomous category does not feature any CSF, primarily because these CSF do not operate independently. The typical MCDM approach is based on considering these CSF independent of each other, thereby providing credibility to our selected research methodology and design.



Like any study undertaken, this study also has its limitations. Firstly, it considers inputs from a small group of academicians and industry experts, thereby challenging the generalization of the results. Second, as BT still is in the nascent stage and is presently undergoing rapid transformation, this study may not have utilized the full advantage of the emerging technology. Thirdly, the current study focusses on India and so it may not capture the challenges faced by other developing nations given that factors such as culture, government support, etc., vary across nations.

This study could be further enhanced by adopting a mixed-method approach, like ISM with system dynamics or ISM with case study to unearth new dimensions. Also, there is a scope to conduct a similar study which integrates both the developing and the developed nations, thereby providing better clarity. With BT, tracing the compete process from the raw material supplier to the ultimate consumer, aspects such as carbon footprints, greenhouse gas emissions, etc., could be accurately captured, thereby providing scope for research on holistic supply chain management. With the use of BT in SSCM, the roles and responsibilities of various supply chain partners would change, thereby challenging the existing theories. This provides an opportunity to enhance the body of knowledge in the supply chain arena.

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