# Modelling the barriers of supply chain transparency in the post-COVID-19 scenario

Sanjukta Chatterjee* and
Debmallya Chatterjee

S.P. Jain Institute of Management and Research,
Mumbai, 400058, India
Email: pgp19.sanjukta@spjimr.org
Email: debmallya.chatterjee@spjimr.org
*Corresponding author

**Abstract:** Transparent supply chains have slowly gained prominence because of their utility in resolving sustainability concerns and improving operational efficiency and decision making. It requires companies to know more about their upstream chain and communicate it to their internal and external stakeholders. This in turn helps build resilience into the supply chains, making response quicker in the face of disruptive events such as the COVID-19 pandemic. Despite both the necessity and obligation, companies are struggling with implementing a transparent supply chain because of unclear reasons. In this paper, we identify and model those barriers in implementing transparent supply chains. Results suggest that customer privacy drives other barriers in the system and hence should be given adequate importance while forming the data pipeline for transparent supply chains. Vague short-term ROI, low technology adoption, and underdeveloped infrastructure also emerged as critical barriers that managers should carefully mitigate while implementing transparency in supply chains.

**Keywords:** COVID-19; supply chain transparency; supply chain resilience; sustainability; implementation barriers; interpretive structural modelling; ISM; MICMAC analysis.

**Reference** to this paper should be made as follows: Chatterjee, S. and Chatterjee, D. (2022) ‘Modelling the barriers of supply chain transparency in the post-COVID-19 scenario’, *Int. J. Logistics Economics and Globalisation*, Vol. 9, No. 3, pp.277–301.

**Biographical notes:** Sanjukta Chatterjee works in India, as a TAS probationer in the Tata Group. She completed her MBA from S.P. Jain Institute of Management and Research (SPJIMR), Mumbai in April 2021. She majored in operations and supply chain management. She holds a BTech degree in Electrical Engineering from National Institute of Technology, Durgapur.

Debmallya Chatterjee is currently a Professor and Head of Operations and Supply Chain Area at SPJIMR, Mumbai. He holds a PhD in Multi-criteria Decision Making from Indian School of Mines (IIT-ISM, Dhanbad), MTech in Operations Research from National Institute of Technology (NIT-D) and, MSc in Mathematics from University of Burdwan, West Bengal. He is also trained at Harvard Business School, Boston on teaching pedagogy. His research interests are in the areas of multi-criteria decision-making applications to business, interpretive structural modelling application and fuzzy cognitive map applications. He teaches subjects such as operations research, business research methods, service operations, quantitative methods, problem solving and decision making, operations management and simulation modelling with ARENA at SPJIMR, Mumbai.

## 1 Introduction

Transparent supply chains are comparatively new in the business world and were created mainly to cater to social and environmental sustainability needs which stemmed from rapidly growing industrial activities. While the industrial growth of the last century brought prosperity, there have also been a series of negative consequences which affected the environment at large. As public awareness increased, there was a need to make the industrial ecosystem more sustainable. This awareness caused the World Commission on Environment and Development to release the Brundtland Report [Brundtland, (1987), p.41], which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". To address the initial concerns, green supply chain management (GSCM) was developed to ensure the protection of the environment (Schaltegger et al., 2014). This gained momentum in the 2000s, and the concept broadened to sustainable supply chain management (SSCM) which catered to environmental and societal aspects. One way for companies to ensure that they are operating a sustainable supply chain is to establish a transparent supply chain (Brun et al., 2020; Bag et al., 2021d). Besides ensuring sustainability, a transparent supply chain also helps build resilience, improve operational efficiency, and remove other vulnerabilities such as security issues (Gunasekaran et al., 2015; Yang et al., 2021). It supports quick decision-making by providing real-time visibility into the activities of different entities of the supply chain (Finkenstadt and Handfield, 2021). Also, it prevents theft and adulteration during transportation, thus ensuring that the product quality and timely delivery are maintained, saving a lot of the company's expenses in the process (Francisco and Swanson, 2018). While companies often have a quantum of data available that may enable supply chain visibility, they often do not have the necessary technological interventions to make sense of the data and present it in a helpful manner (Williams et al., 2013). Having a high level of transparency in all aspects of the supply chain might not consistently deliver the best results, but a high level of transparency in well-researched, relevant aspects of the supply chain will provide a substantial competitive advantage to the organisation (Barratt and Oke, 2007; Gunessee and Subramanian, 2020).

Although there are no formal definitions of a transparent supply chain, it incorporates visibility across the different entities of a supply chain and communicates to both internal and external stakeholders (Bateman and Bonanni, 2019). When a company creates a supply chain such that it can collect information on a real-time basis (from its suppliers, transporters, distributors, etc.) and subsequently document and communicate it to external parties (such as customers, the government, NGOs, etc.), then such a supply chain can be deemed as transparent.

While the concept of transparent supply chains has been in existence since the beginning of the century, its benefits and implementation for better supply chain resilience are not very well understood (Ivanov, 2021). Similarly, its implementation has been extremely slow in companies (Capgemini Research Institute, 2018). As COVID-19 has made the supply chains fragile, the need for onboarding innovations such as big data analytics (Bag et al., 2021a), supply chain visibility, etc. came to the fore, which will help make the supply chains resilient and help gain a competitive advantage (Bag et al., 2021b). During the COVID-19 period, implementing a transparent supply chain becomes more important for the companies because of many reasons – improved visibility into lower-tier suppliers (Alicke et al., 2020), better tracking of logistics, ability to ensure safety and signal the same to customers (Končar et al., 2020b), proper monitoring of the health status of the employees (Outhwaite and Martin-Ortega, 2019) and so on. Some companies have already implemented supply chain visibility, amongst other measures, to mitigate the challenges introduced by COVID-19 (Butt, 2021). In addition to black swan crises like COVID-19, today's market is filled with man-made crises, environmental risks, and macro-economic factors which cause Supply Chain Vulnerability (Agrawal and Pingle, 2020). Thus, companies have accelerated incorporating transparency into their supply chains to reap all the possible benefits (Caridi et al., 2014) that come from supply chain visibility. Because of COVID-19, companies planning to implement transparent supply chains somewhere down the line now have to implement them in a much shorter duration to become more resilient in today's uncertain times. COVID-19 accelerated the process, as is typical of its nature. And to implement a shorter duration, companies need to have proper visibility into the barriers they can expect to encounter. Once the companies know about the barriers, planning will be more thorough, and thus, execution will become much faster. This formed the motivation for our research. We strive to prepare an organised list of barriers, deriving knowledge from existing research that will support organisations in their implementation process and add to the existing knowledge base on the topic of supply chain transparency. Based on this, the research questions being addressed in this study are:

a Which are the major barriers that companies may face while implementing transparent supply chains?

b What is the influence that the barriers have on one another and on the overall system?

Basis these research questions, we have identified the barriers to the implementation of transparent supply chains from extant literature and then establishing the most influential barriers using modelling techniques.

We have modelled the inter-relationships among these barriers, using interpretive structural modelling (ISM) and cross-impact matrix multiplication applied to classification (MICMAC) analysis, to identify the critical barriers. ISM is a qualitative method developed by John N. Warfield (Olsen, 1982) and is used to understand relationships between the factors that influence a system. MICMAC analysis was developed by Michel Godet and François Bourse (Chandramowli et al., 2011) and is used to classify the factors according to their criticality. This is done by developing a graph which classifies the factors according to the driving power and dependence power. Researchers have been using ISM and MICMAC analysis to identify the influencing factors and their inter-relationships across many complex applications in the domain of supply chain and operations. Applications of ISM and MICMAC analysis have ranged from mapping factors and establishing relationships between various kinds of supply chains to developing GSCM frameworks, from vendor selection to modelling risks across global supply chains (Chatterjee and Dhaigude, 2020; Bag, 2014, 2019; Gupta et al., 2017; Bag and Anand, 2015; Gorane and Kant, 2013; Thakkar et al., 2008; Faisal et al., 2006; Mandal and Deshmukh, 1994).

Section 2 comprises of the literature review. Section 3 presents the methodology, while Section 4 covers results and discussions. Section 5 presents the conclusions and Section 6 discusses the limitations and future scope of the research.

## 2 Literature review

### *2.1 Transparent supply chains and their benefits*

Although transparent supply chains are gaining prominence and many companies are looking forward to implementing them, there is no clear, accepted definition of the concept as of now. While there is no established definition of transparent supply chains, they can be categorised into the following two constituents, both intertwined with each other but having different sets of characteristics and implications (Bateman and Bonanni, 2019; Harbert, 2020).

1 Visibility – the term 'visibility' is focused more on the B2B data sharing among the different entities operating within the supply chain, which helps them collaborate more effectively, solve problems quickly and take better decisions related to orders, shipments, inventory, and transportation.

2 Disclosure – the term 'disclosure' is all about sharing the collected information with external stakeholders such as the customers, the NGOs, the investors, and the Governments for various purposes. Through disclosing information, the company signals accountability and ensures that quality, safety, and ethical standards are met.

Transparent supply chain is a fairly new concept. Consumers a few decades ago did not bother about finding out where products they bought came from (Bhaduri and Ha-Brookshire, 2011). Companies maintained stringent safety, quality and ethical controls within their premises but had no control on what was happening upstream (Calvert, 2020). Although many companies have systems to measure social and environmental impact of internal operations, out of them only a third has systems in place to assess impacts of their suppliers (Linich, 2014).

However, at the turn of the century people started getting more interested in knowing about the origin of the raw materials, their social and environmental impact, along with their adherence to quality and safety standards (Bhaduri and Ha-Brookshire, 2011). There were rising social and environmental concerns among the public as scandals across different industries exposed the fragile nature of the existing supply chains (Brun et al., 2020). A few among many such scandals that damaged the reputation of the global companies are the Rana Plaza garment factory collapse which happened in Bangladesh (Brun et al., 2020), usage of slave labour in the Thai seafood industry (Bateman and Bonanni, 2019), Mars chocolate plastic contamination incident in 50-plus countries (Hartman, 2016), etc. These kinds of scandals led to the creation of regulatory acts like Dodd Frank Act for 'conflict minerals' (Harbert, 2020), California's Transparency in Supply Chains Act (Birkey et al., 2018), The Drug Quality and Security Act (Outterson, 2013), The Food and Drug Act (Linich, 2014), The Accord on Fire and Building Safety in Bangladesh (Reinecke and Donaghey, 2015), etc. which attempt to mandate disclosures so that safe and sustainable conditions are ensured by companies and their suppliers for the workers, the environment and the products as well.

Further, NGOs across the world started investigating into human rights issues and environmental concerns at supplier factories of global companies, which caused an increase in awareness amongst consumers (Harbert, 2020). NGOs like Ethical Trading Action Group (ETAG) (Doorey, 2011) and Fashion Revolution (Brun et al., 2020) played key roles in initiating public campaigns which forced companies to investigate their supplier networks and factories for sustainable practices and conditions, and then disclose the same to the consumers. Consumers may even be willing to pay a premium of 2% to 10% for products which traverse through a transparent supply chain (Kraft et al., 2018). Lastly, institutional pressures have also encouraged companies to implement technologies and innovative practices, such as transparent supply chains, which contribute to the circular economy and generate a focus on sustainability (Bag et al., 2021c).

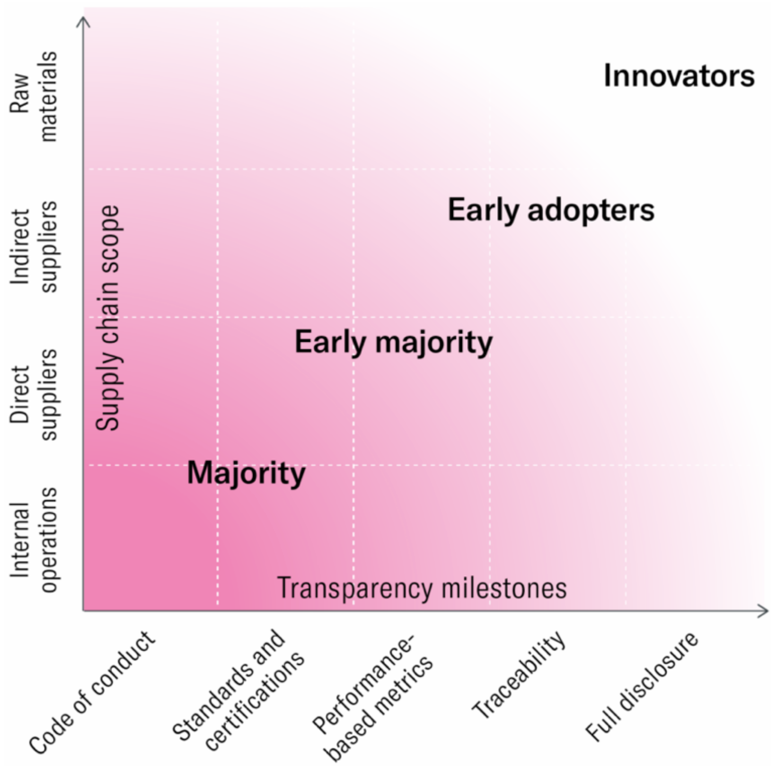
The increased transparency would therefore lead to enhanced reputation for the company and help develop customer trust and loyalty (Harbert, 2020). In addition to the increase in revenue potential, transparent supply chains may also help in better market valuation for the companies implementing them (Kalkanci and Plambeck, 2018). Investors, while analysing the risks and costs that a company may face in the future, depend on the disclosure reports released by these companies. If the companies are not disclosing enough information, then the investors just assume the worst which leads to lower valuations (Calvert, 2020). Also, many investors nowadays favour impact investing, which is the process of investing in companies not only for the financial returns but also for ensuring that money goes into responsible companies who will actively resolve social and environmental issues (Bugg-Levine and Emerson, 2011). To attract the attention of such investors, companies need to maintain high environmental, social and governance (ESG) scores which can be increased through supply chain transparency (Harbert, 2020).

While these were external risks and subsequent benefits that transparent supply chains could bring, there are numerous internal risks as well which can be mitigated by increasing transparency in the supply chains (Končar et al., 2020b). Implementation of transparency in supply chains would improve their operational efficiency (Bateman and Bonanni, 2019), reduce the risk of thefts and adultery (Francisco and Swanson, 2018), and thereby increase their resilience at difficult times (Gunasekaran et al., 2015). Increased visibility at different points of the supply chain could help companies take decisions faster based on real-time information (Zelbst et al., 2020). It also aids companies identify their problems and potential risks faster, thus enabling them to resolve and mitigate them more efficiently (Zhu et al., 2018). Transparent supply chains, where data is collected from each link and communicated across the chain, will experience better collaboration among its members thus leading to quicker problem resolution and crisis management (Brun et al., 2020). Using a transparent supply chain, companies can set stringent standards and accountability for the suppliers, identify when there is a deviation and penalise the suppliers suitably so that the deviations don't repeat in the future (Venkatesh et al., 2020). Companies which have been implementing transparency experience interest from a wider talent base who are motivated and willing to stay, and lesser attrition rates (Rattalino, 2018). Patagonia, a leader in sustainability and supply chain transparency, has an annual employee turnover rate of less than 4% (Stappmanns, 2016).

## 2.2 Implementation of transparent supply chains

Many companies have started implementing supply chain transparency at various levels – from supplier list disclosure (Doorey, 2011) to end-to-end integration using blockchain / IoT/RFID (Zelbst et al., 2020). Blockchain technology has gained traction in this domain and is used most often to implement transparent supply chains because of benefits such as data immutability, improved sustainability, decentralisation, shared information and building resilience – all of which are important components of a transparent supply chain (Mukherjee et al., 2021). Bateman and Bonanni (2019) state that companies can be classified into different levels when supply chain transparency is measured along two dimensions – depth of collaboration (supply chain scope) and breadth of disclosure (transparency milestones). The different stages are shown in Figure 1.

**Figure 1** How transparent is your supply chain (see online version for colours)




*Source:* Bateman and Bonanni (2019)

Mattel Inc., the world's largest toy company, voluntarily crafted a code of conduct called global manufacturing principles (GMP) which provided compliance standards, guidance on external monitoring and full public disclosure to ensure maximum transparency (Sethi et al., 2011). On the other hand, Patagonia, a shoe company, is a well-known innovator. Through its footprint chronicles initiative, Patagonia traces all its raw material suppliers and factories across the globe and discloses the same on its website (Polley, 2020).

While these were two ends of the spectrum, there are many other companies which implement the principles of transparent supply chains to varying degrees. In 2019, Nestle announced that it would release data on raw material sources pertaining to 15 of its most used ingredients such as dairy, cocoa, spices, meat, etc. (Nestle, 2019). Nike and Levi-Strauss started disclosing their entire supplier list since April 2005 and October 2005 respectively (Doorey, 2011), after facing public criticisms stemming from human rights violation disclosures made by NGOs such as United Students Against Sweatshop (USAS), Fair Labour Association (FLA) and Workers' Rights Consortium (WRC). De Beers, a major diamond explorer and miner, has implemented blockchain technology to provide complete traceability to avoid conflict diamonds. The company has also been providing a special ID on all its Forever-mark diamonds which consumers can search on their website. This helps them communicate to their consumers that they provide diamonds coming from sources that don't involve insurgency funding or forced labour (Sachdev, 2019).

## *2.3 Urgency for transparent supply chains post Covid-19*

While many companies have started the process of making their supply chains transparent, the implementation has been slow and filled with challenges (Doorey, 2011). As a result, most of the world's supply chains remained unprepared in the face of an adverse situation such as the COVID-19 pandemic. The onset of the COVID-19 pandemic ravaged the supply chains, and the fragility of the supply chains was exposed (Mollenkopf et al., 2020). An Accenture article by Freeman (2020) states that 94% of the Fortune 1000 companies were disrupted by the pandemic. To mitigate such disruptions and to be resilient to future shocks, companies need to create visibility into their raw material suppliers, factories, and warehouses worldwide (Alicke et al., 2020).

The benefits of transparent supply chains to tackle COVID-19 and future black swan events are many. Having a transparent supply chain will help companies easily identify critical raw materials, their supply origin and hence the vulnerability in procuring them (Jan, 2020). For example, the Indian pharmaceutical industry was completely disrupted in the initial months of the pandemic, as 70% of the active pharmaceutical ingredients (APIs) were sourced from manufacturers in China whose factories were closed down to stem the outbreak (Chatterjee, 2020). Had there been visibility into tier-I suppliers and beyond, pharmaceutical manufacturers would have been able to identify alternate sources for the APIs much faster (Zhu et al., 2020). Consumers have also become more conscious of the origin of the products, their quality and authenticity, and the hygiene conditions at factories and during transportation, because of the infectious nature of COVID-19 (Mehta et al., 2020). Hence, transparent supply chains will help companies provide the necessary information to its customers and gain their trust and loyalty (Montecchi et al., 2019). To control the spread of COVID-19 cases amongst employees, factory workers and other stakeholders in the supply chain, it becomes important for companies to be able to identify the source of the infection and trace it till the supplier, so that necessary actions can be taken on time (Mollenkopf et al., 2020). Post COVID-19, companies particularly stand to gain from transparent supply chains by increasing their operating efficiency and reducing costs (McMaster et al., 2020). Risk assessment and subsequent decision-making (Wright et al., 2020) can be made a lot faster if there is real-time data available at different points, which will help companies take 'pre-emptive action' (Kemp, 2020). Thorough track-and-trace using the transparent supply chain will also reduce the chances of product pilferage (Saberi et al., 2019) and adulteration (Arwani et al., 2018), thus reducing costs and increasing safety respectively. A transparent end- to-end supply chain would also help the companies in accurate demand sensing (Wood et al., 2017), and hence optimal planning, thus preventing bullwhip effect (Sachdev, 2019) which saves resources and prevents overstocking. All the above aspects will help companies become much more resilient in the face of adversities. Lastly, a Deloitte report states another potential benefit of having a transparent supply chain. It conjectures that "as COVID-19 has a way of accelerating trends because it exposes and inflames existing vulnerabilities", investors may be more interested in socially and environmentally sustainable companies, which can be achieved through a transparent supply chain (Jan, 2020).

## *2.4 Barriers in implementation of transparent supply chains*

Although companies have either become intentional about making their supply chains transparent, or they are forced by circumstances to do so, there are certain barriers which companies face in the process. Based on the systematic literature review and supply chain experts' opinions, the following lists of barriers were synthesised.

1 *Data quality, collection, and storage (DQCS)* – Harbert (2020) argues that many companies wouldn't be able to or wouldn't want to collect vast amounts of data. Collection of huge quantities of data at multiple locations involves huge costs and logistical difficulties. Till date, many companies use Excel spreadsheets and paper for data collection and storage, which makes real-time data availability impossible. Human error and counterfeiting at the boundaries of data transmission may also result in erroneous data which will defeat the purpose of collecting the data (Rogerson and Parry, 2020). Similarly, downstream customer data may also be erroneous (Bateman and Bonanni, 2019). Companies need to be absolutely sure of the data that they collect because the same data is going to be disclosed as per mandates. Hence, data quality is a real concern, especially when information exists in siloes today.

2 *Vague short-term ROI (VSTR)* – learning about the supply chain, i.e., getting adequate visibility into the different entities of the supply chain, requires companies to spend a lot of money and efforts. If the learning cost is too high, companies often find that their ROI in the short-term is insignificant and often unmeasurable (Calvert, 2020). Technologies like blockchain and IoT have very high costs of installation (Luthra et al., 2018). "It's a different type of ROI, and that can be hard for a CFO [to justify]" (Bateman and Bonanni, 2019).

3 *Decrease in competitive advantage (DCA)* – many companies do not want to disclose their data for proprietary concerns (Harbert, 2020). They fear that divulging too much information will cause them to lose their competitive advantage (Bateman and Bonanni, 2019; Doorey, 2011).

4 *Lack of stakeholder awareness (LSA)* – stakeholders in the supply chain, both upstream and downstream, are incognisant of the need of having a transparent supply chain (Končar et al., 2020a). Often the stakeholders fail to understand the requirement and benefits of a transparent supply chain because of which it becomes difficult for the companies to onboard them (Egels-Zandén and Hansson, 2016). The gap in understanding the relevant technologies and utilising them also stems from the cultural differences among the different entities in the supply chain. For example, while the manufacturer may be technologically mature, it's upstream and downstream partners may operate at a more rudimentary level, and understanding the benefits of establishing such an elaborate practice may seem unnecessary or confusing to them (Bag et al., 2021e). All these factors ultimately result in delay in the implementation.

5 *Customer privacy (CP)* – many companies hesitate to share customer data with other stakeholders to prevent the risk of violating customer privacy and confidentiality, as it will lead to a decline in customer trust and loyalty (Sachdev, 2019). Usage of tracking technologies often lead to companies being unable to protect users' data which may lead to security concerns (Končar et al., 2020a). Any such cases leading to security breaches will cause huge public uproar damaging the company's reputation.

6 *Low technology adoption (LTA)* – technologies like blockchain and IoT are in nascent stages, are not well-understood and hence are not easily adopted by users (Francisco and Swanson, 2018). Further, there's a lack of skilled personnel with sufficient training, who will be able to apply these advanced technologies (Ahmed and Omar, 2019).

7 *Underdeveloped infrastructure (UI)* – the lack of internet connections, frequent interruptions, low adoption of Wi-Fi, etc. also pose major problems (Luthra et al., 2018). Further, underdeveloped infrastructure in developing regions makes it difficult for companies to effectively manage interconnected devices and equipment (Botta et al., 2016) across its many supply chain stakeholders.

8 *Regulatory issues (RI)* – when it comes to technologies such as blockchain and IoT, problems of standardisation, certification and permits specific to the country may delay the whole implementation process (Al-Fuqaha et al., 2015). As the technologies are new, and there have been lesser cases of implementation, the government does not yet provide legal and regulatory support for these technologies. Because of the lack of a clearly outlined governance system for such technologies, it becomes difficult and time-consuming to get the necessary approvals while implementing them for a transparent supply chain (Batubara et al., 2018).

A summary of all the barriers and their descriptions are given in Table 1.

**Table 1** Barriers in implementation of transparent supply chains

| *No.* | *Barrier* | *Description of the barrier* |
|---|---|---|
| 1 | Data quality, collection, and storage (DQCS) | Incapability of organisations to collect data which is accurate and real-time, and then store it for analysis and usage. (Harbert, 2020; Bateman and Bonanni, 2019) |
| 2 | Vague short-term ROI (VSTR) | Inability to calculate the gains from the investments made on a transparent supply chain, especially in the short-term, makes it difficult to justify the implementation costs and get approvals. (Calvert, 2020; Luthra et al., 2018; Bateman and Bonanni, 2019) |
| 3 | Decrease in competitive advantage (DCA) | A possible decrease in competitive advantage, which companies anticipate might happen, when their proprietary data is revealed publicly while implementing the transparent supply chain. (Harbert, 2020; Bateman and Bonanni, 2019; Doorey, 2011) |
| 4 | Lack of stakeholder awareness (LSA) | Stakeholders are often unaware of transparent supply chains, their benefits and the technologies involved, thus causing a delay in the onboarding and implementation process. (Končar et al., 2020a; Egels-Zandén and Hansson, 2016) |
| 5 | Customer privacy (CP) | Companies fear loss of reputation over security concerns, which might result from sharing of customers' data across different entities in the supply chain. (Sachdev, 2019; Končar et al., 2020a). |
| 6 | Low technology adoption (LTA) | Unavailability of suitable personnel, with stakeholders across the supply chain, who understand technologies such as blockchain, IoT, etc. and will be able to implement them suitably for a transparent supply chain. (Francisco and Swanson, 2018; Ahmed and Omar, 2019) |
| 7 | Underdeveloped infrastructure (UI) | Lack of suitable infrastructure required to support the technologies which will enable the implementation of a transparent supply chain, especially in developing countries. (Luthra et al., 2018; Botta et al., 2016) |
| 8 | Regulatory issues (RI) | The lack of a suitable governance model for new technologies like blockchain and IoT makes it difficult for organisations to implement them for a transparent supply chain. (Batubara et al., 2018; Al-Fuqaha et al., 2015) |

## *2.5 Gap identification*

From the literature review, it was observed that while there is extensive research on transparent supply chains, their benefits, and the usage of technologies like blockchain and IoT for implementation of transparent supply chains, there's no organised research clearly outlining the challenges that a company might face while making their supply chains transparent. As the need for sustainability and resilience in supply chains keep getting urgent, organisations have been trying to implement transparent supply chains as quickly as possible. Hence, to make the implementation process smooth it becomes imperative for the organisations to understand what the major barriers in implementation of transparent supply chains are and how they can systematically eliminate the barriers to make the implementation process faster.

In our research, we will focus on this gap and identify the barriers that companies face in urgently incorporating transparency in their supply chains and map their intensity of influence on the process. For this purpose, we have collated the most common and influential barriers that have been covered in various literature on the topic of transparent supply chains, post which we have analysed the list using ISM-MICMAC analysis to identify the top barriers having the maximum amount of influence on the system. This will help organisations with a prioritised list of barriers which they can address upfront as they start implementing transparent supply chains.

## 3 Methodology (ISM-MICMAC analysis)

We find ISM-MICMAC analysis appropriate for this research. We identified a list of eight barriers and wanted to find out their interrelationships to understand how they influence one another within the system. This finally leads to the identification of the most influential barriers. ISM is used to analyse systems which have numerous factors with direct or indirect relationships amongst them and establish an order and direction for these relationships (Attri et al., 2013). As we have a complex system which is described by a number of elements and interactions, ISM has been used to derive a graphical model which shows the magnitude and direction of the influence that each factor has on one another. The analysis is further supplemented by MICMAC analysis, which classifies these factors in four quadrants according to their driving power and dependence (Bag and Anand, 2014a).

### *3.1 Steps in ISM*

#### *3.1.1 Identification of factors through literature review*

The first step is performing an extensive literature review of existing research on the topic. This step helps in identification of the many factors pertinent to the problem at hand. In addition to literature review, domain experts are also consulted to ensure that we have a comprehensive set of implementation barriers.

#### *3.1.2 Pair-wise comparisons in consultation with domain experts*

The next step in the process is identification of the underlying relationships among the factors that were established in the previous step. The method to do so is pair-wise comparison between the factors, for which a questionnaire is prepared. Three types of questions are asked for each pair – does each member of the pair influence the other, what is its direction of influence, and what is its intensity of influence. Domain experts (See Table 2) are consulted in this process, where they fill the questionnaire.

**Table 2** Details of domain experts interviewed

| *S. no.* | *Industry* | *Experience* |
|---|---|---|
| Domain expert 1, 3, 4, 6, 7, 8 | Supply chain consulting | Average 30 years |
| Domain expert 2, 5, 9, 10 | FMCG, E-commerce, manufacturing | Average 35 years |

#### *3.1.3 Structural self-interaction matrix*

This step is followed by the development of a structural self-interaction matrix (SSIM) of the factors, using the inputs from domain experts on the pair-wise comparisons. The SSIM represents whether or not one factor influences another. The SSIM is developed from the pair-wise comparisons of factors collected through interviewing domain experts. The symbols, D, O, B and X are used in this process to denote the nature of relationship between the pair of factors, *i* and *j*. D, O, B and X stand for 'direct', 'opposite', 'both way' and 'no relation' among the factors, respectively.

D means factor *i* will influence factor *j*

O means factor *j* will influence factor *i*

B means factor *i* and factor *j* will influence each other

X factor *i* and factor *j* have no relation.

### *3.1.4 Reachability matrix*

Next, the SSIM is converted to an initial reachability matrix by replacing the cell values with either 0 or 1, and then it is converted to a final reachability matrix once the property of transitivity has been checked. The property of transitivity tells us that if element i leads to element j, and element j leads to element k, then element i should lead to element k. The final reachability matrix is then divided into various levels depending on the driving power (reachability set) and dependence (antecedent set) of the factors in the reachability matrix. The reachability set comprises of the factor itself and other factors which it may influence. The antecedent set consists of the factor itself and other factors, which may influence it. Intersections of these two sets are mapped for all the factors. The factor with the same reachability and intersection sets is called the top level or the first level in the ISM hierarchy.

Once the first level factor is identified, it is taken out from the list of factors and the same process is repeated to identify the factor at the next level. The iterations continue till the levels of each factor have been determined.

### *3.1.5 Directed graph*

Next, a directed graph is drawn according to the levels of each factor and the final reachability matrix. If a causal relationship is present between factor *i* and factor *j*, it is presented by a directed edge. All these directed edges combined with the factors positioned at their respective levels leads to the formation of the di-graph. It helps us understand the inter-relationships among the factors from a systemic perspective. The digraph gives the hierarchical relationships among the factors. The topmost levels indicate factors that have minimal influence on the system. On the other hand, the bottom levels indicate factors that have significant influence on the system.

## *3.2 MICMAC analysis*

The purpose of the MICMAC analysis is to classify the factors according to their driving power and dependence power. The different factor types are then studied for their impact on the system. The final reachability matrix is used to derive the driving power and dependence power. The MICMAC analysis results in all the factors getting grouped into four clusters, namely 'autonomous', 'independent', 'dependent' and 'linkage.'

Cluster 1 Autonomous factors have a very weak or no dependence on other factors as well as low driving power on other factors.

Cluster 2 Independent factors have high driving power but low dependence on other factors.

Cluster 3 Dependent factors are exactly opposite to independent factors. They have high dependence on other factors but low driving power.

Cluster 4 Linkage factors have both high dependence on other factors and a high driving power. They are the most sensitive factors within the system.

## 4 Results and discussion

### *4.1 Interpretive structural modelling*

#### *4.1.1 Structural self-interaction matrix*

The SSIM is plotted considering pair-wise comparison data collected from interviews with supply chain experts, and the cells are indicated by D, O, B or X according to the key mentioned above in the methodology section.

For example, ‘data quality, collection and storage’ influences the barrier ‘decrease in competitive advantage’ because proprietary data leaks may happen if the storage is not secure enough, which will impact their competitive position. Hence, the symbol ‘D’ has been used in the cell where they intersect. ‘Customer privacy’ impacts the barrier ‘Vague short-term ROI’, because adequate investments have to be made in technologies to ensure that customer data is absolutely safe, which increases the capital costs and reduces the short-term ROI. Hence, the symbol ‘O’ has been used at their intersection. ‘Low technology adoption’ and ‘underdeveloped infrastructure’ both influence one another. Without technological expertise, infrastructure would not be developed adequately and without proper infrastructure, technologies can’t be implemented successfully. Hence, the symbol ‘B’ has been used at their intersection. Lastly, ‘customer privacy’ and ‘regulatory issues’ do not influence one another and hence the symbol ‘X’ has been used at their intersection.

The SSIM is shown in Table 3.

**Table 3** Structural self-interaction matrix

| *Factors* | *DQCS* | *VSTR* | *DCA* | *LSA* | *CP* | *LTA* | *UI* | *RI* |
|---|---|---|---|---|---|---|---|---|
| DQCS | B | B | D | O | O | O | O | B |
| VSTR | | B | D | D | O | B | B | X |
| DCA | | | B | O | X | O | O | X |
| LSA | | | | B | X | B | B | X |
| CP | | | | | B | D | D | X |
| LTA | | | | | | B | B | X |
| UI | | | | | | | B | X |
| RI | | | | | | | | B |

### *4.1.2 Reachability matrix*

The SSIM is now converted to a binary matrix, by replacing D, O, B and X with 0 or 1 as per the rules of transformation given i*n Table 4.*

**Table 4** Transformation rules for initial reachability matrix

| *If the (i, j) entry of the SSIM is* | *Entry in the initial reachability matrix will be* | |
|---|---|---|
| | *(i, j) entry* | *(j, i) entry* |
| D | 1 | 0 |
| O | 0 | 1 |
| B | 1 | 1 |
| X | 0 | 0 |

The initial reachability matrix is shown in *Table 5*.

**Table 5** Initial reachability matrix

| *Factors* | *DQCS* | *VSTR* | *DCA* | *LSA* | *CP* | *LTA* | *UI* | *RI* |
|---|---|---|---|---|---|---|---|---|
| DQCS | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| VSTR | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| DCA. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| LSA. | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| CP | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| LTA. | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| UI. | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| RI | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

The final reachability matrix is developed after checking for the property of transitivity and incorporating it in the initial reachability matrix. For example, DQCS leads to VSTR, which in turn leads to LSA. Hence, the value for the inter-relationship between barriers DQCS and LSA has been changed from 0 to 1*, to incorporate the property of transitivity in the final reachability matrix.

The final reachability matrix is shown in Table 6.

**Table 6** Final reachability matrix

| *Factors* | *DQCS* | *VSTR* | *DCA* | *LSA* | *CP* | *LTA* | *UI* | *RI* |
|---|---|---|---|---|---|---|---|---|
| DQCS | 1 | 1 | 1 | 1* | 0 | 1* | 1* | 1 |
| VSTR | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| DCA. | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| LSA. | 1 | 1* | 1 | 1 | 0 | 1 | 1 | 0 |
| CP | 1 | 1 | 1* | 1* | 1 | 1 | 1 | 0 |
| LTA. | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| UI. | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| RI | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Note: *Based on transitivity checks.

### *4.1.3 Level partitions*

Once the final reachability matrix is prepared, the 'reachability set' and 'antecedent set' are found for each of the barriers. The reachability set can be determined by considering the factor itself and all other factors it may have an influence on, i.e., all other factors whose intersection with the concerned factor is 1 in the horizontal direction in the final reachability matrix. Similarly, the antecedent set can be determined by considering the factor itself and all other factors it is influenced by, i.e., all other factors whose intersection with the concerned factor is 1 in the vertical direction in the final reachability matrix. For example, for the barrier DQCS, the reachability set will consist of DQCS and all the other barriers having the value 1 in their horizontal intersections with DQCS, i.e., VSTR, DCA, LSA, LTA, UI and RI. Similarly, the antecedent set for DQCS will be DQCS and VSTR, LSA, CP, LTA, UI, RI.

Next, the intersection set is derived from the intersection of the reachability and antecedent sets. Wherever the intersection set matches with the reachability set, the corresponding barrier is termed as Level I. Table 7 shows the partition made in iteration 1. From the table, we can observe that the intersection set, and reachability set were the same for barriers C and H, i.e., DCA and RI respectively, and hence both the barriers are marked as Level I. The process keeps reiterating till all the barriers are assigned levels.

**Table 7** Level partition in iteration 1

| *Code for factors* | *Factors* | *Reachability set* | *Antecedent set* | *Intersection set* | *Level* |
|---|---|---|---|---|---|
| A | DQCS | A, B, C, D, F, G, H | A, B, D, E, F, G, H | A, B, D, F, G, H | |
| B | VSTR | A, B, C, D, F, G | A, B, D, E, F, G | A, B, D, F, G | |
| C | DCA | C | A, B, C, D, E, F, G | C | I |
| D | LSA | A, B, C, D, F, G | A, B, D, E, F, G | A, B, D, F, G | |
| E | CP | A, B, C, D, E, F, G | E | E | |
| F | LTA | A, B, C, D, F, G | A, B, D, E, F, G | A, B, D, F, G | |
| G | UI | A, B, C, D, F, G | A, B, D, E, F, G | A, B, D, F, G | |
| H | RI | A, H | A, H | A, H | I |

The complete level partitions of all the barriers are shown in Table 8. These levels now lead to the creation of the digraph which represents causality or inter-relationships among the factors.

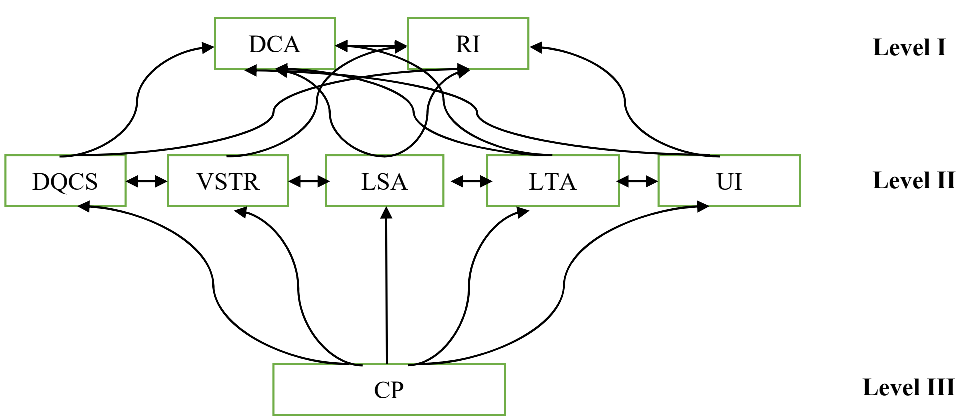
**Table 8** Complete level partitions of all factors

| *Code for factors* | *Factors* | *Reachability set* | *Antecedent set* | *Intersection set* | *Level* |
|---|---|---|---|---|---|
| C | DCA | C | A, B, C, D, E, F, G | C | I |
| H | RI | A, H | A, H | A, H | I |
| A | DQCS | A, B, D, F, G | A, B, D, E, F, G | A, B, D, F, G | II |
| B | VSTR | A, B, D, F, G | A, B, D, E, F, G | A, B, D, F, G | II |
| D | LSA | A, B, D, F, G | A, B, D, E, F, G | A, B, D, F, G | II |
| F | LTA | A, B, D, F, G | A, B, D, E, F, G | A, B, D, F, G | II |
| G | UI | A, B, D, F, G | A, B, D, E, F, G | A, B, D, F, G | II |
| E | CP | E | E | E | III |

### *4.1.4 Formation of the ISM-based model (di-graph)*

The objective of this ISM model is to establish a hierarchy of the factors, i.e., implementation barriers, obtained through literature review. For doing so, the di-graph is plotted according to the levels assigned to the barriers in the previous process. As factor E, i.e., CP was assigned Level III, it is at the bottom, while factors C and H, i.e., DCA and RI are at the topmost level in the hierarchy. Relations among the factors flow from the bottom level to the topmost level. Figure 2 presents the hierarchy, along with the direction of the relations. Arrows represent the direction of influence of one barrier on the other, and the hierarchical order (top to bottom) represents the increasing driving power of the barriers.

**Figure 2** ISM di-graph (see online version for colours)




Results show that 'customer privacy' being at the bottom of the hierarchy drives all other barriers in the system, whereas barriers such as 'decrease in competitive advantage' and 'regulatory issues', being at the top of the hierarchy, get driven by all the other barriers.

### 4.2 MICMAC analysis

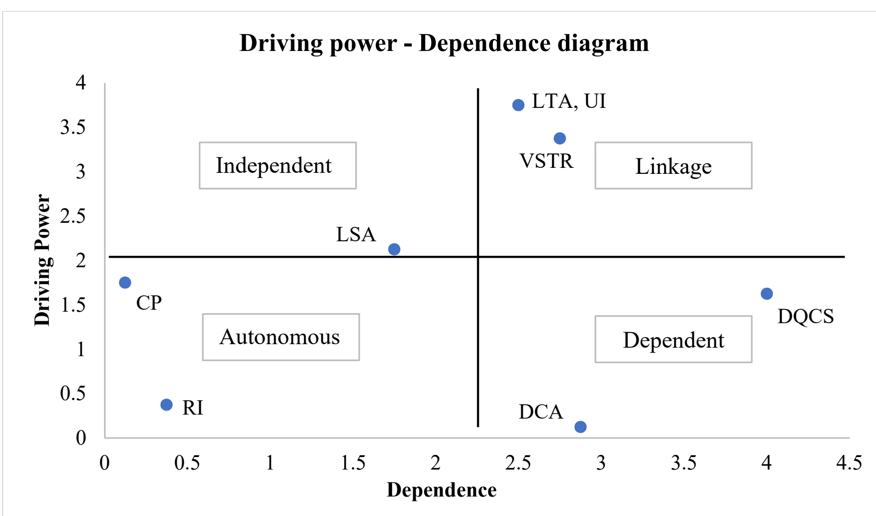
The MICMAC analysis is performed to understand the strength of dependence and driving power of a particular barrier on the other barriers (Bag and Anand, 2014b). The dependence and driving power are calculated by considering the intensity of the pair-wise comparisons done in consultation with the supply chain experts. The final reachability matrix with driving power and dependence, shown in Table 9, forms the input to the analysis.

**Table 9** Reachability matrix with driving power and dependence

| *Factors* | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *Driving power* |
|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 5 | 5 | 0 | 0 | 0 | 0 | 2 | 1.625 |
| B | 6 | 1 | 3 | 5 | 0 | 6 | 6 | 0 | 3.375 |
| C | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.125 |
| D | 4 | 0 | 4 | 1 | 0 | 4 | 4 | 0 | 2.125 |
| E | 5 | 4 | 0 | 0 | 1 | 2 | 2 | 0 | 1.750 |
| F | 7 | 6 | 5 | 4 | 0 | 1 | 7 | 0 | 3.750 |
| G | 7 | 6 | 5 | 4 | 0 | 7 | 1 | 0 | 3.750 |
| H | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.375 |
| Dependence | 4.000 | 2.750 | 2.875 | 1.750 | 0.125 | 2.500 | 2.500 | 0.375 | |

MICMAC analysis is presented in Figure 3. The barriers are classified into four quadrants based on their driving power and dependence in the system.

**Figure 3** MICMAC diagram (see online version for colours)




The results demonstrate that three barriers 'vague short-term ROI', 'low technology adoption' and 'underdeveloped infrastructure' are in the linkage category. These are sensitive barriers as they both influence other barriers and also get influenced by the other barriers in the system.

'Regulatory issues' is in the autonomous category with both low driving power and dependence on other factors. 'Data quality, collection and storage' and 'decrease in competitive advantage' exhibit some amount of dependence on the other barriers in the system but have a low driving power on the other barriers. 'Lack of stakeholder awareness' and 'customer privacy' are in the independent category (or on the borderline) indicating their substantial influence on all the other barriers in the system, but very little dependence on them.

### *4.3 Theoretical and practical implications*

The theoretical implication of the above research lies in expanding the knowledge base of transparent supply chains. A substantial number of studies existed in the domain which talks about the definition of a transparent supply chain, the use cases of a transparent supply chain, the benefits that an organisation may derive from a transparent supply chain and the case studies of the various technologies that are being used to implement transparent supply chains. While some of the papers also talked about a few of the barriers that organisations come across while implementing transparent supply chains, there was no existing research which listed out all the possible barriers in an exhaustive manner. With this research, we have added to the existing literature and now an organised list of barriers in the implementation of a transparent supply chain is made available in the literature.

Practical implication of the research lies in the prioritisation of important barriers. Organisations can now refer to this body of knowledge during their journey of implementing transparent supply chains and keep in mind the list of prioritised barriers which they may encounter in the process. This will help them plan and systematically mitigate the barriers to make the implementation process smoother. Thereby, organisations motivated by macro-economics factors, institutional pressures, environmental factors, etc. will develop and mobilise their resources to build transparent supply chain capabilities and in the process, improve their resilience and operational performance (Dubey et al., 2019).

## 5 Conclusions

To make implementation of transparent supply chains faster and easier, companies would need to build end-to-end connected systems using technologies such as blockchain, IoT, RFID, etc. However, companies hoping to reap the benefits of a transparent supply chain need to have a clear view of the barriers they may face in the implementation process, both internal and external. Awareness of the barriers and their behaviour in the system will help companies analyse the barriers in their own context and tackle them in a systematic, more efficient way.

In this paper, eight barriers to the implementation of transparent supply chains were identified through extensive literature review, namely 'data quality, collection and storage', 'vague short-term ROI', 'decrease in competitive advantage', 'lack of stakeholder awareness', 'customer privacy', 'low technology adoption', 'underdeveloped infrastructure', and 'regulatory issues'. These eight factors were then compared in pairs to generate the data required for ISM and MICMAC analysis. The pair-wise comparisons for inter-relationships between the factors, along with direction and intensity, were done in consultation with supply chain experts. The hierarchy model, made with the help of the ISM technique, revealed that 'customer privacy' has significant influence on the system while 'data quality, collection and storage', 'vague short-term ROI', 'lack of stakeholder awareness', 'low technology adoption' and 'underdeveloped infrastructure' have the next highest driving power and 'decrease in competitive advantage' and 'regulatory issues' are the least impactful.

From the MICMAC analysis, which also considered the intensity of influence that each barrier has on the other, we observed that 'vague short-term ROI', 'low technology adoption' and 'underdeveloped infrastructure' are the three barriers having the highest driving power as well as dependence on the other barriers. As ISM does not consider intensity of influence in its calculations, these three barriers came in the second level, with lesser influence than 'customer privacy'. However, ISM and MICMAC analysis combined shows that 'vague short-term ROI', 'low technology adoption' and 'underdeveloped infrastructure' are the most impactful barriers in the implementation process of transparent supply chains. Thus, supply chain managers should deliberate well on these three barriers before starting the implementation process. Expected ROIs should be calculated, both for the short-term and the long-term, and management should be cognisant with the long-term benefits and consider them in their decision-making. At the same time, companies should decide upon and prepare a plan on how deep they will embed the technology, and exactly what information they would want to collect according to their requirements. This will help them control the costs, while covering enough ground to meet their needs. Technology expertise should also be built at a quick pace, onboarding experts of technologies such as blockchain and IoT, which are to be used for making the supply chains transparent. It should also be ensured that the technology expertise is not restricted to the manufacturing company which is initiating the transparent supply chain. Each and every stakeholder in the supply chain should be provided with sufficient knowledge of the technologies that will be implemented, along with personnel support for a successful execution. Companies should focus on building adequate infrastructure, like IoT sensors, Wi-Fi connections, RFID tags, RFID scanners, servers, and data storage facilities not only within the organisation but also for its stakeholders such as suppliers, transporters, distributors, etc.

'Lack of stakeholder awareness' and 'Customer privacy' have been found to be on the borderline of independent and autonomous barriers. This indicates that they have moderate influence on the system. Hence, they should also be considered in detail, once the above three barriers are resolved. Once the companies have critically evaluated their expected ROI and their investments on the required technology expertise and infrastructure, they should ensure that the different stakeholders are apprised of the implementation process, the technologies being used and the benefits that they can expect from it. This would ensure that they truly understand the need for supply chain transparency and remain willing to cooperate during the implementation process. Also, companies should always remember that an underlying factor of utmost importance in the whole process is ensuring that customer privacy is not compromised at any point.

MICMAC analysis showed that 'Data quality, collection and storage' and 'Decrease in competitive advantage' have very high dependence on other factors but very low driving power, and thus very low influence on the system. Hence, companies don't need to delve deeper in these barriers before the other barriers, having higher influence, are considered thoroughly, and decided upon. Lastly, ISM-MICMAC analysis shows that ‘regulatory issues’ lies at the top of the hierarchy, i.e., has barely any influence on the system and is also not dependent on the other barriers. It is thus an autonomous barrier which needs to be considered only at the end, once all the other barriers have been deliberated upon and taken care of.

## 6 Limitations and future scope

As transparent supply chains are getting onboarded across organisations, many new nuances related to the implementation process are expected to arise. Newer technologies and more innovative practices maybe utilised for implementation in the future. As these changes keep happening in the process, there will be consequent modifications to the list of barriers identified in this research. Hence, this list of barriers and their level of influence on the system can’t be treated as final. Instead, the study has to be refreshed as fresh barriers get identified and included. Also, the supply chain experts who were consulted for the pair-wise comparisons belonged to different industries such as e-commerce, FMCG, manufacturing and supply chain consulting. This resulted in a generic, all-encompassing view of the factors and the influence that they have on the implementation process. Hence, in the future industry specific studies can be done taking inputs from supply chain experts belonging to that particular industry. This will help develop a more specific list of barriers and will clarify if the list of barriers remains the same across all industries or vary from one industry to another.

Lastly, this research has focused on identifying the most influential barriers that impact the implementation of transparent supply chains. This leads to a future scope for carrying out research on how these barriers can be systematically mitigated to ensure that companies can implement transparent supply chains faster.

## References

Agrawal, N. and Pingle, S. (2020) ‘Mitigate supply chain vulnerability to build supply chain resilience using organisational analytical capability: a theoretical framework’, *International Journal of Logistics Economics and Globalisation*, Vol. 8, No. 3, pp.272–284.

Ahmed, W. and Omar, M. (2019) ‘Drivers of supply chain transparency and its effects on performance measures in the automotive industry: case of a developing country’, *International Journal of Services and Operations Management*, Vol. 33, No. 2, pp.159–186.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M. and Ayyash, M. (2015) ‘Internet of things: a survey on enabling technologies, protocols, and applications’, *IEEE Communications Surveys & Tutorials*, Vol. 17, No. 4, pp.2347–2376.

Alicke, K., Azcue, X. and Barriball, E. (2020) *Supply-chain Recovery in Coronavirus Times – Plan for Now and the Future*, McKinsey & Company [online] https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/Supply%20chain%20recovery%20in%20coronavirus%20times%20plan%20for%20now%20and%20the%20future/Supply-chain-recovery-in-coronavirus-times-plan-for-now-and-the-future.pdf (accessed 19 March 2021).

Arwani, M., Santoso, I. and Rahmatin, N. (2018) ‘A dynamic model for managing adulteration risks of dairy industry supply chain in Indonesia’, *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering (AFSSAAE)*, Vol. 1, No. 1, pp.1–8.

Attri, R., Dev, N. and Sharma, V. (2013) 'Interpretive structural modelling (ISM) approach: an overview', *Research Journal of Management Sciences*, Vol. 2319, No. 2, p.1171.

Bag, S. (2014) *Developing a GSCM Model for the Indian Rubber Goods Manufacturing Sector* University of Petroleum and Energy Studies (UPES) [online] http://hdl.handle.net /10603/183109 (accessed 10 October 2021).

Bag, S. (2019) 'Contextual relationship among 3 C's and innovative green procurement practices using ISM and its validation using MICMAC analysis', in *Green Business: Concepts, Methodologies, Tools, and Applications*, pp.346–364, IGI Global, Pennsylvania, USA.

Bag, S. and Anand, N. (2014a) 'Modeling green supply chain management framework using ISM and MICMAC analysis', *African Journal of Business Management*, Vol. 8, No. 22, pp.1053–1065.

Bag, S. and Anand, N. (2014b) 'Modeling soft dimensions of FMS and their interrelationship using ism and micmac analysis', *Prabandhan: Indian Journal of Management*, Vol. 7, No. 10, pp.43–54.

Bag, S. and Anand, N. (2015) 'Modelling barriers of sustainable supply chain network design using interpretive structural modelling: an insight from food processing sector in India', *International Journal of Automation and Logistics*, Vol. 1, No. 3, pp.234–255.

Bag, S., Dhamija, P., Luthra, S. and Huisingh, D. (2021a) 'How big data analytics can help manufacturing companies strengthen supply chain resilience in the context of the COVID-19 pandemic', *The International Journal of Logistics Management*, Vol. ahead-of-print, No. ahead-of-print.

Bag, S., Gupta, S., Choi, T. M. and Kumar, A. (2021b) 'Roles of innovation leadership on using big data analytics to establish resilient healthcare supply chains to combat the COVID-19 pandemic: a multimethodological study', *IEEE Transactions on Engineering Management*, Ahead of print, doi: 10.1109/TEM.2021.3101590.

Bag, S., Pretorius, J.H.C., Gupta, S. and Dwivedi, Y. K. (2021c) 'Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities', *Technological Forecasting and Social Change*, Vol. 163, No. 1, p.120420.

Bag, S., Telukdarie, A., Pretorius, J.H.C. and Gupta, S. (2021d) 'Industry 4.0 and supply chain sustainability: framework and future research directions', *Benchmarking: An International Journal*, Vol. 28, No. 5, pp.1410–1450.

Bag, S., Viktorovich, DA, Sahu, AK and Sahu, AK (2021e) 'Barriers to adoption of blockchain technology in green supply chain management' *Journal of Global Operations and Strategic Sourcing*, Vol. 14, No. 1, pp.104–133.

Barratt, M. and Oke, A. (2007) 'Antecedents of supply chain visibility in retail supply chains: a resource-based theory perspective', *Journal of Operations Management*, Vol. 25, No. 6, pp.1217–1233.

Bateman, A. and Bonanni, L. (2019) 'What supply chain transparency really means', *Harvard Business Review* [online] https://hbr.org/2019/08/what-supply-chain-transparency-really-means (accessed 18 March 2021).

Batubara, F. R., Ubacht, J. and Janssen, M. (2018) 'Challenges of blockchain technology adoption for e-government: a systematic literature review', *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*, pp.1–9.

Bhaduri, G. and Ha-Brookshire, J.E. (2011) 'Do transparent business practices pay? Exploration of transparency and consumer purchase intention', *Clothing and Textiles Research Journal*, Vol. 29, No. 2, pp.135–149.

Birkey, R.N., Guidry, R.P., Islam, M.A. and Patten, D.M. (2018) 'Mandated social disclosure: an analysis of the response to the California Transparency in Supply Chains Act of 2010', *Journal of Business Ethics*, Vol. 152, No. 3, pp.827–841.

Botta, A., De Donato, W., Persico, V. and Pescapé, A. (2016) 'Integration of cloud computing and internet of things: a survey', *Future Generation Computer Systems*, Vol. 56, No. 1, pp.684–700.

Brun, A., Karaosman, H. and Barresi, T. (2020) 'Supply chain collaboration for transparency', *Sustainability*, Vol. 12, No. 11, p.4429.

Brundtland, G. H. (1987) *Report of the World Commission on Environment and Development: Our Common Future*, Brundtland Commission [online] https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf (accessed 18 March 2021).

Bugg-Levine, A. and Emerson, J. (2011) 'Impact investing: Transforming how we make money while making a difference', *Innovations: Technology, Governance, Globalization*, Vol. 6, No. 3, pp.9–18.

Butt, A.S. (2021) 'Strategies to mitigate the impact of COVID-19 on supply chain disruptions: a multiple case analysis of buyers and distributors', *The International Journal of Logistics Management*, Vol. ahead-of-print, No. ahead-of-print.

Calvert, D. (2020) 'The costs and benefits of supply chain transparency', *Stanford Graduate School of Business* [online] https://www.gsb.stanford.edu/insights/costs-benefits-supply-chain-transparency (accessed 19 March 2021).

Capgemini Research Institute (2018) *Blockchain – Key to a New Age of Supply Chain Transparency and Trust*, October [online] https://www.capgemini.com/de-de/wp-content/uploads/sites/5/2018/10/Blockchain-in-Supply-Chain-Country-Insights-Summary-Deck-Germany.pdf (accessed 20 March 2021).

Caridi, M., Moretto, A., Perego, A. and Tumino, A. (2014) 'The benefits of supply chain visibility: a value assessment model', *International Journal of Production Economics*, Vol. 151, No. 1, pp.1–19.

Chandramowli, S., Transue, M. and Felder, F. A. (2011) 'Analysis of barriers to development in landfill communities using interpretive structural modeling', *Habitat International*, Vol. 35, No. 2, pp.246–253.

Chatterjee, D. and Dhaigude, A.S. (2020) 'An integrated fuzzy cognitive map approach in modelling factors of management quality in banking performance', *Global Business Review*, Vol. 21, No. 3, pp.763–779.

Chatterjee, P. (2020) 'Indian pharma threatened by COVID-19 shutdowns in China', *The Lancet*, Vol. 395, No. 10225, p.675.

Doorey, D.J. (2011) 'The transparent supply chain: from resistance to implementation at Nike and Levi-Strauss', *Journal of Business Ethics*, Vol. 103, No. 4, pp.587–603.

Dubey, R., Gunasekaran, A., Childe, S. J., Blome, C. and Papadopoulos, T. (2019) 'Big data and predictive analytics and manufacturing performance: integrating institutional theory, resource-based view and big data culture', *British Journal of Management*, Vol. 30, No. 2, pp.341–361.

Egels-Zandén, N. and Hansson, N. (2016) 'Supply chain transparency as a consumer or corporate tool: the case of Nudie Jeans Co' *Journal of Consumer Policy*, Vol. 39, No. 4, pp.377–395.

Faisal, M.N., Banwet, D. K. and Shankar, R. (2006) 'Supply chain risk mitigation: modeling the enablers', *Business Process Management Journal*, Vol. 12, No. 4, pp.535–552.

Finkenstadt, D.J. and Handfield, R. (2021) 'Blurry vision: supply chain visibility for personal protective equipment during COVID-19', *Journal of Purchasing and Supply Management*, Vol. 27, No. 3, p.100689.

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

Freeman, O. (2020) 'Accenture: how robust is your supply chain?', *Supply Chain Digital* [online] https://www.supplychaindigital.com/technology-4/accenture-how-robust-your-supply-chain (accessed 19 March 2021).

Gorane, S. J. and Kant, R. (2013) 'Supply chain management: modelling the enablers using ISM and fuzzy MICMAC approach', *International Journal of Logistics Systems and Management*, Vol. 16, No. 2, pp.147–166.

Gunasekaran, A., Subramanian, N. and Rahman, S. (2015) 'Supply chain resilience: role of complexities and strategies', *International Journal of Production Research*, Vol. 53, No. 22, pp.6809–6819.

Gunessee, S. and Subramanian, N. (2020) 'Ambiguity and its coping mechanisms in supply chains lessons from the Covid-19 pandemic and natural disasters', *International Journal of Operations & Production Management*, Vol. 40, Nos. 7/8, pp.1201–1223.

Gupta, H., Hasteer, N. and Majumdar, R. (2017) 'Interpretive structure modelling (ISM) for feature dependency in sentiment analysis', *7th International Conference on Cloud Computing, Data Science & Engineering-Confluence*, IEEE, pp.86–91.

Harbert, T. (2020) 'Supply chain transparency, explained', *M.I.T. Sloan School of Management* [online] https://mitsloan.mit.edu/ideas-made-to-matter/supply-chain-transparency-explained (accessed 19 March 2021).

Hartman, L.R. (2016) 'Mars recalls chocolate in 50-plus countries due to potential plastic contamination', *Food Processing* [online] https://www.foodprocessing.com/industrynews/2016/mars-recalls-chocolate-in-50-plus-countries-due-to-potential-plastic-contamination/ (accessed 19 March 2021).

Ivanov, D. (2021) 'Digital supply chain management and technology to enhance resilience by building and using end-to-end visibility during the COVID-19 pandemic', *IEEE Transactions on Engineering Management*, pp.1–11.

Jan, O. (2020) 'COVID-19 impacts on supply chains, sustainability and climate change', *Deloitte* [online] https://www2.deloitte.com/global/en/blog/responsible-business-blog/2020/covid-19-impacts-on-supply-chains-sustainability-and-climate-change.html (accessed 19 March 2021).

Kalkanci, B. and Plambeck, E.L. (2018) 'Reveal the supplier list? A trade-off in capacity vs. responsibility', *Manufacturing & Service Operations Management*, Vol. 22, No. 6, pp.1251–1267.

Kemp, L. (2020) 'How supply chain transparency can help businesses make the right calls', *World Economic Forum* [online] https://www.weforum.org/agenda/2020/06/supply-chain-transparency-can-pre-risk/ (Accessed 20 March 2021).

Končar, J., Grubor, A., Marić, R., Vučenović, S. and Vukmirović, G. (2020a) 'Setbacks to IoT implementation in the function of FMCG supply chain sustainability during COVID-19 pandemic', *Sustainability*, Vol. 12, No. 18, p.7391.

Končar, J., Vučenović, S. and Marić, R. (2020b) 'Green supply chain management in retailing based on internet of things', *Integration of Information Flow for Greening Supply Chain Management*, pp.181–202, Springer, Cham.

Kraft, T., Valdés, L. and Zheng, Y. (2018) 'Supply chain visibility and social responsibility: Investigating consumers' behaviors and motives', *Manufacturing & Service Operations Management*, Vol. 20, No. 4, pp.617–636.

Linich, D. (2014) 'The path to supply chain transparency', *Deloitte*2https://www2.deloitte.com/us/en/insights/topics/operations/supply-chain-transparency.html (accessed 20 March 2021).

Luthra, S., Garg, D., Mangla, S.K. and Berwal, Y. P. S. (2018) 'Analyzing challenges to Internet of Things (IoT) adoption and diffusion: an Indian context', *Procedia Computer Science*, Vol. 125, pp.733–739.

Mandal, A. and Deshmukh, S.G. (1994) 'Vendor selection using interpretive structural modelling (ISM)', *International Journal of Operations & Production Management*, Vol. 14, No. 6, pp.52–59.

McMaster, M., Nettleton, C., Tom, C., Xu, B., Cao, C. and Qiao, P. (2020) 'Risk management: rethinking fashion supply chain management for multinational corporations in light of the COVID-19 outbreak', *Journal of Risk and Financial Management*, Vol. 13, No. 8, p.173.

Mehta, S., Saxena, T. and Purohit, N. (2020) 'The new consumer behaviour paradigm amid COVID-19: permanent or transient?', *Journal of Health Management*, Vol. 22, No. 2, pp.291–301.

Mollenkopf, D.A., Ozanne, L.K. and Stolze, H.J. (2020) 'A transformative supply chain response to COVID-19', *Journal of Service Management*, Vol. 32, No. 2, pp.190–202.

Montecchi, M., Plangger, K. and Etter, M. (2019) 'It's real, trust me! Establishing supply chain provenance using blockchain', *Business Horizons*, Vol. *62*, No. 3, pp.283–293.

Mukherjee, A.A., Singh, R.K., Mishra, R. and Bag, S. (2021) 'Application of blockchain technology for sustainability development in agricultural supply chain: justification framework', *Operations Management Research*, pp.1–16.

Nestle (2019) *Nestlé Speeds Up Efforts Towards Full Supply Chain Transparency*, Nestlé Global, 1 February [online] https://www.nestle.com/media/pressreleases/allpressreleases/nestle-full-supply-chain-transparency (accessed 21 March 2021).

Olsen, S.A. (1982) *Interpretive structural modeling', Group Planning and Problem Solving Methods in Engineering Management*, John Wiley and Sons, Inc.: New York, NY, USA.

Outhwaite, O. and Martin-Ortega, O. (2019) 'Worker-driven monitoring – redefining supply chain monitoring to improve labour rights in global supply chains', *Competition & Change*, Vol. 23, No. 4, pp.378–396.

Outterson, K. (2013) 'The drug quality and security act-mind the gaps', *The New England Journal of Medicine*, Vol. 370, No. 2, pp.97–99.

Polley, L. (2020) 'Introducing the new footprint chronicles on Patagonia.com', *Patagonia* [online] http://www.patagonia.com/stories/introducing-the-new-footprint-chronicles-on-patagoniacom/story-18443.html (accessed 20 March 2021).

Rattalino, F. (2018) 'Circular advantage anyone? Sustainability-driven innovation and circularity at Patagonia, Inc', *Thunderbird International Business Review*, Vol. 60, No. 5, pp.747–755.

Reinecke, J. and Donaghey, J. (2015) 'The 'accord for fire and building safety in Bangladesh' in response to the Rana Plaza disaster', in *Global Governance of Labour Rights*, pp.257–277, Edward Elgar Publishing, UK and USA.

Rogerson, M. and Parry, G.C. (2020) 'Blockchain: case studies in food supply chain visibility', *Supply Chain Management*, Vol. 25, No. 5, pp.601–614.

Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L. (2019) 'Blockchain technology and its relationships to sustainable supply chain management', *International Journal of Production Research*, Vol. 57, No. 7, pp.2117–2135.

Sachdev, D. (2019) 'Enabling data democracy in supply chain using blockchain and IoT', *Journal of Management*, Vol. 6, No. 1, pp.66–83.

Schaltegger, S., Burritt, R., Beske, P. and Seuring, S. (2014) 'Putting sustainability into supply chain management', *Supply Chain Management*, Vol. 19, No. 3, pp.322–331.

Sethi, S.P., Veral, E.A., Shapiro, H.J. and Emelianova, O. (2011) 'Mattel, Inc.: global manufacturing principles (GMP) – a life-cycle analysis of a company-based code of conduct in the toy industry', *Journal of Business Ethics*, Vol. 99, No. 4, pp.483–517.

Stappmanns, F. (2016) 'Sustainable Business model innovation: the cases of Patagonia Inc. and Bureo Skateboards', *InImpact: The Journal of Innovation Impact*, Vol. 8, No. 2, pp.349–364.

Thakkar, J., Kanda, A. and Deshmukh, S.G. (2008) 'Interpretive structural modeling (ISM) of IT-enablers for Indian manufacturing SMEs', *Information Management & Computer Security*, Vol. 16, No. 2, pp.113–136.

Venkatesh, V.G., Kang, K., Wang, B., Zhong, R.Y. and Zhang, A. (2020) 'System architecture for blockchain based transparency of supply chain social sustainability', *Robotics and Computer-Integrated Manufacturing*, Vol. 63, No. 1, p.101896.

Williams, B.D., Roh, J., Tokar, T. and Swink, M. (2013) 'Leveraging supply chain visibility for responsiveness: The moderating role of internal integration', *Journal of Operations Management*, Vol. 31, Nos. 7–8, pp.543–554.

Wood, L.C., Reiners, T. and Srivastava, H. S. (2017) 'Think exogenous to excel: alternative supply chain data to improve transparency and decisions', *International Journal of Logistics Research and Applications*, Vol. 20, No. 5, pp.426–443.

Wright, O., Maeseneer, K.D., Gurski, L. and Presti, S.L. (2020) Respond, reset and renew: navigating the impact of COVID-19 in consumer goods', *Accenture* [online] https://www.accenture.com/_acnmedia/PDF-121/Accenture-COVID-19-Consumer-Goods-Rapid-Response.pdf (accessed 17 March 2021).

Yang, J., Xie, H., Yu, G. and Liu, M. (2021) 'Antecedents and consequences of supply chain risk management capabilities: An investigation in the post-coronavirus crisis', *International Journal of Production Research*, Vol. 59, No. 5, pp.1573–1585.

Zelbst, P.J., Green, K.W., Sower, V.E. and Bond, P.L. (2020) 'The impact of RFID, IIoT, and blockchain technologies on supply chain transparency', *Journal of Manufacturing Technology Management*, Vol. 31, No. 3, pp.441–457.

Zhu, G., Chou, M.C. and Tsai, C.W. (2020) 'Lessons learned from the COVID-19 pandemic exposing the shortcomings of current supply chain operations: a long-term prescriptive offering', *Sustainability*, Vol. 12, No. 14, p.5858.

Zhu, S., Song, J., Hazen, B.T., Lee, K. and Cegielski, C. (2018) 'How supply chain analytics enables operational supply chain transparency', *International Journal of Physical Distribution & Logistics Management*, Vol. 48, No. 1, pp.47–68.