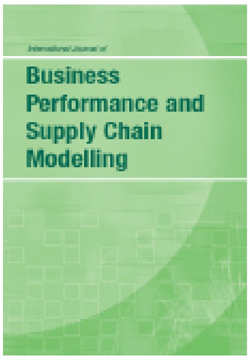


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# Modelling cloud computing adoption barriers for Indian SMEs' supply chain using TISM and MICMAC analysis

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# Modelling cloud computing adoption barriers for Indian SMEs' supply chain using TISM and MICMAC analysis

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**Abstract:** The implementation of CC can have an impact on the performance of small and medium-sized enterprises by changing the process of designing, producing, delivering, and discarding products. CC is advantageous to emerging countries, particularly India, and requires a comprehensive description for proper understanding and application in business. The aim of this paper is to identify the impediments to CC adoption from the perspective of Indian SMEs. The present research work is to identify the barriers to adopting CC in Indian SMEs using extensive literature and the response obtained from experts. The second main objective of this research is to develop an interpretive hierarchy of CC adoption barriers using TISM technique and categorise these identified barriers into different clusters using MICMAC analysis. This paper identifies four driving barriers named: 1) lack of government support; 2) low understanding of CC; 3) limitation of IT system; 4) lack of connectivity.

**Keywords:** digital technology; supply chain integration; supply chain relationship; inhibiting factor for ICT adoption; cloud computing adoption.

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## 1 Introduction

In today's global market, the organisation cannot sustain itself without an efficient, effective, and agile supply chain (SC). To boost the SC efficiency and effectiveness, the organisation will have to bring customers, suppliers, logistics activities, financial flow activities, interdepartmental activities, and intradepartmental activities together on a single platform (Novais et al., 2019; Xing et al., 2016). Successful integration of customers, suppliers, logistics activities, financial flow activities, product development activities, internal activities, and intradepartmental activities ensure the effectiveness, efficiency, and agility of the SC activities (e.g., material flow and information flow integration) (Lyu et al., 2017; Subramanian and Abdulrahman, 2017). A higher level and quality of information exchange improves organisational performance and gives businesses a competitive advantage in terms of cost, quality, delivery consistency, and time to market (Doumbia et al., 2021; Shete et al., 2021; Li et al., 2006). Organisations have been forced to adopt digital technologies to sustain in the global market. Organisations are discussing digital technology and debating how it is well-suited to integrate the SC partners successfully. Digital technology is changing how organisations purchase, produce, sell, and collaborate with SC partners (Oswald and Kleinemeier, 2017; Popkova et al., 2021). Organisational acceptance of digital technology is not a recent phenomenon. This revolution in digital technologies is related to their capabilities and the widespread acceptance of these tools by customers, employees, trading partners, and organisations. The organisation has embraced emerging technologies in recent decades as a result of technological advances. Cloud computing (CC), internet of things (IoT), and big data analytics are three most common emerging technologies that have been adopted or tried out in Indian manufacturing industry. As a result of these technologies and the globalisation of the workforce, consumer behaviour is changing. These technologies also allow businesses to become more profitable and creative.

CC has received enormous attention in both the public and private sectors as a result of the growing reputation of the shared network connecting people globally and within the enterprise. SC partners' communication and collaboration, logistics processes, and financial flow activities are all evolving as a result of CC (Liu et al., 2016). CC is an IT service platform in which customers receive computing capabilities on-demand across a network in a self-service manner, independent of device or location (Bruque-Cámara et al., 2016). Khayer et al. (2020) addressed that CC allows businesses to turn the traditional business model into a digital technology-driven business model, improve successful collaboration, and enhance IT capabilities (Khayer et al., 2020).

Indian small and medium sized enterprises (SMEs) are rushing to adopt and use CC for organisation operations and communication among SC partners due to its enormous potential benefits. SMEs in India have a lower IT budget than large corporations, making it difficult for them to develop internal IT resources (such as software, hardware, and IT infrastructure). As a result, Indian SMEs rely heavily on external IT expertise to achieve their desired results (Thakkar et al., 2008). Therefore, CC is the best option for Indian manufacturing SMEs to make SC effective, efficient, and agile without investing in IT infrastructure and to boost the economy. As we know, the Indian manufacturing industry's contribution to the national GDP is about 15%–16% and employs 12% of the working population. SMEs account for over 90% of all businesses and more than half of all jobs in the globe. In India, this industry accounts for around 45% of manufactured output, more than 40% of exports, and over 28% of GDP, while employing approximately 111 million people (Government of India, 2019–2020). Recently to transform the Indian Industry digitally, an initiative 'Digital India' was taken by the Government of India. The initiatives 'smart cities' and 'digital India' offer a huge opportunity to use CC and other technology. As a growing economy, it is critical for India's manufacturing industry to deal with the numerous barriers and benefits of CC adoption initiatives (Luthra and Mangla, 2018). Till now, CC has not experienced extensive adoption among Indian manufacturing SMEs. The implementation of CC in Indian manufacturing SMEs is hampered by a number of factors. The major constraint for SMEs is a lack of resources (for example, financial constraints), but the high cost and risk associated with IT initiatives prevents SMEs from quickly adapting or deploying CC (Priyadarshinee et al., 2017). Public-private partnership and encouragement to information and communication technology (ICT) providers are the main challenges in adopting CC in Indian food SMEs. Along with this, the coordination between different departments and collaboration and strategic alliances across the SC are the barriers that are mainly influenced by other obstacles in the adoption of CC (Singh et al., 2019). Therefore, the need arises to identify the obstacles in adopting CC in Indian SMEs for sustainable growth of their SC. Hence the objectives of this research paper are:

1 to uncover the critical barriers in the adoption of CC in Indian manufacturing SMEs
2 identify the essential driving barriers, linkage barriers, and dependent barriers by modelling the barriers using total interpretive structural modelling (TISM) and MICMAC analysis.

The remaining layout of this work is organised as follows. The literature related to this work and CC adoption barriers is provided in Section 2. Research methodology and the TISM process are explained in Section 3. The TISM development is explained and shown in Section 4. Classification of barriers and MICMAC analysis is explained in Section 5. Discussion of result and implication are explained in Section 6. Finally, conclusions, along with future potential in the area, are explained in Section 7.

## 2 Review of literature

Digital transformation is the process of implementing digital tools and capabilities by an organisation to change the internal and external processes. Digital technology is undoubtedly changing how organisations purchase, handle material, handle transportation activities, warehousing activities, and mode of communication among trading partners (Bonnet and Nandan, 2011). The latest ICT patterns do not primarily emphasise the internet's role in social networking. The internet has evolved into a medium for machine and product communication. The internet provides a comprehensive approach that goes beyond the potential and capabilities of conventional manufacturing organisations (Oswald and Kleinemeier, 2017). Supercomputing, smarter world, cyber security, CC, and hyper-connectivity are 5 leading technology trends today, and it seems that they will be notable over the next 10–15 years. Supercomputing comprises of in-memory computing and big data analytics. The smarter world includes smart sensors or robotics, 3D printing, machine learning, augmented reality, and artificial intelligence. Hyper connectivity includes social and business networks for collaboration and customer interface, IoT, and mobility (Ivanov et al., 2021). Cyber security is used for securing data, securing interactions, and securing identities. CC has received a lot of attention in both the public and private sectors due to the increasing reputation of the shared network connecting people globally and within the organisation (Basl, 2017). Now a day's, a new technology; block chain is also a hot topic for debate. Many organisations are going to adopt block chain for securing data. This research paper mainly focuses on the adoption of CC; therefore, this study will identify the critical barriers in adopting CC in SMEs.

CC is a type of computing that uses Internet techniques to offer IT-enabled capabilities (such as software, hardware, platform, infrastructure, and expert) as a service. It stores, manages, and processes data using a network of remote servers hosted on the internet – also known as the cloud – rather than a local server or a personal computer (Low et al., 2013; Alshamaila et al., 2013). Software as a service (SaaS), platform as a service (PaaS), infrastructure as a service (IaaS), and expert as a service (EaaS) are the four delivery models available to companies. Cloud may be private, public, hybrid, and community cloud. Microsoft office online and Google apps (Gmail) are an example of SaaS. Microsoft Azure and force.com are examples of the PaaS. Amazon cloud and Google cloud are examples of IaaS. On-demand self-service, broad network access, resource pooling, rapid elasticity, and measured services are among the five basic characteristics of CC. On-demand self-service computing allows a customer to control computing resources such as server time and network storage on their own, without having to deal with the service provider. Broad network access gives access to resources that are offered over the internet. Consumers can use heterogeneous systems to access these features through the network (e.g., cell phones, PC, workstations). Resources pooling allocates computing resources (e.g., servers, storage, processor, and memory) to customers based on their needs. Rapid elasticity refers to the ability to adjust capabilities quickly inward and outward in response to consumer demand. Resources utilisation can be monitored, regulated, and reported to the consumer using measured service characteristics, which enables transparency for both the provider and the consumer (Oliveira et al., 2014; Subramanian and Abdulrahman, 2017).

### *2.1 CC in Indian SMEs SC*

CC drastically lowers the cost of entry for SMEs seeking to profit from compute-intensive business insights that were previously only available to large companies. SMEs are trying to migrate from traditional SC to CC enabled SC for effective and efficient SC activities (Gangwar et al., 2015). A large enterprise has implemented many IS practices to improve the operational performance of the organisation. Material requirement planning (MRP), manufacturing resources planning (MRPII), enterprise resources planning (ERP), and electronic data interchange (EDI) are the main IS practices that are fully implemented in large organisations. MRP, MRPII, EDI, and ERP coordinate order fulfilment by synchronising material and resources available to customer demand and providing information among SC partners within and outside the organisation (Bayraktar et al., 2009). Due to the low budget of SMEs, SMEs cannot invest in IT infrastructure. Obtaining operational efficiency without pre-investment in IT infrastructure can only be possible by the successful implementation of CC (Subramanian and Abdulrahman, 2017). Software, platform, and infrastructure from different places can now be combined into the same environment because to advancements in CC technology. CC has a positive impact on the product modelling process (Lyu et al., 2017). CC can provide visibility to warehousing activity, transportation activity, distribution activity, and material handling activity with the help of RFID, barcoding, and warehousing management system (WMS), and ERP. Besides, CC can enable tracking of the raw material, unfinished goods, and final products for the customers and suppliers with GPS (Gupta and Jones, 2014). CC can be linked with many IS software (e.g., WMS, ERP, design software) for the integration of product development process, logistics activities, financial flow activities, supplier's activities, internal department activities, intradepartmental activities, and customers activities successfully (Novais et al., 2019; Subramanian and Abdulrahman, 2017; Yue et al., 2015).

A network of data and the information generated from the different departments will be stored in the cloud for sharing purposes, which will provide several advantages:

- the ability to use the cloud tool anywhere
- the ability to use and access cloud data anywhere
- the ability to use and access real-time cloud data
- it will enhance the forecast accuracy of the material
- better resources planning
- better operational efficiency
- cost-saving
- real-time access to information
- reduced lead time in production.

Many studies have addressed the technical and operational issues related to CC. They include selecting CC services based on costs and security concerns (Oliveira et al., 2014). Many authors have evaluated CC adoption from an organisational perspective. In this study, CC adoption is basically based on the aspect of the technology organisations environment (TOE) framework. There are various barriers to the adoption of CC in manufacturing SMEs. These barriers are related to the organisations (facilitating condition and management support), technology, and environment (government and trading partners). These barriers are identified using an extensive literature review and are explained in the next part.

## *2.2 CC adoption barriers*

From extensive literature review and response obtained from experts (from industry and academia), 13 factors are identified for this study.

### *2.2.1 Low understanding of CC*

Both managers of organisations and researchers have only a rudimentary understanding of CC. The adoption of CC in Indian manufacturing SMEs primarily requires highly organised research for a clear concept of CC and profits originated from its adoption. SMEs have a lower level of CC adoption than large manufacturing companies (Luthra and Mangla, 2018). Managers or policymakers of SMEs are unsure about the implications of CC in the SC.

### *2.2.2 Low management support and dedication towards digital strategy and vision*

Technology adoption necessitates a significant change in business processes and SC operations. As a result, SMEs' skills in terms of employee training and development, as well as knowledge management initiatives must be improved. CC cannot be implemented without the commitment and support of management (Oliveira et al., 2014). Management must focus on employee training, workshops on CC technology, and SC integration with technology adoption.

### *2.2.3 Lack of digital skills and capabilities*

The adoption of CC requires highly skilled professionals. Acquisitions of data generated from a different object (RFID tags, intelligent sensors, RFID readers, social networks, and mobile networks) require highly trained professionals. Thus, management should start focusing on improving their employee capabilities. To ensure the system's adaptability, the design, deployment, and management of CC networks should be user-friendly, requiring strong technical and functional abilities (Priyadarshinee et al., 2017).

### *2.2.4 Lack of competency in reimaging business model*

Industries must develop a new business model in the digital age. Due to the huge amount of data generated by many devices, the data was pushed to big data through the integration of various systems. At that time, organisations need to perform a value creation and proposition across the business model, and the value chain originated from cloud data. Only a very few of creations and proposition processes based on cloud data will be successful. Out of a million possibilities, just a few methods or occurrences are worthwhile (Oswald and Kleinemeier, 2017). Thus, this is a challenge for top management and highly skilled professional to reimage business models. Lack of competency in the reimaging business model will be highly influenced by the long payback period of technology implementation.

### *2.2.5 High adoption and operating cost of CC*

To develop the capabilities of an organisation, the organisation needs advanced equipment to generate and store data, internet facilities, IT systems, and sustainable process innovations. Financial constraints for acquiring advanced equipment and internet facilities are considered critical challenges among business organisations. The cost involved in developing digital skills enhances the operating cost of CC (Luthra and Mangla, 2018; Priyadarshinee et al., 2017).

### *2.2.6 Limitation of IT system in organisation and lack of infrastructure*

Infrastructure and information systems are crucial to the adoption of CC. Small manufacturing industries in India are mainly placed in rural areas. Thus, the lack of infrastructure and limitation of the IT system in an organisation is a big challenge for SMEs' technology implementation. The lack of infrastructure and restriction of IT system can enhance the problem of scalability and complexity of data and network (Lian et al., 2014).

### *2.2.7 Long payback period*

CC in manufacturing SMEs comprises a variety of sensing, actuating, storing devices, and equipment, all of which enhance the investment cost. Depending on the area of CC in SMEs' SC, the payback period may be longer than expected. Thus, the long payback period is also a key barrier in the adoption of CC (Luthra and Mangla, 2018).

### *2.2.8 Coordination and collaboration issues with SC partners*

For the successful implementation of CC, coordination and transparency among SC partners are essential. SC partners must be aware of the technology implementation process and how technology implementation affects the conventional method. Thus, SC partners must involve in the process of technology implementation for better communication mechanisms and quality of information sharing among partners (Gupta et al., 2013).

### *2.2.9 Connectivity issues (internet issues, standardisation issues of data and network)*

Poor internet connectivity is an essential barrier to the adoption of CC. Without internet connectivity, data generated from different devices and departments cannot be transmitted to the organisation's cloud. Standardisation of data and network is vital for better integration of operating interface for every user with any data generated devices (Gangwar et al., 2015).

### *2.2.10 Lack of government support and policies*

In 2017, Indian Government launched the digital MSME schemes, but they did not reveal the roadmap for transforming the conventional business functions into a digital business. The Indian Government has encouraged MSMEs towards a new business approach, but they are not clear about the consequences of digital transformation in MSMEs. The government of India should conduct workshops and conferences about the implementation of ICT technology (Low et al., 2011).

### *2.2.11 Complexity and scalability issues of data and network*

More data storing and interpreting devices are expected to be connected in the future as the network grows in size. Data collecting from a wide number of tools and departments would be a significant challenge in terms of complexity and scalability. The scalability issue of data and network would be intensified if the IT system is limited (Mezgár and Rauschecker, 2014).

### *2.2.12 Seamless integration issue of network*

While implementing ICT, heterogeneous data will be generated from different devices and different departments. Thus, integration and compatibility of these heterogeneous data and devices is a big issue for the organisation (Mezgár and Rauschecker, 2014).

### *2.2.13 Security and privacy issue of data*

Security and privacy is the prime requirement to transform the conventional organisation into the CC-based organisation and traditional SC into the CC-based SC. In organisations, the SC system has inherent security vulnerabilities that attackers exploit. SC partners are the primary source of security vulnerabilities (Subramanian and Abdulrahman, 2017).

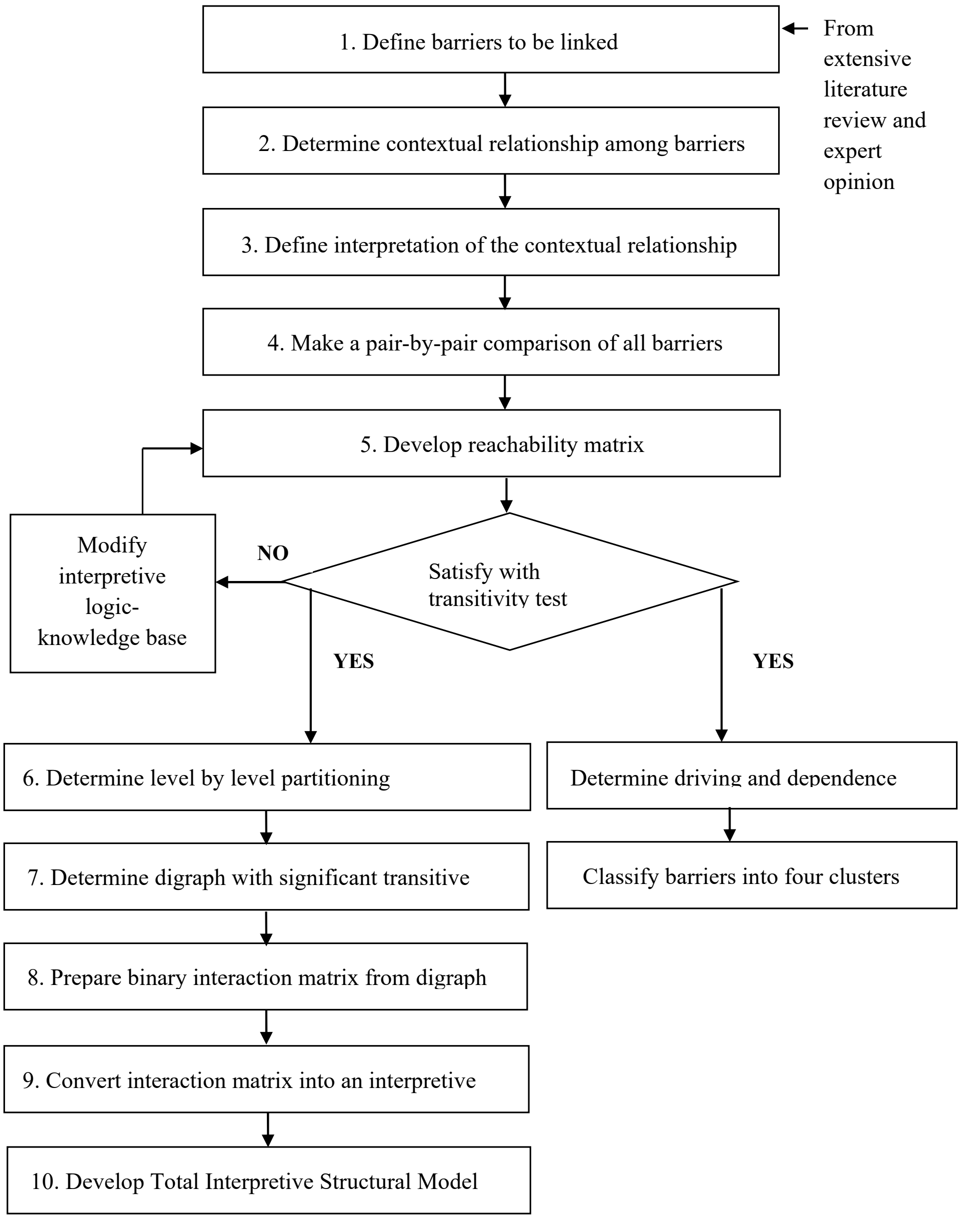
## 3 Research methodology

The TISM technique is used in this research. The TISM approach is used to use a multi-level hierarchical framework to define the relationship between different barriers to CC, making the complicated relationship clear as well as prioritising the selected barriers to CC adoption (Jena et al., 2017).

### *3.1 Total interpretative structure modelling*

Interpretive structural modelling (ISM) was suggested by Warfield (1974) to link factors in a detailed framed model. ISM depicts a complex systems model of attributes or components that are connected to one another both directly and indirectly. ISM is used to analyse the relationship between the identified barriers, resulting in a better understanding of the hierarchical structure of a system. Node interpretation is typically accomplished in ISM by defining the elements that signify it. In a pair-wise comparison, however, the links' explanation is limited to the elements' contextual relationship and the direction of that relationship. The relationship interpretation in the ISM is a little vague because it does not specify how directed links can achieve the defined contextual relationship (Sushil, 2012). As a result, the constructed digraph representing the relationship between identified pieces must be properly comprehended. The author used the TISM technique to solve this problem. TISM includes an interpretative matrix that provides an absolute interpretation of a digraph's relationship (Jena et al., 2017). MICMAC analysis identifies the driver barriers, linkage barriers, and dependent barriers depending on the basis of their driving and dependent power. This paper aims to uncover the key barriers and model the barriers using TISM and MICMAC analysis in adopting CC (Jena et al., 2017). A schematic diagram for research methodology is shown in Figure 1.

**Figure 1** Schematic diagram for research methodology




*Source:* Modified from Sushil (2012)

## 4 TISM Model development

The TISM applied for understanding the relationship between the CC adoption barriers in Indian manufacturing SMEs is described below.

### *4.1 Identification and definition of barriers*

An extensive literature review and expert opinion are being used to identify the cloud computing adoption barriers (CCoB) in the Indian SMEs SC. The CCoB described in this paper has been primarily accomplished through the use of various types of literature reviews. Considering the following electronic database: Elsevier (Science direct), Emerald Insight, Scopus, and Springer over the 2009–2019-time frame, including scientific papers, journals, articles, government reports, and business reports from companies. Three experts validate the identified CCoBs. Out of these, two experts were from industry, one from academia. Two experts are the SC head of industry, place in the national capital region of India, and one practitioner is currently working on digital technology under the CISCO project. Thirteen CC adoption barriers are selected for the final study explained in Section 2.2. The contextual relationship among barriers was developed by using an extensive literature review and expert opinion.

### *4.2 Total interpretive structural model*

To create a pair-wise relationship between adoption barriers, a structural self-interaction matrix (SSIM) is used. Four symbols show the direction of the relationship between the adoption barriers (i and j).

V When CCoBi has an effect on CCoBj.

A When CCoBj has an effect on the CCoBi.

X When both CCoBs have an influence on each other.

O When both CCoBs have no influence on each other.

The expert responses are utilised to construct the SSIM, which is given in Table 2. The SSIM inputs are used to construct an initial reachability matrix, which is then transitively checked. The initial reachability matrix is a binary matrix generated by converting the SSIM symbols V, A, X, and O into binary values 0 and 1 using the following guidelines:

**Table 1** Conversion of symbol

| *The symbol used in SSIM* | *Conversion in initial reachability matrix* |
|---|---|
| V | The (i, j) entry is changed to 1, and the corresponding (j, i) entry is changed to 0. |
| A | The (i, j) entry is changed to 0, and the corresponding (j, i) entry is changed to 1. |
| X | The (i, j) entry is changed to 1, and the corresponding (j, i) entry is also chnaged to 1. |
| O | The (i, j) entry is changed to 0, and the corresponding (j, i) entry is also changed to 0. |

**Table 2** SSIM

| *Barriers* | *B13* | *B12* | *B11* | *B10* | *B9* | *B8* | *B7* | *B6* | *B5* | *B4* | *B3* | *B2* | *B1* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low understanding of cloud computing (B1) | O | O | O | A | V | O | O | V | O | O | O | V | V |
| Low management support and dedication (B2) | O | A | A | A | A | O | A | A | O | V | A | V | |
| Lack of digital skills and capabilities (B3) | A | X | X | A | A | O | O | A | V | V | V | | |
| Lack of competency in reimaging business model (B4) | O | O | O | O | O | A | A | O | O | V | | | |
| High adoption and operating cost of cloud computing (B5) | A | A | A | A | A | V | V | O | V | | | | |
| Limitation of IT system in organization and lack of infrastructure (B6) | O | V | V | A | O | O | O | V | | | | | |
| Long payback period (B7) | O | O | O | O | O | V | V | | | | | | |
| Coordination and collaboration issues with supply chain partners (B8) | O | O | O | O | O | V | | | | | | | |
| Connectivity issues (internet issues, standardisation issues of data) (B9) | V | V | O | O | V | | | | | | | | |
| Lack of government support and policies (B10) | O | O | O | V | | | | | | | | | |
| Complexity and scalability issues of data and network (B11) | X | X | V | | | | | | | | | | |
| Seamless integration issue of network (B12) | X | V | | | | | | | | | | | |
| Security and privacy issue of data (B13) | V | | | | | | | | | | | | |

**Table 3** Initial reachibility matrix

| *Barriers* | *B1* | *B2* | *B3* | *B4* | *B5* | *B6* | *B7* | *B8* | *B9* | *B10* | *B11* | *B12* | *B13* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low understanding of cloud computing (B1) | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Low management support and dedication (B2) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lack of digital skills and capabilities (B3) | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| Lack of competency in reimaging business model (B4) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| High adoption and operating cost of cloud computing (B5) | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Limitation of IT system in organisation and lack of infrastructure (B6) | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| Long payback period (B7) | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Coordination and collaboration issues with supply chain partners (B8) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Connectivity issues (internet issues, standardisation issues of data) (B9) | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| Lack of government support and policies (B10) | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Complexity and scalability issues of data and network (B11) | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Seamless integration issue of network (B12) | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Security and privacy issue of data (B13) | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

**Table 4** Final reachibility matrix

| *Barriers* | *B1* | *B2* | *B3* | *B4* | *B5* | *B6* | *B7* | *B8* | *B9* | *B10* | *B11* | *B12* | *B13* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low understanding of cloud computing (B1) | 1 | 1 | 1* | 1* | 1* | 1 | 0 | 0 | 1 | 0 | 1* | 1* | 1* |
| Low management support and dedication (B2) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lack of digital skills and capabilities (B3) | 0 | 1 | 1 | 1 | 1 | 0 | 1* | 1* | 0 | 0 | 1 | 1 | 1* |
| Lack of competency in reimaging business model (B4) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| High adoption and operating cost of cloud computing (B5) | 0 | 1* | 0 | 1* | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Limitation of IT system in organisation and lack of infrastructure (B6) | 0 | 1 | 1 | 1* | 1* | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1* |
| Long payback period (B7) | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Coordination and collaboration issues with supply chain partners (B8) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Connectivity issues (internet issues, standardisation issues of data) (B9) | 0 | 1 | 1 | 1* | 1 | 0 | 1* | 1* | 1 | 0 | 1* | 1 | 1 |
| Lack of government support and policies (B10) | 1 | 1 | 1 | 1* | 1 | 1 | 1* | 1* | 0 | 1 | 1* | 1* | 0 |
| Complexity and scalability issues of data and network (B11) | 0 | 1 | 1 | 1* | 1 | 0 | 1* | 1* | 0 | 0 | 1 | 1 | 1 |
| Seamless integration issue of network (B12) | 0 | 1 | 1 | 1* | 1 | 0 | 1* | 1* | 0 | 0 | 1 | 1 | 1 |
| Security and privacy issue of data (B13) | 0 | 1* | 1 | 1* | 1 | 0 | 1* | 1* | 0 | 0 | 1 | 1 | 1 |

Note: 1* refers to significant transitive linkage.

The initial reachability matrix is shown in Table 3. The final reachability matrix with a transitive link (either normal transitive or significant transitive link) is shown in Table 4. If the collected responses obtained from experts are greater than 50%, the transitive link is regarded a significant transitive link; otherwise, the transitive link is considered a normal transitive link, and their responses are utilised to convert the knowledge base into the reachability matrix. The level partitioning process continues until the level of each barrier is identified, and it is shown in Table 5. In the form of a digraph, CC adoption barriers in SMEs are depicted. In a digraph, only those transitive links whose interpretation is crucial are kept. Figure 2 depicts a digraph with a significant transitive link. The interpretive matrix and digraph data are utilised to create a TISM-based model for CC adoption barriers in Indian manufacturing SMEs. A final TISM based model for barriers is portrayed in Figure 3.

## 5 Classification of barriers: MICMAC analysis

The MICMAC analysis is used to determine how dependent and powerful barriers are. It is mostly used to identify the barriers that primarily drive the entire system.

The barrier's driving power is represented by a '1' entry in the rows, and the barrier's dependency power is represented by a '1' entry in the column. It consists of categorising the barriers into four groups, which are discussed below.

- Cluster I-autonomous barriers

  The driving and dependence power of these barriers is low. They do not seem to have much of a connection to other barriers. As a result, they are not a part of it. There is no barrier to this cluster.

- Cluster II-dependent barriers

  These barriers have weak driving power but strong dependence on other barriers. There are five barriers (B2, B4, B5, B7, and B8) in this cluster.

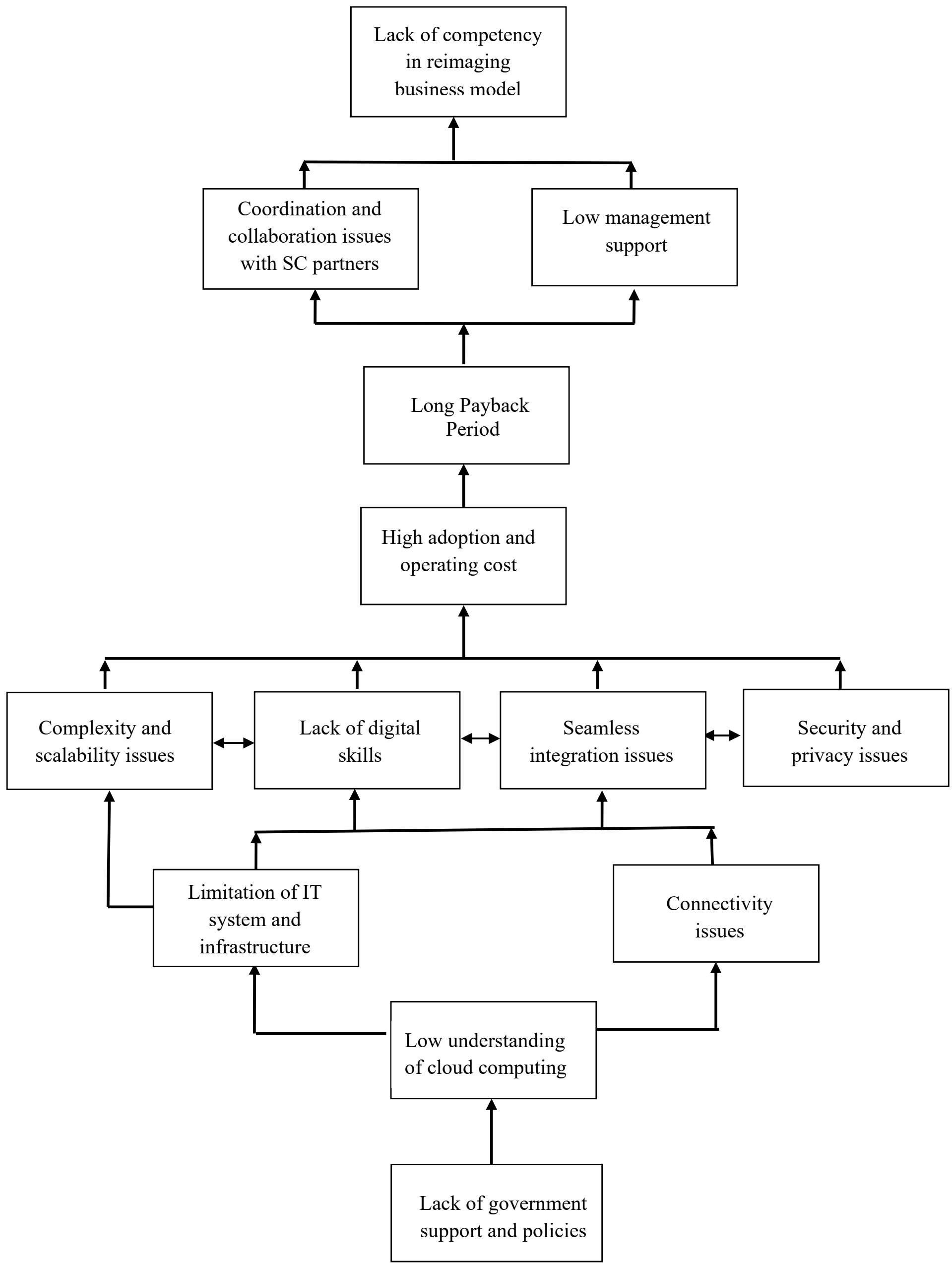
- Cluster III-linkage barriers

  These barriers have strong driving power as well as dependence. These barriers are inextricably linked to others, and any action taken against them will have an influence on others as well. This cluster contains four barriers (B3, B11, B12, and B13).

- Cluster IV-independent barriers

  These barriers have strong driving power but weak dependence on other barriers. These are regarded as major barriers that ultimately drive the system. This cluster contains four barriers (B1, B6, B9, and B10).

**Figure 2** Ism model




Note: All of the significant transitive linkages in a digraph are shown by dotted lines.

**Figure 3** Digraph with significant transitive links

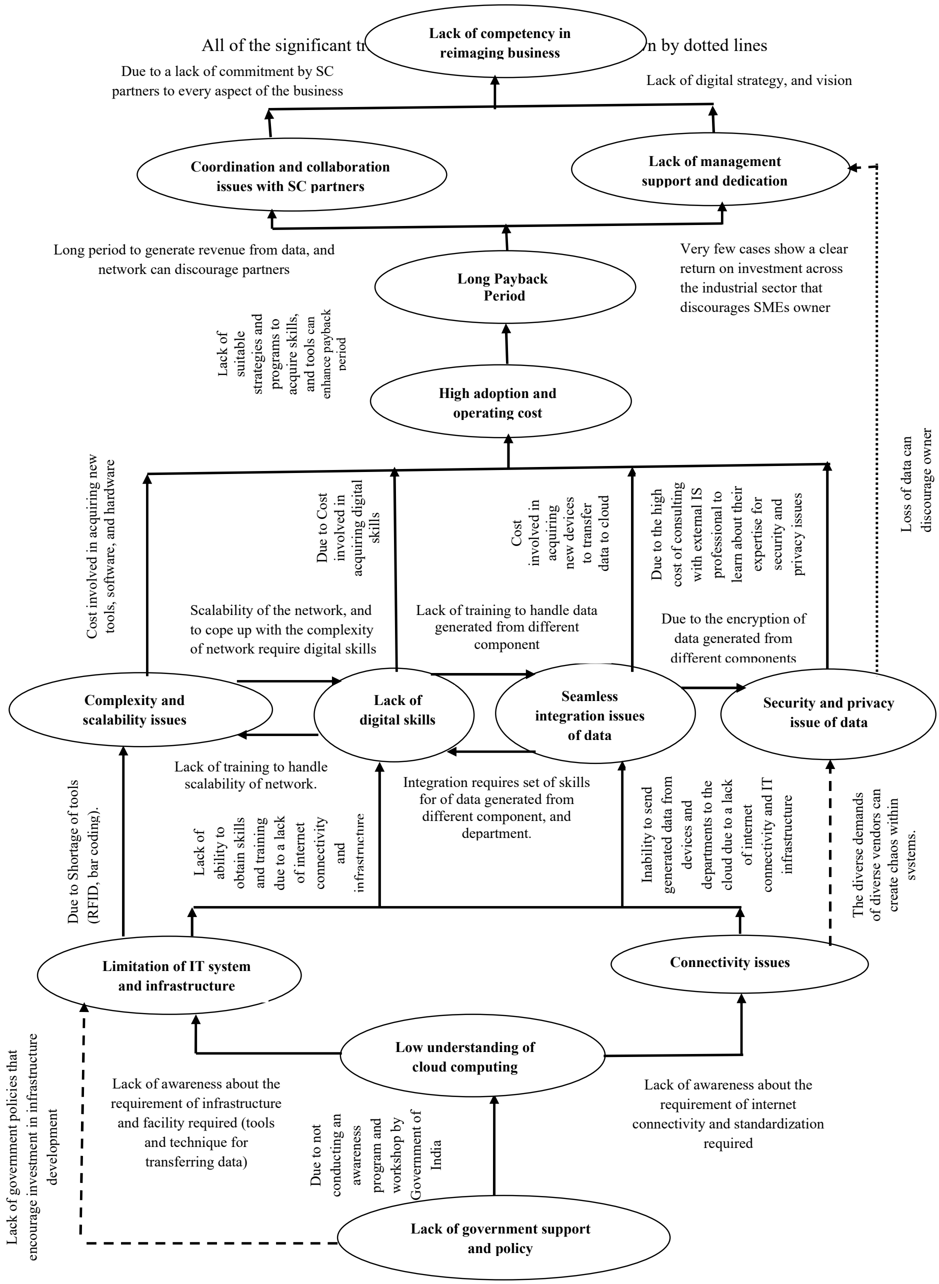


**Table 5** Level partitioning of reachability matrix

| *Barriers* | *Reachability set* | *Antecedent set* | *Intersection* | *Level* |
|---|---|---|---|---|
| *Iteration 1* | | | | |
| B1 | {1, 2, 3, 4, 5, 6, 9, 11, 12, 13} | {1, 10} | {1} | |
| B2 | {2, 4} | {1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 13} | {2} | |
| B3 | {2, 3, 4, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13} | |
| B4 | {4} | {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13} | {4} | I |
| B5 | {2, 4, 5, 7, 8} | {1, 3, 5, 6, 9, 10, 11, 12, 13} | {5} | |
| B6 | {2, 3, 4, 5, 6, 11, 12, 13} | {1, 6, 10} | {6} | |
| B7 | {2, 4, 7, 8} | {3, 5, 7, 9, 10, 11, 12, 13} | {7} | |
| B8 | {4, 8} | {3, 5, 7, 8, 9, 10, 11, 12, 13} | {8} | |
| B9 | {2, 3, 4, 5, 7, 8, 9, 11, 12, 13,} | {1, 9} | {9} | |
| B10 | {1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12} | {10} | {11} | |
| B11 | {2, 3, 4, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B12 | {2, 3, 4, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B13 | {2, 3, 4, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 11, 12, 13} | {3, 11, 12, 13} | |
| *Iteration 2* | | | | |
| B1 | {1, 2, 3, 5, 6, 9, 11, 12, 13} | {1, 10} | {1} | |
| B2 | {2} | {1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 13} | {2} | II |
| B3 | {2, 3, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13} | |
| B5 | {2, 5, 7, 8} | {1, 3, 5, 6, 9, 10, 11, 12, 13} | {5} | |
| B6 | {2, 3, 5, 6, 11, 12, 13} | {1, 6, 10} | {6} | |
| B7 | {2, 7, 8} | {3, 5, 7, 9, 10, 11, 12, 13} | {7} | |
| B8 | {8} | {3, 5, 7, 8, 9, 10, 11, 12, 13} | {8} | II |
| B9 | {2, 3, 5, 7, 8, 9, 11, 12, 13,} | {1, 9} | {9} | |

**Table 5** Level partitioning of reachability matrix (continued)

| *Barriers* | *Reachability set* | *Antecedent set* | *Intersection* | *Level* |
|---|---|---|---|---|
| *Iteration 2* | | | | |
| B10 | {1, 2, 3, 5, 6, 7, 8, 10, 11, 12} | {10} | {11} | |
| B11 | {2, 3, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B12 | {2, 3, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B13 | {2, 3, 5, 7, 8, 11, 12, 13} | {1, 3, 6, 9, 11, 12, 13} | {3, 11, 12, 13} | |
| *Iteration 3* | | | | |
| B1 | {1, 3, 5, 6, 9, 11, 12, 13} | {1, 10} | {1} | |
| B3 | {3, 5, 7, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13} | |
| B5 | {5, 7} | {1, 3, 5, 6, 9, 10, 11, 12, 13} | {5} | |
| B6 | {3, 5, 6, 11, 12, 13} | {1, 6, 10} | {6} | |
| B7 | {7} | {3, 5, 7, 9, 10, 11, 12, 13} | {7} | III |
| B9 | {3, 5, 7, 9, 11, 12, 13,} | {1, 9} | {9} | |
| B10 | {1, 3, 5, 6, 7, 10, 11, 12} | {10} | {11} | |
| B11 | {3, 5, 7, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B12 | {3, 5, 7, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B13 | {3, 5, 7, 11, 12, 13} | {1, 3, 6, 9, 11, 12, 13} | {3, 11, 12, 13} | |
| *Iteration 4* | | | | |
| B1 | {1, 3, 5, 6, 9, 11, 12, 13} | {1, 10} | {1} | |
| B3 | {3, 5, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13} | |
| B5 | {5} | {1, 3, 5, 6, 9, 10, 11, 12, 13} | {5} | IV |
| B6 | {3, 5, 6, 11, 12, 13} | {1, 6, 10} | {6} | |
| B9 | {3, 5, 9, 11, 12, 13,} | {1, 9} | {9} | |
| B10 | {1, 3, 5, 6, 10, 11, 12} | {10} | {11} | |
| B11 | {3, 5, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B12 | {3, 5, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | |
| B13 | {3, 5, 11, 12, 13} | {1, 3, 6, 9, 11, 12, 13} | {3, 11, 12, 13} | |
| *Iteration 5* | | | | |
| B1 | {1, 3, 6, 9, 11, 12, 13} | {1, 10} | {1} | |
| B3 | {3, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13} | V |
| B6 | {3, 6, 11, 12, 13} | {1, 6, 10} | {6} | |

**Table 5** Level partitioning of reachability matrix (continued)

| *Barriers* | *Reachability set* | *Antecedent set* | *Intersection* | *Level* |
|---|---|---|---|---|
| *Iteration 5* | | | | |
| B9 | {3, 9, 11, 12, 13,} | {1, 9} | {9} | |
| B10 | {1, 3, 6, 10, 11, 12} | {10} | {11} | |
| B11 | {3, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | V |
| B12 | {3, 11, 12, 13} | {1, 3, 6, 9, 10, 11, 12, 13} | {3, 11, 12, 13,} | V |
| B13 | {3, 11, 12, 13} | {1, 3, 6, 9, 11, 12, 13} | {3, 11, 12, 13} | V |
| *Iteration 6* | | | | |
| B1 | {1, 6, 9} | {1, 10} | {1} | |
| B6 | {6} | {1, 6, 10} | {6} | VI |
| B9 | {9} | {1, 9} | {9} | VI |
| B10 | {1, 6, 10} | {10} | {11} | |
| *Iteration 7* | | | | |
| B1 | {1} | {1, 10} | {1} | VII |
| B10 | {1, 10} | {10} | {11} | |
| *Iteration 8* | | | | |
| B10 | {10} | {10} | {10} | VIII |

**Figure 5** MICMAC analysis of CC barriers

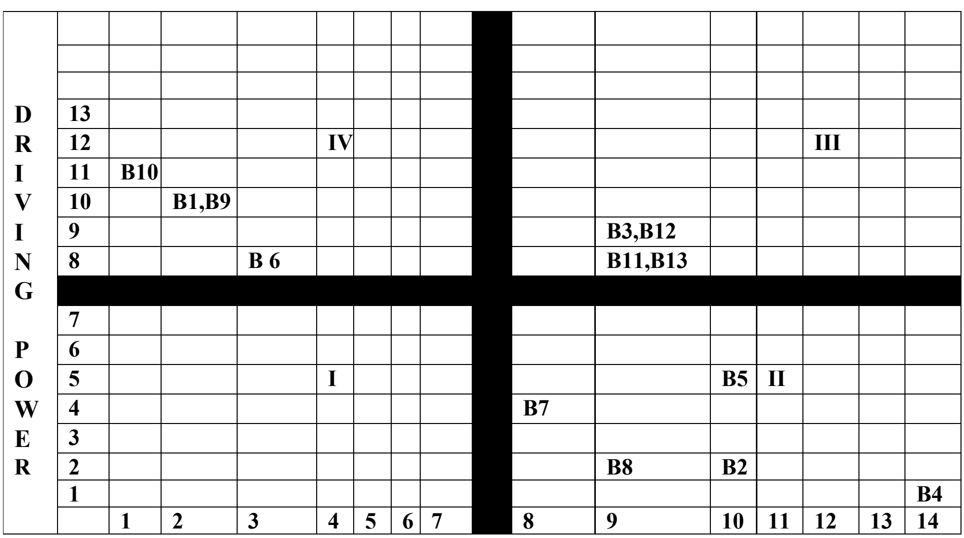


**Table 6** Interpretive matrix

| *Bs* | *B1* | *B2* | *B3* | *B4* | *B5* | *B6* | *B7* | *B8* | *B9* | *B10* | *B11* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B1 | --------- | -------- | -------- | -------- | ------- | Lack of awareness about the requirement of infrastructure and facility required (tools for transferring data ) | ------ | ------- | Lack of awareness about the requirement of internet connectivity and standardization required for data | ----- | -------- |
| B2 | ------ | -------- | --------- | Lack of digital strategy and vision | ------------ | --------- | ---------- | . | -------------- | ------ | ------- |
| B3 | ------ | ------- | --------- | ---------- | Due to Cost involved in acquiring digital skills and talents | ---------- | --------- | ---------- | ---------- | ----- | Lack o training handle scalability networ |
| B4 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | --------- | ---------- | ---------- | ----- | --------- |
| B5 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | Lack of suitable strategies and programs to acquire skills, and tools can enhance payback period | ---------- | ---------- | ----- | --------- |
| B6 | ---------- | ---------- | Lack of ability to obtain skills and training due to a lack of iinfrastructure | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ------ | Due tc Shortage c tools (RF bar codir |
| B7 | ---------- | Very few cases show a clear return on investment across the industrial sector that discourages SMEs owner | ---------- | ---------- | ---------- | ---------- | Long period to generate revenue from data, and network can discourage partners | ---------- | ------ | --------- - | --------- |

**Table 6** Interpretive matrix (continued)

| *Bs* | *B1* | *B2* | *B3* | *B4* | *B5* | *B6* | *B7* | *B8* | *B9* | *B10* | *B11* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B8 | ---------- | ---------- | ---------- | Due to a lack of commitment by SC partners to every aspect of the business | - | ---------- | ---------- | ---------- | ---------- | ---------- | ------ |
| B9 | ---------- | ---------- | Lack of ability to obtain skills and training due to a lack of internet connectivity | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ------ | --------- |
| B10 | Due to not conducting awareness program and workshop by Government of India | ---------- | ---------- | ---------- | ---------- | Lack of government policies that encourage investment in infrastructure development | ---------- | ---------- | ---------- | ------ | --------- |
| B11 | ---------- | ---------- | Scalability of the network, and to cope up with the complexity of network require digital skills | ---------- | Cost involved in acquiring new tools, software, hardware | ---------- | ---------- | ---------- | ---------- | ------ | --------- |
| B12 | ---------- | ---------- | Due to Requirement of new set of skills for acquisition of data generated from different component and department | ---------- | Cost involved in acquiring new devices to transfer data to cloud | ---------- | ---------- | ---------- | ---------- | ------ | --------- |
| B13 | ---------- | Loss of data can discourage owner to adopt CC | ---------- | ---------- | Due to the high cost of consulting with external IS professional to learn about their expertise for security issues | ---------- | ---------- | ---------- | ---------- | ------ | --------- |

## 6 Discussion and implications

One of the primary goals of this study is to develop an interpretive hierarchy of CC adoption barriers and provide clear definitions and insights to practitioners, policymakers, and managers so that these barriers may be removed and CC can be used successfully in Indian manufacturing SMEs. 13 CC adoption barriers are identified and defined here, and their relationship is analysed here by using TISM based modelling. TISM interprets the level of all these barriers and how these barriers influence one another. The driving power and dependence of these barriers are presented using MICMAC analysis. The following are among the consequences of the TISM base model and MICMAC analysis. There is no autonomous barrier. That means all of the identified barriers have a high driving power, or a high dependence, or both. There are five dependent barriers that come under the dependence cluster II category. These barriers are 'low management support and lack of digital strategy (B2)', 'lack of competency in the reimaging business model (B4)', 'high adoption and operating cost of CC (B5)', 'long payback period (B7)', 'coordination and collaboration issue with SC partners (B8)' 2 of the 5 barriers, 'low management support and lack of digital strategy (B2)', and 'coordination and collaboration issue with SC partners (B8)', are on the same TISM level. These six barriers have a low driving power but a high dependence. The first level of the TISM hierarchy is 'lack of competency in the reimaging business model (B4)', while the second level is 'Low management support and lack of digital strategy (B2)', and 'coordination and collaboration issue with SC partners (B8)'. All of these barriers are highly dependent on the barriers in Cluster IV. Cluster III contains four barriers, each of which has a strong driving power as well as a strong dependence. These barriers are 'lack of digital skills and capabilities (B3)', 'complexity and scalability issue of data and network (B11)', 'seamless integration issue of data and network (B12)', 'security and privacy issue of data (B13)'. These barriers are inextricably linked to others, and any action taken against them will have an influence on others as well.

The findings identify the 'lack of competency in re-imaging the business model' of CC in the SMEs as a significant reason for the lack of CC adoption. This signifies that at SMEs, the ability to reimaging the business model is critical, and it can only happen if managers are convinced of the benefits and increased profitability that CC can deliver. Previous studies imply that successful validations are required to adopt ICT (IoT) in the retail industry (Kamble et al., 2019). This finding is consistent with previous studies (Kamble et al., 2019). The lack of competency is currently associated with a lack of management support and digital strategy, and coordination and collaboration issues with SC partners. Top management support helps SMEs to go for the adoption of CC at right time. Previous studies support that managers usually express fear and reluctance to changes to the current state of the business model (Thakkar et al., 2008). Previous studies also support that trading partner power was statistically significant for CC adoption in the high-tech industry (Low et al., 2011). The high implementation cost and long payback period of CC are considered as reasons for the lack of management support and coordination with SC partners. Suppliers to SMEs, according to Thakkar et al. (2008), are typically small, fragmented entities with limited cash to invest (Thakkar et al., 2008). The deployment of CC in SMEs requires a strong IT infrastructure that includes not only dependable internet connectivity, but also the capacity to connect suppliers and customers at multiple levels of SC. The IT infrastructure of most SMEs is unable to keep up with the constantly increasing and changing market needs. As a result, SMEs should have a strong IT plan in place for the future development of CC. The base of the TISM hierarchy is government support and policies, which affect a low understanding of CC, and lack of IT system and infrastructure. Government policies that encourage investment in infrastructure development can be beneficial (Thakkar et al., 2008; Khayer et al., 2020). Previous studies also support that conferences, training events, and publications of papers are all way for the Government to enhance IT understanding and use (Thakkar et al., 2008; Khayer et al., 2020). Singh et al. (2019) also supports that Government policies and decisions are critical for ICT applications in Indian SMEs to grow sustainably. ICT applications will assist in SC reform and innovation. This would boost the competitiveness of Indian SMEs (Singh et al., 2019).

Thus policymakers and managers of manufacturing SMEs should focus on barriers that have strong driving power on level wise. These barriers mainly influence all other barriers in the present study, four barriers are identified as key barriers. These barriers have strong driving power but weak dependence. These barriers are 'low understanding of CC (B1)', 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)', 'lack of government support and policies (B10)'. Out of these four barriers, 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)' form the same level in TISM hierarchy. 'Low understanding of CC (B1)', 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)', 'lack of government support and policies (B10)' controls the CC adoption in Indian manufacturing SMEs. 'Lack of government support and policies (B10)' form the lowest level in TISM hierarchy. Usually, these four 'low understanding of CC (B1)', 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)', 'lack of government support, and policies (B10)' form the base of TISM hierarchy. Thus, these four barriers should be handled carefully to reduce their effect on the adoption of CC in Indian manufacturing SMEs. These four barriers 'low understanding of CC (B1)', 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)', 'lack of government support, and policies (B10)' will help together to control other barriers. As a result, the four barriers of 'low understanding of CC (B1)', 'limitation of IT system and lack of infrastructure (B6)', 'connectivity issues (B9)', and 'lack of government support and policies (B10)' should be resolved as quickly as possible. Linkage barriers, which are outlined in cluster III, should also be emphasised. The outcome of this study reveals that by effectively controlling key barriers (cluster IV) and linkage barriers (cluster III), the dependent barriers (cluster II) will be controlled automatically.

## 7 Conclusions

The authors emphasise the importance of the TISM technique over the ISM approach in this study by demonstrating its ability to provide interpretation. The importance of this study is that it identifies the barriers to CC adoption in Indian manufacturing SMEs. Based on their driving power and dependence, the TISM hierarchy divides these barriers into eight-level hierarchy. MICMAC analysis classifies these barriers into four clusters based on their driving power and dependence. All the barriers are identified by extensive literature reviews and responses obtained from experts. In this study, the interpretive hierarchy of CC adoption barriers provides clear definitions and information to the practitioners, policymakers, and managers to diminish these barriers for successfully adopting CC in Indian manufacturing SMEs. The outcomes of this study reveal and can support to policymakers and managers of Indian SMEs to understand the critical barriers of CC adoption in Indian SMEs. The most significant application of this study is for Indian SMEs that need to assure the right level of infrastructure flexibility, performance, and agility to manage unpredictable demand and geographic distribution while handling largely predictable workloads. According to the literature, Indian SMEs in various manufacturing sectors want to stay competitive and quickly adapt to new business models. CC lowers the obstacle for SMEs looking to gain access to compute-intensive business insights previously exclusively available to major corporations and provides IT services without investing in infrastructure. This study's foremost contribution lies in developing eight levels TISM hierarchy of 14 identified barriers to show the interrelationship among these barriers. Thus, policymakers and managers can emphasise these critical barriers to the successful adoption of CC in Indian SMEs.

There are a number of limitations to this study. To begin with, finding CC adoption barriers was a challenge. The TISM model was developed using numerous important constructs from the three main aspects (TOE); future research can expand the TISM model by including more significant constructs from the three main aspects. The TISM-based model is highly dependent on the expert team's opinions, which may be biased. TISM is used to develop an interpretive model for 13 barriers, although this model is not statically validated. Case studies and structural equation modelling (SEM) can be applied to further explain and support the findings. SEM can validate a theoretical model that has already been constructed, but it is impossible to formulate an original model for evaluation. TISM is capable of producing a theoretical model by using different techniques like brainstorming etc. Thus TISM and fuzzy MICMAC are the first to create a conceptual model.

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