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Exploring adoption barriers of ICT in SMEs using an ISM-MICMAC approach

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This article studies the barriers to the adoption of Information and Communication Technologies (ICT) among Small and Medium Enterprises (SMEs). 11 barriers are identified to ICT adoption from the extant literature and collected data from nine SME owners. Detailed analysis of barriers helped to develop the Interpretative Structural Modeling (ISM) framework and to categorize those barriers using *"Matrice d'impacts Croises multiplication appliquee a un classment"* (MICMAC) analysis. The results of the study show that there are seven different levels in the ISM model, where barrier B1 (Cultural Barrier) at the topmost levDel in the model signifies being highly dependent, while barrier B11 (Lack of visionary leadership) at the bottom signifies the key driving factor. This study establishes a contextual relationship between barriers. This study adds to the present literature related to barriers to ICT adoption in SMEs in developing nations and proposes a model to overcome these barriers.

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Introduction

In a fast-paced world, driven by innovation and technology, the success of an economy is dependent on various business ideas that are allowed to be nurtured and become profitable business ventures. SME's role is pivotal in developing society and economy as SMEs help create jobs and wealth in diverse sectors, producing different products and services. SMEs account for 45% of the industrial production in India and 49.5% of the exports IBEF (India Brand Equity Foundation). These figures are not very different among the developing nations.

ICT adoption is desirable as it helps in information flow and improves knowledge management within the organization to bring efficiency and reduce costs. There has been a surge in digital adoption among firms, where 93% of small-business owners were using at least one technology platform in 2022, and that number grew to 99% in 2024. 77% of the SMEs envisage adopting promising technology such as AI and Metaverse by 2024 (US Chamber Report; https://www.uschamber.com/assets/documents/Impact-of-Technology-on-Small-Business-Report-2024.pdf). According to the World Economic Forum (2022), they are vital to the world economy as they represent 90% of the businesses and their contribution to global jobs and GDP stands at 70%. Globally, there has been an increase in the digitalization project, where the total expenditure was $2.15 trillion in 2023 (Sherif et al., 2024), and this is expected to reach a whopping $3.9 trillion by 2027 (Elsersy et al., 2021). These figures emphasize the growing importance of ICT adoption among companies (Saeedikiya, Salunke, & Kowalkiewicz, 2025) and thus provide a rationale for this study.

Small and Medium Enterprises (SMEs) are the engines of growth for an economy (Owalla et al., 2022). SMEs help the country to grow socially and economically by bringing innovations, creating employment opportunities, and generating income (He et al., 2017). In the world of technology, which has touched almost all aspects of human life. Information and Communication Technologies (hereafter ICT) aim to serve the customer and clients by being more efficient, accountable, and with better quality service (Gupta et al., 2008). The liberalization of economies, across the globe, paved the way for ICT as a cost-efficient tool to compete with bigger organizations in attracting customers (Tan et al., 2010). The use of ICT is likely to rise at a higher pace in the future as it brings in efficiency, cost reduction, and consistency, among others. Technology-based adoptions promote real-time decision-making that allows firms to refine operational performance (Curtin et al., 2007), and SMEs are yet to exploit the benefits of ICT, which will help them enhance their business, yielding more job opportunities and performance in the future. ICT technologies are being used more internally and externally in SMEs, consisting of consumers, vendors, etc. This results in increased investment in ICT in SMEs (Soto-Acosta and Merono-Cerdan, 2008). SMEs are also now able to gain economic efficiencies and cost savings by adopting ICT, which only large businesses were privy to (Schlenker and Crocker, 2003). The adoption of ICT positively influences the SECI (Socialization, Externalization, Combination, and Internalization) by creating knowledge in Spanish SMEs, which in turn helps in organizational learning (Lopez-Nicolas and Soto-Acosta, 2010). Innovation has a critical role in the economic advancements of countries, and a catalyst for this is SMEs. Digital technologies influence innovation, and it is an essential element in the innovation ecosystem, as per theory of innovation evolution (Du & Wang, 2024). The role of Digital technology and infrastructure in innovation is emphasized by Xie et al. (2024), who reported that it provides significant benefits to SMEs, specifically to manufacturing SMEs, by enabling them to innovate their business model. Using data from 25 European countries of Generation Z entrepreneurs, Saeedikiya et al. (2024) found that cognitive factors such as risk-taking ability, identification of opportunities, and self-efficacy are instrumental in steering the innovation, and digital infrastructure plays the role of enabler to it.

Adoption of ICT is a long-term and structural change in human resources (Tarutė & Gatautis, 2014), strategy, organizational and management system level (Giotopoulos et al., 2017) is required. These structural changes lead to improvement in performance, innovations, growth, expansion and internalization. Structural change and technological progress positively influence innovation, which impacts the economic growth of a country (Zhou et al., 2021).

SMEs in developing countries bump into problems in adopting ICT due to the limited resources and lack of understanding of ICT benefits (Chapman et al., 2000). Moreover, the ICT applications are primarily designed to keep the structure and characteristics of large organizations, not of SMEs (Jun and Cai, 2003). SMEs can adopt and implement ICT if they have the requisite understanding and knowledge about the adoption of ICT and how it can affect their business decision (Giotopoulos et al., 2017).

SMEs are essential to India's overall industrial sector. SMEs are crucial to achieving the national goals of inclusive and equitable growth. Definition provided by the Ministry of MSMEs, Government of India, an SME will not exceed Rs. 125 crores as an investment and Rs. 500 crores as annual turnover (MSME, 2025).

There are enough studies that focus on e-commerce, cloud computing, knowledge management in SMEs (Hedman and Gimpel, 2010), digital solutions (Xie et al., 2022), and ICT adoption (Ritchie and Brindley, 2005; Tan et al., 2010), however, there is a lack of research on the barriers to the adoption of ICT in the existing literature from which SMEs can get knowledge and learn from. SMEs must be aware of and understand how to adopt ICT in business operations.

The present study gives insight into barriers to ICT adoption by SMEs. Existing literature is synthesized to identify the barriers. Experts were interviewed to identify the relationship that exists among these barriers. Further, these barriers were organized into the Interpretative Structural Modeling to help identify the hierarchy of barriers considered in this study.

The results suggest that a lack of visionary leadership is a considerable barrier, while the cultural barrier is the least important barrier to ICT adoption. The outcome of the study will also add to the literature by identifying the barriers to ICT adoption in SMEs, along with highlighting the importance to SMEs.

Technology has become very important for businesses, including SMEs; however, the attitude of owner-managers is not receptive towards the adoption of technology in SMEs and is linked with technological infrastructure in the SMEs (Admiraal and Lockhorst, 2009). Higher-level competencies are required to drive new technology adoption (Thoumrungroje and Racela, 2022; Selase et al., 2019), and found that there exists a positive relationship between technology usage and the market performance of SMEs. The present study addressed the following questions.

RQ1. What are the barriers to adopting ICT among SMEs in India?

RQ2. Does there exist any relationship between these barriers?

RQ3. What is the classification and the hierarchical structure of these barriers?

RQ4. What can be the proposed framework that can help to increase ICT adoption among SMEs in India?

The present study provides a model of barriers impacting SMEs in adopting ICT, thus extending the body of knowledge.

The study also extends the application of the ISM methodology for exploring the barriers to ICT adoption. The results of the study will help the owners of SMEs understand the barriers and the contextual relationship among those barriers, which will help them towards ICT adoption. The study will also be useful to policymakers to make policies that will help in the adoption of ICT among SMEs.

Literature review

The adoption of ICT among SMEs and their performance is affected by various barriers (Ipinnaiye, 2017). Literature on SMEs and their technology orientation is studied, and it was found that ICT adoption among SMEs is the key element in aligning these SMEs with current technologies (Franco and Pissarra, 2012). SMEs have constraints related to infrastructure, capital, human resources, and regulations. These restrictions lead to various barriers to IT adoption. A thorough literature review helped us to identify such barriers which include a lack of trained and skilled staff lack of education and knowledge of managers or owners (Zhao and Thompson, 2019), lack of capital (Luypaert et al., 2016), knowledge management, and knowledge transfer (Hyrk-känen et al., 2022), lack of security and privacy (Miklian and Hoelscher, 2022), cost of IT infrastructure (Zhou and Verburg, 2020), size of the SMEs (Hilmersson et al., 2022) and lack of visionary leadership (Honjo and Kato, 2022; Lee et al., 2019). The present study explored eleven major challenges for the adoption of ICT in SMEs, however, there could be more challenges, such as organizational inertia, legacy systems (Saeedikiya, Salunke, & Kowalkiewicz, 2024), Change management, lack of advice and inability of clients to adopt ICT (Nazir & Khan, 2024). Literature exploring these eleven barriers is briefly discussed in the following subsections:

Cultural barrier. Twati and Gammack (2006), as well as Rauch et al. (2019), identified organizational culture as a critical barrier affecting the adoption of ICT. Unless an organization inclines to the adoption of ICT and ITES, it will fail to adapt to such change in the future (Twati and Gammack, 2006). This study further explored the relevance of culture (Rizos et al., 2016) and other factors in the adoption of ICT in an organization.

Lack of trained and skilled staff. Adoption and implementation of ICT can be outsourced to other firms (Idris et al., 2023), and the availability of "skilled staff" is considered one of the important parameters in associations. Factors such as the skills of staff affect the adoption of electronic commerce technologies by SMEs (Lawson et al., 2003). Lack of skilled staff to perform ICT-related operations results in adverse effects on a company's performance and consumes critical capital (Abdullah et al., 2018; Duan et al., 2002). Neef, Hirzel, and Arens (2018) advocate that the lack of skilled staff is a limiting factor in IT adoption. Staff training on ICT has emerged as a key issue in information system management because, in the recent past, the extension and complexity of ICT applications have changed a lot (Chen et al., 2007). The digitization of an organization is highly influenced by the availability of a skilled workforce (Branca et al., 2020); therefore, an organization considering the adoption of ICT should have skilled manpower to implement and cater to such change. In the present study, the lack of training of staff is considered a factor affecting ICT adoption.

Lack of policies, standards, and regulations. Regulations play the role of controller for the operations performed using IT and ITES. Sharma and Sehrawat (2020) identified the lack of government policy and standards as the most critical factor in the

adoption of cloud computing, which is an advanced IT tool. Policies and regulations (Chen et al., 2019) determine the quantum of applicable ICT for an organization (Bedue and Fritzsche, 2022). It is of utmost importance to consider restrictions vis-à-vis rules and regulations issued by regulators to ensure a controlled application and intervention of IT into business (Lawson et al., 2003; Rizos et al., 2016; Stockdale and Standing, 2004). The availability of funds and proper policies by regulators determine the success of ICT adoption (Pissarides, 1999).

Lack of education and knowledge among managers and owners. This is another important variable that determines the adoption of information technology advancements. Knowledge of a manager to handle business activities and the transfer of such knowledge is a crucial element in the implementation of information technology projects in an organization (Kuruppuarachchi et al., 2002). The main barrier to better utilization of ICT in SMEs is the lack of proper knowledge, education, and skills of managers and owners (Arendt, 2008). ICT adoption is one of the requisites of modern industry (Lasch et al., 2013); therefore, the education and skills of the owner to handle such adoption contributed insignificantly (Branca et al., 2020).

Lack of capital. Capital is treated as the backbone of every project in an organization. Pissarides (1999) identified a lack of funds as the main obstacle to growth in terms of ICT adoption. An important barrier to the adoption of ICT in SMEs is the limited financial resources (Abdullah et al., 2018; Rizos et al., 2016). Financial constraints impact the development of SMEs significantly (Cecere et al., 2020; Kannabiran and Dharmalingam, 2012; Migiro, 2006) identified a lack of resources, a lack of internal IT staff, a lack of IT infrastructure, and a perceived lack of information security as specific impediments to ICT adoption in Indian auto ancillaries. In a survey conducted by Marri, Gunasekaran, and Sohag (2007), it was observed that most of the companies spent less than even 1% of their total revenue on R&D and the adoption of new technology.

Knowledge management and knowledge transfer. Knowledge of a manager to handle business activities and the transfer of such knowledge is a crucial element in the implementation of information technology projects in an organization (Kuruppuarachchi et al., 2002). The main barrier to better utilization of ICT in SMEs is a lack of proper knowledge management and its transfer (Arendt, 2008).

Lack of security and privacy. Nayal et al. (2025) identified limited data privacy or security as the foremost barrier to modern technology acceptance. It is crucial to solve privacy and security concerns to increase data transparency (Sousa et al., 2022). Threats to businesses from data privacy and security include the replication of false data, unauthorized access, disclosure of sensitive data, etc. (Kamble et al., 2019). Issues with data privacy and security include vulnerability to attacks, data ownership, the right to govern and use data, the veracity of data, and stakeholder privacy concerns (Astill et al., 2019). Lack of security and privacy is also studied as a barrier by Branca et al. (2020), Kumar, Singh, and Dwivedi (2020), Lawson et al. (2003), Neef, Hirzel, and Arens (2018), Rauch et al. (2019) in their respective studies.

Cost of ICT infrastructure. The cost of adoption is considered one of the factors affecting the adoption of ICT in an organization (Lawson et al., 2003; Migiro, 2006). This factor is studied by exploring its aspects, such as the cost of experts or consultants, transaction cost, resource costs (Rizos et al., 2016), and the cost of

research and development. The cost of adopting information and communication technology (ICT) in an organization is relatively higher (Eze et al., 2013; Pissarides, 1999) because of perceived competition and the requirement for dedicated IT infrastructure (Kannabiran and Dharmalingam, 2012).

Lack of IT-based infrastructure. The presence of ICT in a business depends on the availability of IT-based infrastructure. Kannabiran and Dharmalingam (2012) and Abdullah et al. (2018) found the lack of IT-based infrastructure as a constraint in advanced ICT adoption. In their study, Kannabiran and Dharmalingam (2012) found that only 17% of the SMEs adopted information technology due to the presence of constraints such as perceived benefits, perceived competitive pressure, etc. Neef, Hirzel, and Arens (2018) have identified a lack of IT infrastructure as a specific barrier to ICT adoption. A study conducted by Singh, Thakkar, and Jenamani (2022) advocates the importance of IT-based infrastructure for the adoption of ICT in MSMEs, specifically in developing countries. Lack of IT-based infrastructure is one of the probable elements of ICT adoption in an organization (Migiro, 2006; Moktadir et al., 2018; Wasim et al., 2024).

Size of SMEs. "Size of SMEs" is considered one of the variables to study the determinants of ICT adoption using the ISM approach. Eze et al. (2013) conducted research on ICT adoption in small and medium-sized businesses (SMEs) and hypothesized that this adoption is influenced by both the SME's size and the competitive environment. Supyuenyong, Islam, and Kulkarni (2009), as well as Kannabiran and Dharmalingam (2012) mentioned in their study that it is easy for SMEs to adopt new things and monitor them due to the advantage of being of small size, reflecting the association between firm size and management style. Understanding the critical variables for ICT adoption is significant for the development of modern industry (Sommer, 2015). The size of an organization is considered one such variable in studying ICT adoption by Deng, Duan, and Luo (2020).

Lack of visionary leadership. SMEs should address the barriers to ICT adoption and should address them to ensure the success of such adoption of ICT. Giotopoulos et al. (2017) identified visionary leadership as one of the potential determinants of ICT adoption. Industry 4.0 necessitates ICT adoption, and visionary leadership plays an important role in such adoption (Kumar, 2021). Visionary leadership, along with other barriers, is considered by Stockdale and Standing (Stockdale and Standing, 2004) to study the benefits of such consideration in e-marketplace participation. Owners' attitude and knowledge towards ICT impact more on ICT adoption in comparison to other factors (Nair et al., 2019).

The present study will categorize different barriers to ICT adoption for SMEs and propose a framework using those barriers. Interpretive structural modeling (ISM) is found to be an appropriate method to find the relations among the barriers and categorize those barriers to build a structural model (Sindhu et al., 2016). The results will be useful to the owner-managers of SMEs, practitioners, consultants, IT professionals, government, and regulators in removing the barriers to ICT adoption in emerging economies.

Research gaps

ICT has brought efficiency, transparency, and speed to the operation of business across the world, and SMEs are no exception to this. ICT acts as a tool to increase efficiency in SMEs, along with enabling companies to be competitive by offering innovative products. The access and use of ICT are not the same across SMEs in developing countries. Most SMEs have adopted ICT only in those operations where it is absolutely necessary. Thoumrungroje and Racela (2022) found that SME exporters adopt new technologies to compete in a higher competition and to help in the inventory management system. Organizational barriers inhibit the adoption of ICT among SMEs significantly. Several studies have demonstrated the relationship between technological and organizational changes and how the use of ICT affects firm performance (Boothby et al., 2010; Cao, 2010; Cozzarin and Percival, 2010). Factors affecting decision-making for ICT adoption in SMEs are critical and should be studied (Shahadat et al., 2023). There is no comprehensive research that focuses on the establishment of a hierarchical structure among the challenges faced by SMEs for ICT adoption. This study addresses such a gap by detecting various challenges from existing literature and giving a hierarchical structure to those challenges for SMEs in India.

SMEs started using and adopting ICT practices late; therefore, the research is limited in this domain (Caldeira and Ward, 2002). There exist multiple constraints or reasons for such late adoption. The culture in which SMEs are operating, availability of trained and skilled staff in an organization, lack of policies and standards to support the operation, legal and regulatory restrictions, lack of education and knowledge of managers or owners, lack of capital, knowledge management and knowledge transfer, lack of security or privacy, cost of ICT infrastructure, lack of IT-based infrastructure, size of SMEs and lack of visionary leadership are some of the important factors governing adoption of ICT in SMEs. Table 1 enumerates these barriers:

Research methodology

The methodology adopted in the present study is enumerated in the following paragraphs:

Study design. Interlinks between various factors can be best studied using ISM (Luthra et al., 2014; Warfield, 1974). This paper uses ISM to study the impact of various barriers on ICT adoption by SMEs. Structured interviews were conducted to collect data. The literature review shows that the hierarchical structure of these barriers is not proposed in existing research around the domain.

Selection of participants and data collection. To ensure the relevancy, interviews of the entrepreneurs and experts associated with SMEs are conducted to collect data with their written consent. In total, 9 such experts aged 35-50 years were interviewed. 15 owners and experts were approached, but 6 owners did not show their willingness to be part of the research, so 9 respondents were finally interviewed. The details of the experts are given in Appendix A. The researchers noted the responses related to the relationship among those challenges in a diary and transferred the data to ISM. To arrive at a consensus, the sample size is usually small. However, the experts chosen should have deep knowledge and good experience (Agarwal, Shankar, and Tiwari, 2007). In the past, Rana et al. (2019) used five SME managers, while Luthra et al. (2023) used nine experts as the respondents for the ISM methodology.

Sampling strategy. This study used a purposive sampling technique, as the aim was to collect the data by interviewing experts. This technique helps in achieving the objective of the study by matching the sample. Utmost care has been taken to ensure that only SME owners were interviewed; thus, purposive sampling helps in building confidence in the data and results.

Table 1 Literature on barriers to ICT adoption in SMEs.

S.No.	Barrier	Description	References
B1	Cultural Barrier	Lack of employee openness to new technologies and lack of company environment culture.	Rauch et al. (2019); Rizos et al. (2016)
B2	Lack of Trained and Skilled Staff	The owners may decide against ICT adoption if there is a lack of skilled, expert, and qualified manpower. There could be difficulty in attracting and retaining qualified personnel, along with integrating new technologies with older employees, due to budgetary constraints.	Abdullah et al. (2018); Branca et al. (2020); Duan et al. (2002); Lawson et al. (2003); Migiro (2006); Neef et al. (2018); Pissarides (1999); Rauch et al. (2019)
B3	Lack of Policies, Standards, and Regulations	The government may not have proper legislation, and incentives, for emerging technologies. The unavailability of technological standards coupled with the legal and regulatory restrictions affect ICT adoption.	Lawson et al. (2003); Pissarides (1999); Rizos et al. (2016); Stockdale and Standing (2004)
B4	Lack of Education and Knowledge of Managers-Owners	ICT adoption requires proper knowledge, education, experience, and technical know-how of owners and managers.	Arendt (2008); Branca et al. (2020); Migiro (2006)
B5	Lack of Capital	There are financial constraints that limit the amount of funds and availability of capital. The financial capacity and availability of financial resources may inhibit ICT adoption.	Abdullah et al. (2018); Kannabiran and Dharmalingam (2012); Migiro (2006); Pissarides (1999); Rizos et al. (2016)
B6	Knowledge management and knowledge transfer	There could be apprehension of knowledge erosion by leaving staff and knowledge transfer from experts	Branca et al. (2020); Rauch et al. (2019)
B7	Lack of Security and Privacy	Owner-managers may not use ICT if they are skeptical of data protection, data security, and privacy of transactions. There could be a fear of failure of technologies that may limit ICT adoption.	Branca et al. (2020); Kumar et al. (2020); Lawson et al. (2003); Neef et al. (2018); Rauch et al. (2019)
B8	Cost of ICT Infrastructure	The cost of implementation of ICT is high along with the cost of consultants which could be one of the inhibitors for the owners.	Lawson et al. (2003); Migiro (2006); Pissarides (1999); Rizos et al. (2016)
B9	Lack of IT-Based Infrastructure	There could be an unavailability of software, hardware vendors, and resources, along with the unavailability of ICT infrastructure. Internet cost and technical compatibility may limit ICT adoption	Abdullah et al. (2018); Kannabiran and Dharmalingam (2012); Migiro (2006); Moktadir et al. (2018); Neef et al. (2018)
B10	Size of SMEs	The size of SMEs could limit the adoption of ICT	Kannabiran and Dharmalingam (2012); Sommer (2015)
B11	Lack of Visionary Leadership	Articulated and visionary leadership, along with management support, resources, and knowledge, is required for ICT adoption, and the absence of these may prevent ICT adoption	Giotopoulos et al. (2017); Kumar (2021); Stockdale and Standing (2004)

Research method. The present study uses ISM, which is a methodology based on mathematics, and it helps in presenting a complex problem in a systematic process based on the structural modeling of interconnected matrices (Warfield, 1974). Steps included in the ISM method are as follows:

a. Identification of the factors associated with the implementation of ICT by SMEs and 11 factors have been identified 11 using extant literature in the domain which are listed in Table 1.
b. Develop circumstantial associations between factors identified from the literature.
c. Develop a Structural Self-Interaction Matrix (SSIM) of identified factors through pairwise interaction between factors.
d. Develop an Initial Reachability Matrix (IRM) through SSIM.
e. Convert IRM into Final Reachability Matrix (FRM).
f. Calculate driving and dependence power for all variables post assigning transitivity to the FRM by adding up all ones (including transitive and non-transitive) row-wise and column-wise.
g. Create a reachability set of influencing variables and an antecedent set of these variables and other influencing variables.
h. Create an intersection set from reachability and antecedent sets.

i. Create partition levels based on determining the same intersection and reachability set content.

Rigor and ethics. This study was undertaken by four researchers who are the authors of this paper, and they do research as part of their profession. There was a proper division of work among the researchers, where the first author initiated the idea along with a preliminary literature review. The first and second authors conducted interviews and performed ISM. The interviews were conducted, coded, transcribed, etc., by all the authors. The third and fourth authors started writing the manuscript and were supported by the first and second authors. The authors had to meet several times to conduct interviews, literature surveys, data collection, and finally analyze the data. The authors also ensured that the respondents were made fully aware of the purpose of the study, and they agreed to be part of this. Those SME owners who did not show their willingness were not contacted again.

Data analysis
In this study, data related to the interrelationship between the factors identified are collected from experts in the SME sector selected using a purposive sampling approach. The data analysis using ISM is divided into the following sections:

Table 2 Self-structured matrix for barriers to ICT adoption.

Barriers	Risk factors	11	10	9	8	7	6	5	4	3	2	1
B1	Cultural Barrier	O	A	A	A	A	A	A	A	A	A	-
B2	Lack of Trained and Skilled Staff	O	A	X	A	A	A	A	A	X	-	-
B3	Lack of Policies, Standards, and Regulations	O	A	X	A	A	A	A	A	-	-	-
B4	Lack of Education and Knowledge of Managers-Owners	A	A	V	A	A	A	A	-	-	-	-
B5	Lack of Capital	A	X	V	O	O	V	-	-	-	-	-
B6	Knowledge management and knowledge transfer	A	O	O	V	V	-	-	-	-	-	-
B7	Lack of Security and Privacy	A	A	V	X	-	-	-	-	-	-	-
B8	Cost of ICT infra	A	A	V	-	-	-	-	-	-	-	-
B9	Lack of IT-Based Infrastructure	A	O	-	-	-	-	-	-	-	-	-
B10	Size of the SMEs	A	-	-	-	-	-	-	-	-	-	-
B11	Lack of Visionary Leadership	-	-	-	-	-	-	-	-	-	-	-

Table 3 IRM for barriers to ICT adoption.

Barriers	Challenges	1	2	3	4	5	6	7	8	9	10	11
B1	Cultural Barrier	1	0	0	0	0	0	0	0	0	0	0
B2	Lack of Trained and Skilled Staff	1	1	1	0	0	0	0	0	1	0	0
B3	Lack of Policies, Standards, and Regulations	1	1	1	0	0	0	0	0	1	0	0
B4	Lack of Education and Knowledge of Managers-Owners	1	1	1	1	0	0	0	0	1	0	0
B5	Lack of Capital	1	1	1	1	1	1	0	0	1	1	0
B6	Knowledge management and knowledge transfer	1	1	1	1	0	1	1	1	0	0	0
B7	Lack of Security and Privacy	1	1	1	1	0	0	1	1	1	0	0
B8	Cost of ICT infrastructure	1	1	1	1	0	0	1	1	1	0	0
B9	Lack of IT-Based Infrastructure	1	1	1	0	0	0	0	0	1	0	0
B10	Size of the SMEs	1	1	1	1	1	0	1	1	0	1	0
B11	Lack of Visionary Leadership	0	0	0	1	1	1	1	1	1	1	1

Table 4 FRM for barriers to ICT adoption.

Challenges	1	2	3	4	5	6	7	8	9	10	11	DRP
B1	1	0	0	0	0	0	0	0	0	0	0	1
B2	1	1	1	0	0	0	0	0	1	0	0	4
B3	1	1	1	0	0	0	0	0	1	0	0	4
B4	1	1	1	1	0	0	0	0	1	0	0	5
B5	1	1	1	1	1	1	1*	1*	1	1	0	10
B6	1	1	1	1	0	1	1	1	1*	0	0	8
B7	1	1	1	1	0	0	1	1	1	0	0	7
B8	1	1	1	1	0	0	1	1	1	0	0	7
B9	1	1	1	0	0	0	0	0	1	0	0	4
B10	1	1	1	1	1	1*	1	1	1*	1	0	10
B11	1*	1*	1*	1	1	1	1	1	1	1	1	11
DNP	11	10	10	7	3	4	6	6	10	3	1	71

DRP driving power, *DNP* dependence power.
*Shows existence of the transitivity.

Self-structured interaction matrix (SSIM). Table 2 represents the relationships between each pair of factors. Such a relationship is denoted by V, A, X, and O. Where V indicates the influence of i on j; A indicates j has an impact on i; X indicates i and j impact each other; and O indicates the nonexistence impact of i and j on each other (Kumar et al., 2016; Hughes et al., 2016; Rana, 2020). It is likely that respondents may have conflicting opinions about the factor; however, the respondents were given time to discuss and arrive at a consensus for a factor to be classified as V, A, X, and O. Therefore, Table 2 represents the common opinion of the respondents.

Development of IRM and FRM. Symbols used in the SSIM were converted into binary numbers to get IRM presented in Table 3 (Al-Muftah et al., 2018; Dwivedi et al., 2017; Mangla et al., 2018;

Marri et al., 2007; Mishra et al., 2017). Binary numbers of IRM are obtained as follows:

a. For "V" use "1" in the (i, j) entry and "0" in the (j, i) entry;
b. For "A" use "0" in the (i, j) entry and "1" in the (j, i) entry;
c. For "X" use "1" in both (i, j) and (j, i) entries; and
d. For "O" use "0" in both (i, j) as well as (j, i) entries.

Entries of "1" throughout both rows and columns from FRM were added to determine the driving and dependence power for each driver, as shown in Table 4. A component or set of factors is removed from the procedure after being marked as being related to a level. This process is repeated until each factor has been labeled with at least one level. In the present study, the process is repeated for seven iterations to cover all eleven factors. Table 6 represents all factors and their respective levels.

Table 4 shows the Final Reachability Matrix (FRM), which is prepared while finding the indirect relations between the barriers to ICT adoption. Transitivity is one of the basic assumptions that lead to the preparation of FRM as per the ISM methodology. The IRM table is used to check the indirect relationship among the barriers using transitivity. If the barrier (i, j) in the FRM table has a value of zero, this implies that there is neither a direct nor an indirect relationship between barrier i and barrier j. In this manner, the transitivity is checked for all the values, and if the transitivity is found, the matrix value is written as 1*. After this, DRP (Driving Power) is calculated by totaling the row, i.e., the number of ones in the row, and DNP (Dependence Power) by totaling the column, i.e., the number of ones in the column.

Partitioning of levels. All the components were divided into multiple levels using IRM and FRM. To categorize these elements into different levels, various sets are developed, including the reachability set, antecedent set, and intersection set. A reachability set, for instance, is made up of the variable in question and

Table 5 First interaction of barriers to ICT adoption.

SN	Reachability set (R_i)	Antecedent set (A_i)	$R_i \cap A_i$	Level
B1	1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1	I
B2	1, 2, 3, 9	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 3, 9	
B3	1, 2, 3, 9	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 3, 9	
B4	1, 2, 3, 4, 9	4, 5, 6, 7, 8, 10, 11	4	
B5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	5, 10, 11	5, 10	
B6	1, 2, 3, 4, 6, 7, 8, 9	5, 6, 10, 11	6	
B7	1, 2, 3, 4, 7, 8, 9	5, 6, 7, 8, 10, 11	7, 8	
B8	1, 2, 3, 4, 7, 8, 9	5, 6, 7, 8, 10, 11	7, 8	
B9	1, 2, 3, 9	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 3, 9	
B10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	5, 10, 11	5, 10	
B11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	11	11	

Table 6 Levels assigned to barriers.

Iterations	Level no.	Barriers to ICT adoption
1st	I	Cultural Barrier (B1)
2nd	II	Lack of Trained and Skilled Staff (B2)
		Lack of Policies, Standards, and Regulations (B3)
		Lack of IT-Based Infrastructure (B9)
3rd	III	Lack of Education and Knowledge of Managers-Owners (B4)
4th	IV	Lack of Security and Privacy (B7)
		Cost of ICT infrastructure (B8)
5th	V	Knowledge management and knowledge transfer (B6)
6th	VI	Lack of Capital (B5)
		Size of the SMEs (B10)
7th	VII	Lack of Visionary Leadership (B11)

the variables it influences. The antecedent set is a variable in and of itself, as are other variables that impact it. A junction of antecedent and reachability sets is known as an intersection set. When reachability and intersection sets are equal, factors are designated as Level I, II, and so on.

Table 5 shows that B1 has the intersection and reachability comprised of the same variable, thus assigned level I. In the next step, B1 will be eliminated while all other variables continue to exist, and interaction is found. Such interaction is observed for B2, B3, and B9, and those are assigned level II. This process is followed until all the variables are assigned the levels.

The results of iterations and assignment of levels are shown in Table 6.

Development of the ISM model. The information from Table 6 is used to construct the ISM model for barriers to ICT Adoption in SMEs and is represented in Fig. 1. There are seven different levels in the ISM model. The primary barrier, B11, or a lack of visionary leadership, is found at the bottom level, that is, level VII. The next is level VI, which consists of barriers B5, lack of capital, and B10, Size of SMEs. Therefore, these two barriers are placed in the model subsequently. Similarly, level V has only one barrier, i.e., B6, knowledge management and knowledge transfer and the same finds the next position in the model. In this manner, all the levels are placed in Fig. 1. The cultural barrier of SMEs, B1, is found at the top with level I.

MICMAC analysis. One of the limitations of the ISM model is that it restricts the evaluation of the inter-barrier strength. By taking into account the MICMAC (Matrice d'impacts Croises multipliquee a un classment) analysis, the ISM model

can overcome this weakness (Gorane and Kant, 2013). MICMAC is one of the analytical techniques used in research to classify the barriers into different impact levels and importance (Gupta and Goyal, 2021).

Based on the FRM, MICMAC analysis takes advantage of each variable's driving and dependent abilities. The sum of rows of Table 4, FRM shows the DRP while the sum of columns shows the DNP. The barriers are classified into autonomous variables, dependent variables, linkage variables, and independent variables, based on their DRP and DNP.

The OX axis shows the DNP while the OY axis shows the DRP as shown in Fig. 2. The barrier B1 has DRP of 1 and DNP of 11 so it is placed on the intersection of 1 and 11 in the MICMAC matrix. Similarly, barrier B2 has having DRP of 4 and a DNP of 10 so it is positioned at the intersection of 4 and 10 in the Figure. A similar procedure is followed to partition the level and assignment into various regions.

   I. Autonomous Variables: This includes autonomous barriers that have weak DRP and DNP power. This region could not find any connection with the proposed model, as the barrier was found in this region. It also signifies that this region does not influence other barriers, nor is it influenced by other barriers.
  II. Dependent Variables: This region has high DNP and low DRP. Located at the upper level of the hierarchical model, B1, B2, B3, B4 and B9 are found in this region.
 III. Linkage Variables: This region has high DRP and high DNP. B7 and B8 are located in the middle.
  IV. Independent Variables: This region has barriers having low DNP and high DRP. Located at the bottom, B5, B6, B10, and B11 are found in these regions.

Variables are categorized and enumerated in Table 7.

Figure 2 is the MICMAC diagram with driving and dependence power of impediments to ICT adoption in SMEs.

Discussion

"Lack of visionary leadership (B11)" forms a foundation for other barriers in the process of ICT adoption. Additionally, barriers such as "lack of capital (B5)" and "size of SMEs (B10)" impact each other as major barriers in ICT adoption. Marri, Gunasekaran, and Sohag stated that most companies invest less than a percent of their total revenue on R&D and the adoption of new technology. A very small amount is allocated as capital to the provisions related to ICT adoption in SMEs. This is in conjunction with the size of the SMEs, too. SMEs having comparatively low sizes have less tendency to invest capital in ICT adoption. "Lack of capital (B5)" and "size of SMEs (B10)" would lead to other barriers, i.e., "knowledge management and knowledge
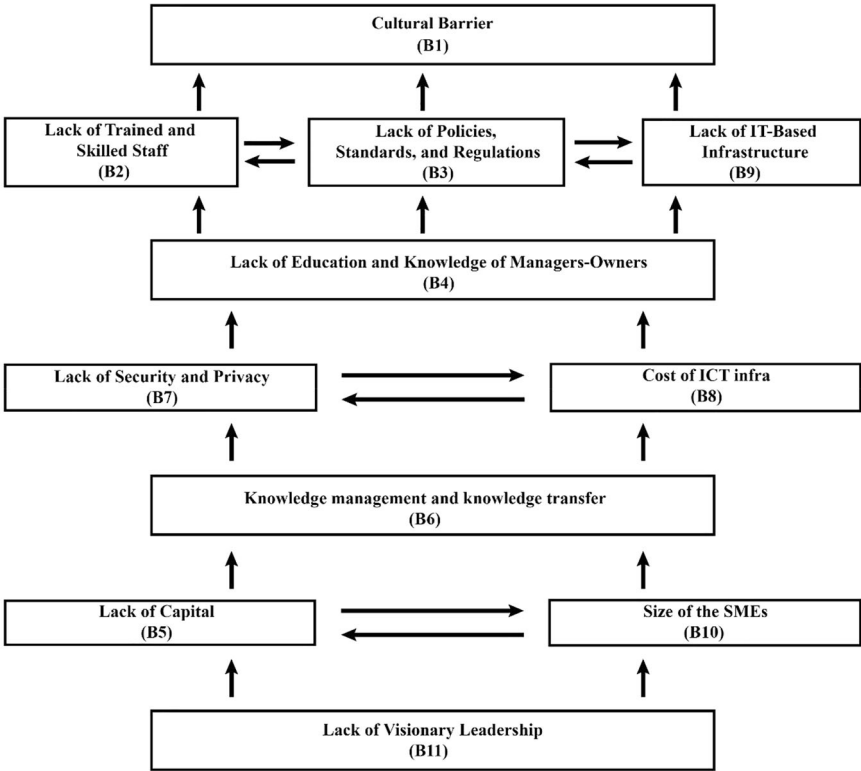
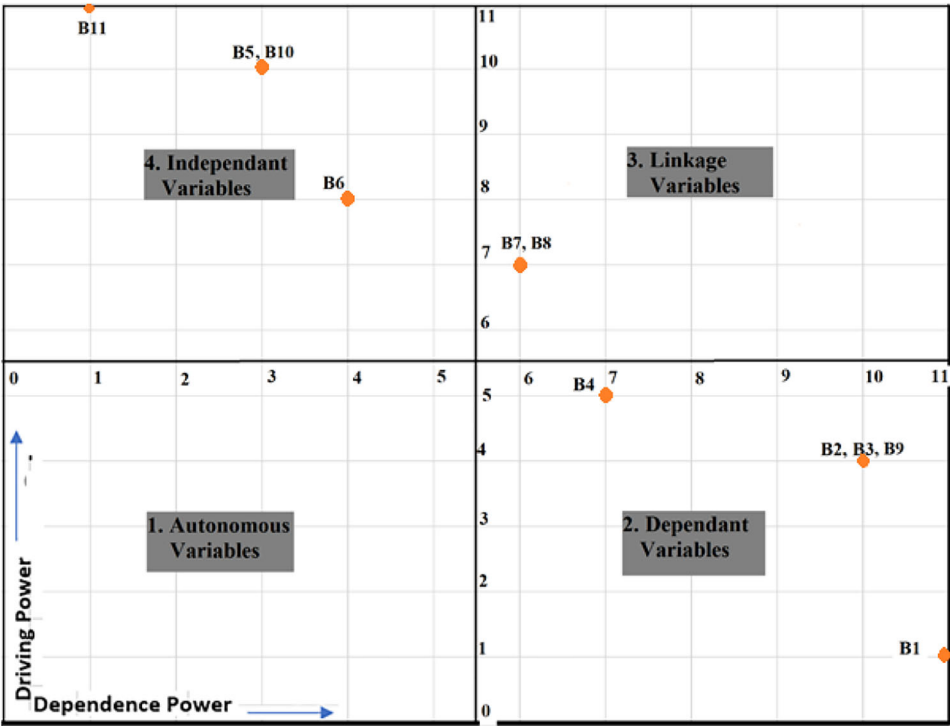**Fig. 1** ISM model for barriers to ICT adoption.

Fig. 2 MICMAC diagram with driving and dependence power.

transfer (B6)", this barrier plays an important role in handling business activities and the transfer of such knowledge is a crucial element in the implementation of information technology projects in an organization. If such transfer of knowledge is missing, this will further lead to a "lack of security and privacy (B7) and cost of ICT infrastructure (B8)". These ordered relationships,

presented in Fig. 1, suggest that the availability of IT infrastructure plays a vital role in adopting the same. This is because SMEs are not enthusiastic about making capital investments in ICT adoption and do not want to raise their cost through such investments. Security and the privacy of information are the main concerns SMEs are highlighting as barriers to adopting the same.

Table 7 Classification of variables.

Category	DRP	DNP	Barriers
Autonomous	Low	Low	Not present
Dependent	Low	High	B1, B2, B3, B4 and B9
Linkage	High	High	B7 and B8
Independent	High	Low	B5, B6, B10 and B11

The adoption of ICT-related developments in the operations of an organization has several difficulties, including privacy and security concerns. Weak authentication and confidentiality are key examples of a lack of privacy protection systems, and this creates issues with the privacy of user data. Resolving privacy and security issues is crucial to increasing data openness. Threats to businesses from data privacy and security include vulnerability to attacks, data ownership, right to govern and use data, the veracity of data, and stakeholder privacy concerns.

To understand the critical impact of these barriers on the development of SMEs, the manager or a person responsible for the technology adoption must have the required acumen to deal with them. "Lack of education and knowledge of managers or owners (B4)" of SMEs is therefore considered significantly important. This barrier acts as a foundation for other barriers, such as "lack of trained and skilled staff" (B2), "lack of policies, standards, and regulations (B3)", and "lack of ICT-based infrastructure (B9)". Lack of education and knowledge of managers or owners of the organization determines the adoption of information technology advancements. Regulations serve as a controller in the execution of operations using ICT. To guarantee that ICT is applied and implemented in businesses in a controlled manner, it is crucial to ensure the operations of SMEs align with the laws and regulations set forth by regulators (Lawson et al., 2003; Rizos et al., 2016; Stockdale and Standing, 2004). Due to recent changes in the scope and complexity of ICT applications, staff training on ICT has become a critical issue (Chen et al., 2007). The training program is required for the employees of SMEs to utilize developing technologies to their full potential. This training included practical exercises and literature to help them that were created to take into account the demands of SMEs (Chapman et al., 2000). These challenges lead to the "cultural barrier (B1)" of the SME. Organizations can easily adapt to change shortly, and the credit goes to the arrival of the internet (Saura et al., 2023), ITeS, and new educational systems, so long as top management is inclined to use ICT and IT-enabled services (Twati and Gammack, 2006).

All in all, the lack of visionary leadership (B11) is a foundation barrier for all other barriers. The cultural barrier of the SMEs (B1) is identified as the last barrier that evolved from "lack of trained and skilled staff" (B2), "lack of policies, standards and regulations" (B3), and "lack of ICT-based infrastructure" (B9).

Theoretical implications. This research provides insight into the barriers and their levels of impact on organizational attitudes about ICT adoption in SMEs. Exploring all barriers studied in this research will help researchers recognize the obstacles to such adoption. First, from a theoretical point of view, there is a dearth of existing research on the identification of the cluster of barriers impacting ICT adoption in SMEs. The driving and dependence power was calculated for each barrier considered in this study and allotted to a particular category based on its power. All the components were divided into multiple levels using IRM and FRM. To categorize these elements into different levels, various

sets are developed, including the reachability set, antecedent set, and intersection set.

Second, this study is the first to establish a thorough framework of hurdles by gathering information from active industry specialists in this field. The primary driving and dependent obstacles, or other barriers that have both of these characteristics, as well as the connections between them, were developed using the ISM methodology. The results of the study also reveal the complex nature of the barriers to ICT adoption among the SMEs. This was done with the help of MICMAC analysis, and these relationships were not known before, thus extending the theoretical contribution of the study. The outcome of the study is the development of a frugal model as shown in Fig. 1 out of the composite factors and rigorous process, which is yet another contribution of the study. Finally, the study makes a contribution to the structural change literature by providing an understanding of the relationship among innovation, digital infrastructure and technology and economic growth from the perspective of SMEs in emerging economies like India. The study highlights the importance of ICT adoption and structural changes impacting the same and adds to the literature of structural change by offering an insight into the technological adoption in SMEs. ICT adoption can be improved among SMEs by addressing the challenges of growth, scalability, efficiency, automation and competitiveness, thereby enhancing the firm-specific structural change discourse.

Practical implications. There are many positive initiatives toward the adoption of ICT by SMEs. The study's findings offer some advice on how to proceed in this area. To connect the barriers examined in this research, organizations and policy-makers need to assess them and determine the right links between them.

There is a strong push towards SMEs from all spheres, and the adoption of ICT will further enable the Indian economy to grow. The study provides key barriers to ICT adoption and establishes the relationship between existing literature and the findings of the present study. This will be useful to the owner-managers of SMEs to recognize the barriers and move towards the adoption of ICT. The visionary leadership, B11, is at the bottom level, which drives all other barriers. If the SMEs can focus on visionary leadership, this will help them overcome the availability of capital to the SMEs and promote overall ICT adoption. Visionary leadership can also be instrumental in overcoming the barrier of the size of SMEs and paving the way for ICT adoption. Results of this study make an important contribution to the ongoing conversation of ICT adoption in SMEs by offering a hierarchical structure of the challenges faced by SME owners. This contribution will lead to the design of appropriate strategies for infusing visionary leadership that will advance ICT adoption in SMEs.

Policymakers will find the findings useful as they can focus on barriers that inhibit ICT adoption and make policies that are suitable for the promotion of ICT adoption among SMEs. The Indian economy aspires to reach $5 trillion by 2025, and research and a proper understanding of ICT adoption will prove to be useful in achieving this target by instituting standards and regulations for the same.

Proposed research model with propositions. Using the framework developed in this study, a few barriers are selected, and a model for ICT adoption in SMEs is created. These barriers are common and identified in the literature recurrently. Future research can be conducted to validate this paper and the barrier used in the following mode.
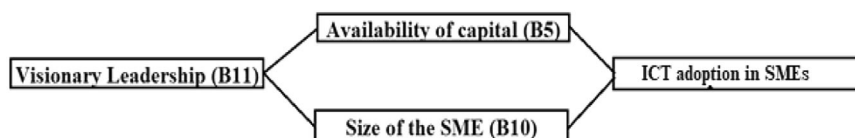
Fig. 3 Proposed model for barriers to ICT adoption.

Off the barriers used in the ISM framework, two such barriers with the highest DRP (Driving Power) are selected, and the following propositions are formed:

Proposition 1. Visionary leadership ensures the availability of optimum resources in an organization and hence will be positively related to the availability of capital.

A visionary leadership style is the primary booster of change management. Leadership style has a significant influence on organizational performance and the degree of its commitment to achieving its goals, strategies, and vision (Zahoor and Lew, 2022). This affects both the relationship between the working individuals and the organization. Conversely, toxic leadership had a highly statistically significant negative relationship with organizational performance. Visionary leaders have the foresight to evaluate the optimum requirement of resources for the organization (Hilmersson et al., 2022).

Proposition 2. Visionary leaders can identify the optimum scale of operations and the respective size of the firm, and hence directly relate to the size of SMEs.

Visionary leadership will result in the successful expansion strategies of an organization (Verreynne et al., 2013). The size of SMEs in terms of capital investment, the number of people working, and the scale of operation shall be positively affected by visionary leadership (Herrera and Sánchez-González, 2013).

Proposition 3. Availability of capital ensures the innovations and hence shall be directly related to the adoption of ICT among SMEs.

As like visionary leadership shall impact positively on the availability of capital. Capital adequacy will ensure ICT adoption in SMEs (Luypaert et al., 2016). One of the barriers to ICT adoption was capital inadequacy. If this barrier is addressed, then ICT adoption will be facilitated on its own in this age of digitization (Grashof and Kopka, 2022; Obeng et al., 2014).

Proposition 4. The size of SMEs ensures the adequacy of resources and hence will be positively related to ICT adoption among SMEs.

The size of the organization in terms of resources of all kinds plays an important role in organizational innovation and development (Gallego et al., 2013). The Size of the SMEs and the competitive environment will positively determine the IT adoption rigor among SMEs (Granata et al., 2018; Herrera and Sánchez-González, 2013). Understanding the critical variables for ICT adoption is significant for the development of modern industry (Alegre et al., 2013; Sommer, 2015). The size of an organization is considered one such variable to study ICT adoption by Deng et al. (2020).

Conclusions, limitations, and future research

The adoption of ICT among SMEs is slow-paced due to the existence of numerous barriers that act as constraints in this development. The goals of this study were to identify barriers to ICT adoption, understand their relationships, and create an ISM framework that would be useful to the SMEs as well as to the policymakers and researchers. An extensive literature review helped in identifying eleven main barriers, which were verified and validated by a group of experts. The use of ISM helped in creating a model that categorizes each barrier and represents the interconnection among those barriers. This will help SME owners, managers, researchers, and academicians to understand the relationship that causes the low adoption of ICT among SMEs. A hierarchical ISM model is created using the ISM methodology, which presents a contextual linkage among the barriers. The results of the study also highlight the importance of analyzing the barriers collectively instead of viewing those in isolation by showing the relationship among those barriers.

The barrier of "Cultural Barrier" (B1) is found to be at the top among others, whereas "Visionary leadership" (B11) is found to be the foundation barrier leading to all other barriers in the adoption of ICT in SMEs. Visionary leadership should be considered as the base barrier, and if this barrier is addressed effectively in the organization, the impact of other barriers can be minimized. The adoption of ICT should be encouraged given the fact that there is a strong positive link between ICT and firm performance, along with the large contributions of SMEs to the economic development of the nation (Bayo-Moriones et al., 2013). Top management vision and government support are strong determinants of ICT adoption in SMEs, among others (Shahadat et al., 2023). The MICMAC diagram in Fig. 2 shows the driving and dependence power of each barrier and the positioning of those into a specific quadrant. A barrier will have more influence on other factors if its driving power is high.

No research or study is without any limitations, and this is also the case with the present study; those limitations are the future scope of work to be addressed by future researchers. Using ISM methodology, the study has sought to construct a contextual relationship between the barriers; however, because the model was created based on a review of literature and opinions of experts, it may be biased. Further studies can be conducted to verify the model's accuracy by performing other multi-criteria decision-making tools and advanced statistical tests such as regression analysis and structural equation modeling. The hierarchical structure of the barriers, that a particular sector is facing, could be another area of future research (Fig. 3).

Data availability
All data generated or analyzed during this study are included in this published article.

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Author contributions

Arti Chandani, Reena Agrawal, Prashant Ubarhande, Kumod Kumar, and Khalid HM Alhamzi are the listed authors for this manuscript. Dr. Arti Chandani: ideation, data collection, data cleaning and writing. Dr. Reena Agrawal: ideation, data collection, and data analysis. Dr. Prashant Ubarhande: data analysis and writing. Mr. Kumod Kumar: writing and reviewing. Mr. Khalid HM Alhamzi: writing and reviewing.

Competing interests

The authors declare no competing interests.

Ethical approval

This research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (1964), including its subsequent amendments and other relevant ethical guidelines. This research received approval from the Research Ethics Committee of Jaipuria Institute of Management on 28th March 2023, and the approval number was 2803/2023. The approval covered the project's timeline, research domain, content, design, methods, participant types, etc., ensuring full compliance with ethical standards for studies involving human participants.

Informed consent

Prior to data collection, participants were informed of the purpose of the study, the methods, the possible risks and benefits, and the methodology to handle and protect data. The data were collected after their verbal consent was obtained before the interview. These interviews were conducted in the first week of April 2023. They were informed that their anonymity is assured, why the research is being conducted and how their data will be utilized. The participants were informed that they had the right to choose whether to participate or not, or they could stop at any time. Also, it was informed that their responses will be anonymous to protect their identities.

Additional information