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Deployment of Interpretive Structural Modeling in Barriers to Industry 4.0: A Case of Small and Medium Enterprises

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Abstract: Small and medium enterprises (SMEs) are vital contributors and significant drivers of any manufacturing sector. The Industry 4.0 (I 4.0) revolution has made the global economy highly competitive and automated, requiring Indian SMEs to adapt more quickly. Therefore, this study aimed to identify the barriers to implementing I 4.0, simplifying the complex interrelationship among such barriers with the help of a suitable model, categorizing them as independent and dependent ones, and, ultimately, leveling the same drivers, autonomous linkages, and dependent forces. The present investigation thoroughly examined the existing literature and summarized the list of barriers into fifteen significant barriers to the smooth establishment of Industry 4.0 in India. The identified barriers were analyzed with the help of Interpretive Structural Modeling (ISM) Diagraph and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis. This study was able to explore the interrelationship among these barriers. The study has found found a lack of support from stakeholders, and insufficient managerial support emerged as a major factor neglected by Indian SMEs. However, uncertainty in the predicted demand for products, the lack of an alternate solution to the technological breakdown, and doubt about the sustainability of Industry 4.0 (relating to its potential to lead to unemployment in society, etc.) are significant contingent barriers. These barriers can impact the other strategic choices related to the successful implementation of Industry 4.0. This study's observations can help decision-makers make strategic decisions to manage the barriers affecting Industry 4.0 in Indian SMEs. This research revealed a scope that can be extended to other South Asian and developing nations. The results of the present work can be further studied with structural equation modeling (SEM) and multiple regression analysis (MRA).

Keywords: Industry 4.0; small and medium enterprises (SMEs); interpretive structural modeling (ISM); MICMAC analysis; barriers; sustainability

1. Introduction

In the modern era, most manufacturing organizations are under intense pressure to achieve sustainable production processes, mass customization, and shortened product life cycles, provide immediate access to customer databases, and engage in intense competition with comparatively lesser times to market. Compared to third-generation hardwired machine automation, the fourth generation (Industry 4.0 or I 4.0) seems well equipped with new software and hardware technologies to deal with the modern manufacturing sector challenges (Pellicciari et al. 2009). The technologies of Industry 4.0 communicate, collect information, and make decisions using cyber–physical systems (Lee et al. 2015). Applying advanced artificial intelligence to production processes and real-time customer demand management adds advantages to existing supply chain management (SCM). Despite the prospective characteristics of I 4.0, there is a need to cope with intense pressure on sustainability in relation to production, processes, prices, customer retention, logistics, and operations (Vaidya et al. 2018).

In recent times, the internet of things and cyber–physical systems have changed the overall attention of manufacturing organizations. Globally, there is no standard definition of smart technologies (Jain et al. 2017). 'Industry 4.0', 'Integrated Industry', or 'Smart factory' that can uphold the entire product life cycle from designing an article to its delivery are commonly used technical terms (Hofmann and Rüsch 2017). The world is struggling to cope with emerging technologies, dynamic processes, novel terminologies (Syreyshchikova et al. 2021b; Tayal et al. 2021), and intense competition in terms of service and quality (Tripathi et al. 2021a). On the same grounds, Indian manufacturing organizations find it challenging to adapt to changing customer needs these days. The new and advanced innovative industrial environment leaves no choice for traditional industries other than to adapt. Technologies such as Industry 4.0, smart manufacturing (SM), 3D printing, IoT, and cyber–physical systems are frequently becoming part of routine processes. Whether large or small, these industries now realize the immediate benefits of this new revolution. Rajput and Singh (2019) analyzed various enablers of Industry 4.0 in Indian manufacturing organizations. Industry 4.0 can also influence supply chain management in a manufacturing organization. With the help of this concept, industrial managers can increase the efficiency, flexibility, and responsiveness of systems and environmental measures (Pedersen et al. 2016). Dutta et al. (2020) considered the priorities of Indian SMEs for digital transformation.

Indian manufacturing organizations are in the pioneering stage of the implementation of I 4.0. Therefore, there is a need to discuss strategies, guidelines, and support technologies (Marques et al. 2017). In the Indian manufacturing sector, there is a massive gap in the implementation of the paradigm technologies of Industry 4.0 (I 4.0). Some researchers found India to be stuck in the second and third industrial revolutions in the manufacturing area. On the other hand, Germany is at the apex of the global manufacturing environment (Pfohl et al. 2017). Therefore, manufacturing organizations need to be technically innovative, focusing on research, development, and better decision making (Feng et al. 2018). In recent times, the focus on the circular economy has increased. Thus, establishments have begun to explore the barriers and challenges of the idea of a circular manufacturing economy in terms of its social, environmental, and economic aspects (Kumar et al. 2019). With the growing global rivalry in the international manufacturing network, there is a dire need to examine the drivers, barriers, and challenges of the manufacturing sector (Mishra et al. 2019). The implementation of ISM and its future prospects have been well explained (Kumar and Goel 2021).

Hence, the present research focuses on investigating the barriers to implementing I 4.0 in the context of the present industrial system in the Indian economy. The motivation behind selecting only Indian industry is that India consists of almost 70 million small and medium enterprises, the second-largest number after China. This figure represents much of the sources of employment in the Indian sub-continent, including both organized and informal labor. However, it is challenging to study the entire manufacturing sector, which comprises large, medium, and small enterprises. Henceforth, this paper will only focus on small and medium enterprises, where installation and automation are still a dream and a big challenge. In India, there are many SMEs in organized and unorganized sectors, the study of which only requires a lot of effort, pain, and patience. The challenges faced by these enterprises are quite different from those of large enterprises. These challenges pose many barriers to implementing the I 4.0 paradigm in Indian SMEs. The research question was formulated as below:

RQ1: What are major and minor barriers to adopting Industry 4.0 in the Indian Small-Scale sector?

Identifying these barriers, will assist industrialists in understanding the emergence of these issues, their actual and required potential to deal with such barriers, and the intensity of each barrier, and will help them make decisions on alternative and corrective actions and follow-up strategies. It will also help policymakers decide on appropriate policies and strategies at the national level to create a conducive environment for adopting I 4.0 in their industries to cope with the global environment.

RQ2: What are the major autonomous and dependent barriers to adopting Industry 4.0 in the Indian Small-Scale sector?

Once these barriers are identified, identifying autonomous and dependent barriers will help strategists frame the necessary course of action. In addition, the identification will help strategists to understand the intensity of the actions required to overcome these barriers. Therefore, this study has limited its scope to identifying the barriers in small and medium manufacturing enterprises (SMEs).

This study involved a rigorous survey of existing literature (discussed in Section 2) in this regard to identify barriers. Similar variables (barriers) identified by various authors in their respective works were grouped under one heading and given a common name.

1.1. Identification of Research Gaps

Undoubtedly, modern industries are moving toward adopting I 4.0 in their existing manufacturing systems. SMEs are also struggling hard in terms of their adoption, awareness, and applications. Most of the applicability of I 4.0 has been studied as a whole, and little effort has been made to understand SMEs' needs and problems in general and a developing nation such as India in particular. Apart from this, a comprehensive survey of literature on I 4.0, SMEs, ISM, and MICMAC analysis showed little interaction. Hence, owing to the dearth of a structured study, the present study attempts to fill this gap with its requisite outcomes.

1.2. Research Motivation, Objectives, and Intended Contribution of the Study

These research gaps have motivated the direction of research, identification and frame of the research objectives, and the intended contribution of the current investigation. Therefore, this study has proceeded with the following research objectives:

- To identify the barriers to I 4.0 in the case of Indian SMEs;
- To model these barriers to I 4.0 with the help of ISM;
- To plot these I 4.0 barriers on four clusters using MICMAC analysis.

1.3. Expected Contributions of the Study

Despite numerous studies discretely conducted on SMEs, I 4.0, ISM, and MICMAC analysis in the recent past, there is a lacuna in terms of a collective effort of all these in a single study. Our extensive literature survey revealed that none of the structured studies generated desired results. Hence, the present study will fill this gap and intends to deploy ISM to implement I 4.0 barriers in Indian SMEs. This study will:

- Summarize the variables drawn from literature acting as barriers to implementing I 4.0.
- Draw the driving and dependent barriers to I 4.0 applicability in Indian SMEs.
- Help policymakers and other stakeholders make relevant decisions while implementing I 4.0 in their units.

In this study, the authors identified fifteen variables that affect barriers to I 4.0 in Indian small and medium manufacturing organizations. Further authors have analyzed the interrelation of the different challenges by using Interpretive Structural Modeling (ISM).

This methodology also provides driving and dependence power by providing structural visualization among the challenges. Thus, this study will help the Indian manufacturing concerns, the espousal of the I 4.0 practices, and effectively resolve the different challenges.

Further, Section 2 of this article discusses the theoretical framework comprising the essential literature survey and identifies barriers to enacting I 4.0. Then, Section 3 describes the examination methodology of ISM techniques. Section 4 talks about the application of methods and the result obtained. Section 5 deals with the results and discussion on the upshots, Section 6 discusses the managerial implications, and lastly, Section 7 presents concluding remarks, limitations, and the future scope of research.

2. Literature Review

This study has examined the barriers to implementing I 4.0 in Indian SMEs. Hence, this study surveyed already published literature available on various databases. Therefore, the literature survey comprised two phases. Phase I explored all related publications. Phase II dealt with screening publications related to ISM's deployment in the case of I 4.0 implementation in SMEs. This survey, in brief, is shown in Figure 1, explaining the process of the study of existing literature.

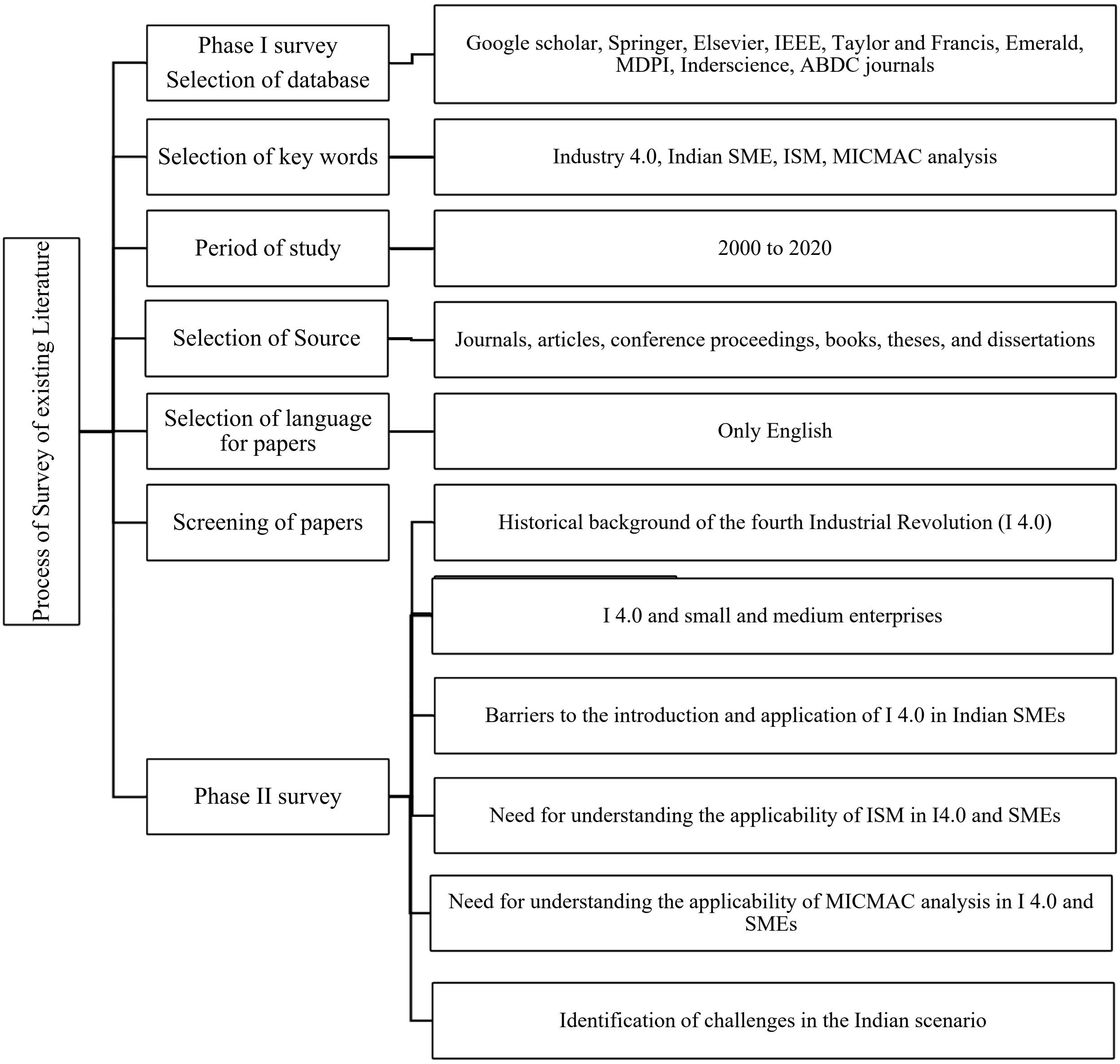

Figure 1. Process of the survey of the existing literature.

2.1. Division of Existing Published Literature

The entire survey of the existing literature passed through three processes, viz, the Exploration Phase, Shepherding Phase, and Final Phase, which are discussed below:

2.1.1. Exploration Phase

This study extensively reviewed the existing literature on barriers discussed by academicians, industry experts, and other research scholars. A comprehensive visit was made to the literature available on well-known electronic published databases, including Springer, Elsevier, IEEE, Taylor and Francis, Emerald, MDPI, Inderscience, ABDC Journals, etc. The sole purpose was to avoid skipping any significant paper drawing barriers to I 4.0. The survey of these databases to identify the barriers included 2012 to 2021. Another survey was also made to determine the scope of applicability of ISM and MICMAC analysis on the barriers identified. This survey was made for the period 1976 to 2021 on the same databases to assure the applicability of these two tools to the barriers of I 4.0.

2.1.2. Shepherding Phase

The next step in the literature survey was to select research publications related to I 4.0. Hence, this study used keywords such as I 4.0, SMEs, ISM, and MICMAC analysis. However, this study only published research papers on these databases and left all other articles, books, and conference proceedings. Moreover, the language of the paper was restricted to English only.

2.1.3. Final Phase

In this phase, relevant studies were shortlisted, and enablers or barriers were explored in the one-to-one analysis of each publication. This study proceeded with articles discussing barriers related to I 4.0. Further, the study has screened to the level of SMEs only and finally wrote them down on paper to give them a common name and platform that represented barriers. The viability of ISM and MICMAC analysis was also explored from other papers in numerous disciplines on the record available on these databases. This study finally drew 15 challenges/barriers to I 4.0 in a global scenario.

2.2. Historical Background of the Fourth Industrial Revolution (I 4.0)

The credit to introduce the fourth generation of the industrial revolution goes to the beautifully designed high-tech strategy of a team of scientists and the German government in 2011. Later, this revolution spread like wildfire due to manufacturing concerns and was thus adopted by developed nations faster. However, developing nations struggle to adopt it and its conceptual requirements. This technique has an initial goal of complete automation, digitalization, machine-to-machine communication, internet of things (IoT), robotics (Pedersen et al. 2016), information revolution, transparency, etc. A significant combination of cyber–physical systems (CPSs) (Lee et al. 2015), IoT (Vaidya et al. 2018), and cloud computing will make a factory smart (Lee et al. 2015), auto-driven, auto-adaptative in manufacturing (Pellicciari et al. 2009), require less human intervention (Pedersen et al. 2016), offer customized production (Kumar et al. 2020b), harness real-time opportunities (Almada-Lobo 2016), and enhance productivity (Hofmann and Rüsch 2017). Rüßmann et al. (2015), Saucedo-Martínez et al. (2018), and Öner et al. (2018) considered big data and analytics, autonomous robots, simulation, horizontal and vertical integration systems, cyber security, additive manufacturing, augmented reality, cloud computing, mobile technologies, artificial intelligence, radio frequency identification, etc., as essential for setting up of I 4.0 in any organization. Once implemented in letter and spirit, this revolution can take global manufacturing to new heights. However, the applicability of I 4.0 differs from one organization to another organization depending on its size.

2.3. Industry 4.0 and Small and Medium Enterprises

The contribution of SMEs to the economic growth of any nation cannot be ignored at all (Singh et al. 2021). However, it has been a tendency that significant concerns are mostly capital intensive and require many assets. Replacement with complete automation of these assets requires enormous funds and a distinct agenda (Haug et al. 2011). The pressure to work in the atmosphere of I 4.0; willingness to accept risk with open arms; effective knowledge, skills, and adequate support from top management; availability of the right competence; sufficient motivation; economic freedom, etc., make any industry ready for I 4.0. However, SMEs target their niche market and are very narrowly infused with their structure (Stentoft et al. 2021). However, ignorance and non-readiness for the next generation of industry transformation are major obstacles. In SMEs, economies of scale are less than large concerns. Hence, I 4.0 proves less advantageous to them (Chonsawat and Sopadang 2020). However, economies have been opened to a new era of information and transparency, making it difficult for small and new enterprises to stand in the queue of competition. Hence, if these SMEs perceive the success rate of this revolution precisely, they will be able to improve their product quality, time savings, cost savings, on-time processes, prolonged customer relationships, etc. (Truong and Khai 2020). However, these SMEs have lower penetration and implementation levels, and technology accessibility depends on the economies and investment returns (Pech and Vrchota 2020). Several barriers often restrict these industries from successfully implementing the I 4.0 system in their existing structure. These barriers are primarily interrelated and dependent upon each other. This relationship among barriers through the method of ISM is explained in the following subsection.

2.4. Barriers to the Introduction and Application of I 4.0 in Indian SMEs

It has been observed from the published literature that most SMEs are quite ignorant about the procedure and applicability of I 4.0 in their organizational systems (Lee et al. 2015). Certain institutions are keen but do not receive adequate managerial support from senior executives (Sima et al. 2020). They are still orthodox and lack an understanding and adaptable approach. Little knowledge (Dutta et al. 2020) about the technicalities and adequate funds' availability further worsens their approach to change. The introduction of IoT and CPS requires huge funding and even support from government machinery, at the ground level, missing and not reaching the ultimate user (Kumar et al. 2019). Once implemented, the whole production mechanism changes and demands enormous investment in research and development (Lee et al. 2015). The lack of long-term vision and enthusiasm among stakeholders in these SMEs makes it quickly uninteresting. Another aspect is that the owners and managers of these SMEs are not adequately qualified and less trained in establishing IT-based infrastructure (Sima et al. 2020). Additionally, there is no coordination and association between SCM members (Phuyal et al. 2020). There is a massive fear among these SMEs regarding the successful implementation of I 4.0 in their system due to factors such as rising unemployment, doubt about sustainability (Tripathi et al. 2021b), alternate solutions in the case of technical breakdowns, uncertain demand, and the overstocking of final products in their warehouses (Kamble et al. 2018).

2.5. The Need for Understanding the Applicability of ISM in I4.0 and SMEs

Keeping in mind the pros of the ISM technique in establishing and identifying the relationship between the issues related to the problem at hand, this technique was deployed in the present investigation. These issues are often interwoven with the contextual and subservient relationship. Some of the issues are so complex that their presence simply complicates the whole structure of the entire system (Syreyshchikova et al. 2021a). Hence, it becomes difficult to articulate the vague system. Here, the method of ISM proves as a panacea and helps identify, refine, build, and transform a vague system into a visible and properly defined model. Moreover, ISM helps explain the complexity lucidly involved in various issues.

The technique of ISM was developed by Warfield (1974) to describe the interrelationship needed to form a single digraph from two other known diagraphs. Using logic equations developed an interconnection matrix that formed a well-defined structure. This structure is identified within the existing system involving complex issues (Farris and Sage 1975; Syreyshchikova et al. 2021c). Since the inception of this technique, many scholars and authors have widely used it to explain the complex, subordinate, inter-woven relationships among the challenges, barriers, drivers, or other issues under their consideration. Vendor selection, lean six sigma enablers, sustainable supply chain practices, lean manufacturing, customer-centricity, IoT in smart cities, knowledge management in the automobile industry, etc., are just a few examples where authors have recently used this technique to explain relationships (Mandal and Deshmukh 1994; Janssen et al. 2019). The importance of variables was determined by structural equation modeling (SEM) on Industry 4.0 and the digitalization of product customization processes (Pech and Vrchota 2022). A framework for mass personalization production based on Industry 4.0 was presented (Wang et al. 2017).

Moreover, this technique can explain relationships in real-life situations and better analyze and explain them (Kaswan and Rathi 2019). The present study also deals with the complexities and subjective relationship among barriers to adopting I 4.0 in SMEs in India. This robust technique, i.e., ISM, can explain the possible reasons for the non-adoption of I 4.0 in Indian SMEs and identify major and minor barriers to its successful implementation. The literature review on SMEs, barriers to implementing I 4.0 in these SMEs, and a detailed survey of ISM applications show that this technique can be effectively used in the present research work.

2.6. Need for Understanding the Applicability of MICMAC Analysis in I 4.0 and SMEs

MICMAC analysis is a method to validate the indirect relationship developed by the interpretative structural modeling technique. Duperrin and Godet developed this system for the comprehensive multiplication of available interconnected matrices in 1973. Unlike the ISM approach, this method explains the importance of issues at hand by the indirect interrelationships between them. This analysis is also popularly called Gray Area Exploration. The deployment of a graph with the driving dependence power of issues helps to reach a valid conclusion. Hence, MICMAC analysis often supplements the ISM approach in explaining major and minor complex driving and dependence powers problems.

Moreover, MICMAC analysis helps group issues related to dependent and independent variables studies. This analysis finds its place in understanding driving and dependence power in several areas comprising knowledge management variables (Singh et al. 2003), Green SCM (Diabat and Govindan 2011), I 4.0 (Kamble et al. 2018), cold supply chain management (Sharma et al. 2021), lean construction, etc. Furthermore, this analysis has been widely applied in finding the enablers of I 4.0, IoT, CPS, and automation in various industries (Kamble et al. 2018). The present study also investigates various barriers to the non-adoption of I 4.0 in Indian SMEs. The review of existing literature on SMEs, barriers to implementing I 4.0 in these SMEs, and a detailed survey of MICMAC analysis and their applications show that this technique can be effectively used in the present research work. The identified barriers are discussed in the following sub-section.

2.7. Identification of Challenges in the Indian Scenario

Different researchers have observed different challenges for I 4.0. For example, Almada-Lobo (2016) and Kamble et al. (2018) marked that a lack of awareness of the implications of I 4.0 is proving to be the biggest challenge for existing and upcoming SMEs, and they need to adopt these technologies with a strong focus on research and development. On the other hand, Feng et al. (2018) suggested improper or insufficient top management support for adopting new technologies. In addition, there is a lack of knowledge and long-term benefits of I 4.0-based know-how (Battaglia et al. 2018).

The authors focused on the need for training in modern technologies. The fund allotment for I 4.0 is very small, while investment requirements are very high. Therefore, there is a need for more fund allotment for these technologies (Almada-Lobo 2016; Prajapati et al. 2019). The lack of awareness of government policies on I 4.0 adoption is also a considerable challenge. Government support for manufacturing organizations is also vital (Jain et al. 2016; Pfohl et al. 2017). With the lack of dedicated resources, the quality of research is affected. Quality research on I 4.0 is the need of the hour. Therefore, the authors suggested quality research on I 4.0 technologies (Almada-Lobo 2016; Luthra and Mangla 2018). Feng et al. (2018) and Luthra and Mangla (2018) explained that small and medium manufacturing organizations believe in short-term planning, while I 4.0 requires long-term implementation planning. Therefore, the researchers suggested long-term planning for the implementation of I 4.0. However, (Pfohl et al. 2017) highlighted information technology infrastructure-based issues in small and medium manufacturing organizations, such as weak network connectivity. They suggested robust network connectivity and smooth and fast information flow. Feng et al. (2018) found a great shortage of skilled and efficient personnel in novel technologies. This study also stressed the necessity of adequate training on technologies and know-how of I 4.0 for personnel at the site or office. Fifteen challenges found through the literature review and experts' opinions on I 4.0 implementation in Indian SMEs are discussed in Table 1.

Table 1. Challenges affecting the implementation of I 4.0.

S. No.	Challenges Affecting the Implementation of I 4.0	Reference
C1	Little awareness	(Almada-Lobo 2016; Hofmann and Rüsch 2017; Luthra and Mangla 2018)
C2	Little managerial support	(Feng et al. 2018; Luthra and Mangla 2018)
C3	Little technical knowledge	(Marques et al. 2017; Prajapati et al. 2019)
C4	Insufficient funds	(Dalmarco et al. 2019; Prajapati et al. 2019)
C5	No clear government policies	(Luthra and Mangla 2018)
C6	Lesser resources for research and development	(Almada-Lobo 2016; Prajapati et al. 2019)
C7	No solid, long-term vision	(Feng et al. 2018; Luthra and Mangla 2018)
C8	Little enthusiasm from stakeholders	(Marques et al. 2017; Prajapati et al. 2019)
C9	Lack of IT-based infrastructure (software and hardware)	(Pfohl et al. 2017; Sharma et al. 2020)
C10	Untrained and unskilled personnel	(Luthra and Mangla 2018; Sommer 2015)
C11	Little coordination and association between SCM members	(Prajapati et al. 2019)
C12	Leading to unemployment in society	(Satapathy 2017; Zezulka et al. 2016)
C13	Doubt about the sustainability of I 4.0	(Jain et al. 2016; Pfohl et al. 2017)
C14	Lack of alternate solutions to the technological breakdown	(Prajapati et al. 2019)
C15	Uncertain predicted demand for a product	(Luthra and Mangla 2018)

3. Material and Methods

The whole process of the present investigation is shown in Figure 2.

3.1. Research Design

This study identified the research gap (already mentioned above) based on an extensive literature survey that outlined research motivation in terms of the objectives and intended contributions of the present investigation, discussed in the previous section.

This present investigation exclusively focuses on understanding the barriers to implementing I 4.0 in Indian SMEs. These barriers were scrutinized thoroughly to comprehend the reasons for the non-adoption of I 4.0 in these SMEs. This study adopted a descriptive research design. This study's target population was SMEs that could not implement I 4.0 in their units. At the primary data-collection stage, a survey was conducted through a self-structured and scheduled questionnaire comprising 15 barriers related to implementing I 4.0 in SMEs in India. Twelve experts from various fields have been contacted in this survey. Data were collected in a brainstorming session. The secondary data related to barriers were collected from published journals, articles, conference papers, reviews, books, and reports on barriers of I 4.0. An empirical analysis of responses followed the survey through the usage of MS Excel. Statistical tools, such as ISM analysis, MICMAC analysis, and the ranking of various barriers, were used to analyze the data.

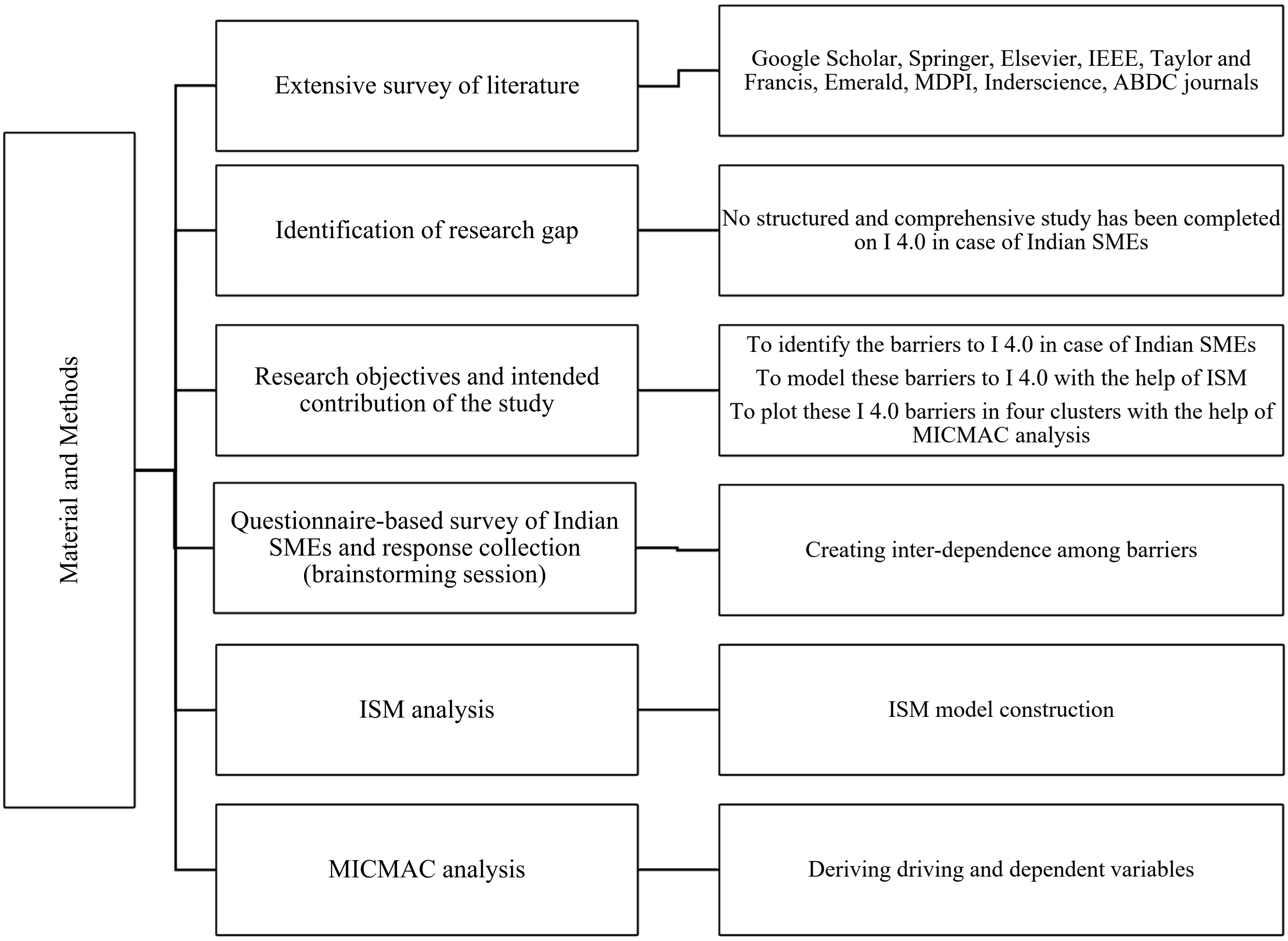

Figure 2. Material and methods used in the present investigation.

3.2. Brainstorming Session on Barriers and Their Inter-Dependence

A detailed literature survey of challenges in implementing I 4.0 was conducted, expert opinions from local industry experts and academia were sought, and a questionnaire was drafted. Then, this questionnaire was sent for content analysis to two local manufacturing entrepreneurs. After final scrutiny, the final questionnaire, containing 14 questions, was framed. Finally, an event was arranged, and twelve experts were invited for a brainstorming session to discuss barriers to the successful implementation of I 4.0 in Indian SMEs. This event comprised six experts from academia, four from industry, and two government officials from the Ministry of MSME, Punjab, India. The experts who were present in the brainstorming session are summarized in Table 2.

The questionnaire was distributed among these technical experts from small and medium manufacturing organizations, government officials, and experienced academic researchers to collect responses. Egos, biases, and copying of responses were eliminated by personal intervention by the investigators, and the chances of margin of error were consequently eliminated. If there was some clash or disagreement in any response, they were resolved through mediation in the following session. Their responses were collected in two sessions on the same day. The responses were compiled, and the veracity of the responses is good and contains no deviation or manipulations. The responses were later summarized in the form of codes. These summarized codes were utilized well ahead for analysis purposes.

Table 2. Experts team for brainstorming.

Sr. No	Code	Working Profile	Designation	Area of Expertise	Experience
1	A-1	Academia	Associate Professor at University	Management	22 Years
2	A-2	Academia	Associate Professor at University	Marketing	20 Years
3	A-3	Academia	Associate Professor at Management Institute	Mechanical Engineer	17 Years
4	A-4	Academia	Assistant Professor in a college	Mechanical Engineer	13 Years
5	A-5	Academia	Assistant Professor in a college	Mechanical Engineer	13 Years
6	A-6	Academia	Assistant Professor in a college	Computer Science Engineer	12 Years
7	I-1	Industry	Owner of a Textile MSME Unit	Engineer by qualification	36 Years
8	I-2	Industry	Area Manager in a Cycle MSME Unit	Production Head in the assembly unit	22 Years
9	I-3	Industry	Production Manager in a Tyre Manufacturing Unit	Chemical Engineering	21 Years
10	I-4	Industry	Technical Engineer in a Sewing Machine Unit	Electrical Engineering	20 Years
11	G-1	Ministry of MSME	Assistant Director (Mechanical)	Mechanical engineer	15 Years
12	G-2	Ministry of MSME	Assistant Director (Electrical)	Electrical Engineer	13 Years

3.3. Deployment of ISM on Barriers

Keeping in mind the robustness of the ISM method in dealing with complex relations (discussed in Section 2.5), the technique of ISM was used to examine the interrelation between the different barriers. In recent times, smart technologies are needed, but implementing these technologies is an uphill task due to different challenges. Kamble et al. (2018) investigated various barriers to implementing I 4.0 in Indian manufacturing using ISM techniques. Singh et al. (2021) applied the ISM technique to the factors identified for improving SMEs' competing effectiveness. Satapathy (2017) applied the ISM approach to find the relationship between challenges and solutions. The ISM technique was developed to find the most influential factor among the complex problem's barriers to decision-making. This technique is mainly used to solve management and operation research problems for decision making, and ISM is one of the multiple criteria decision-making (MCDM) techniques that help build essential interrelationships among all of the challenges (Kumar et al. 2017; 2020a).

The ISM technique's relationship matrix is filled in binary numbers as (0, 1) to develop and explore the relationship between challenges in the application process. However, there is minimal research on analyzing challenges with the ISM technique's help, especially in the I 4.0 domain. Therefore, the ISM technique was used to find the most influential challenges and obtain the contextual relationships among the challenges.

The steps required for the ISM tool application are given below:

- Step 1: Fifteen different challenges are used to apply the ISM tool.
- Step 2: A detailed relation is obtained between the challenges, and the structural self-interaction matrix (SSIM) is constructed based on the relationship in terms of V, A, X, and O.
- Step 3: This SSIM matrix is converted into binary forms (0 and 1), and an initial reachability matrix is found.
- Step 4: A transitivity check of the initial reachability matrix is performed. The transitivity rule states that if Challenge A is related to Challenge B, and Challenge B is connected to Challenge C, Challenge A is necessarily related to Challenge C.
- Step 5: Level segmentation is performed on the final reachability matrix.
- Step 6: A hierarchical structure is framed based on the level partition, which shows the type of relationship among challenges.

4. Results

This section discusses the application of the ISM technique to Industry 4.0 barriers, especially in Indian SMEs, and analyzes the results. This section comprises the Structural Self-Interaction Matrix (SSIM), the Reachability Matrix (RM), level partitions, and ISM model construction.

4.1. Structural Self-Interaction Matrix (SSIM)

In the development of the SSIM matrix, four types of variables are used to indicate the relation between Challenges A and B:

V—Challenge A will help to achieve Challenge B;
A—Challenge B will help to achieve Challenge A;
X—Challenges A and B will help to achieve each other;
O—Challenge A and B do not have any type of relation.

Based on the expert's opinion, the SSIM matrix is developed; for example, Challenge 'C1' (i.e., little awareness) helps achieve Challenge 'C8' (i.e., little enthusiasm from stakeholders). Therefore, this relation is indicated by the symbol 'V' in the SSIM matrix. Challenge 'C2' (i.e., little managerial support) is influenced by Challenge 'C8' (i.e., little enthusiasm from stakeholders). Therefore, this relation is indicated by the symbol 'A' in the matrix and referred to in Table 3.

Table 3. SSIM matrix for challenges.

Challenge Code	C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
C1	O	V	V	V	X	V	X	V	V	V	X	V	X	V	
C2	O	V	V	V	V	V	V	A	V	V	V	V	V		
C3	V	V	V	V	X	X	V	A	V	X	V	V			
C4	O	V	V	O	V	V	V	A	A	X	O				
C5	O	V	V	V	V	V	V	A	V	V					
C6	V	V	V	V	V	V	V	A	V						
C7	V	V	V	V	V	V	V	A							
C8	V	V	V	V	V	V	V								
C9	V	V	V	V	V	V									
C10	V	V	V	V	V										
C11	V	V	V	V											
C12	O	O	V												
C13	O	V													
C14	V														
C15															

The SSIM matrix in Table 3 reveals that the highest number of Vs (total of seven direct Vs and six reverse As) was obtained by Variable C8, the most squeezed variable, contributing the most in terms of the challenges and impact on other barriers, later supervened by C2 and C5. Hence, on the other side, the maximum As were obtained by C15 (eight reverse Vs), with dependence upon other variables supervened by C14, C13, and C12. However, C1 mostly helps to achieve other challenges.

4.2. Reachability Matrix (RM)

Subsequently, for the SSIM matrix development, the SSIM matrix is transformed into the initial RM by converting V, A, X, and O into binary numbers ('0' and '1'). The resulting conversion is based upon the convention, as indicated in Table 4.

Table 4. Conversion rule of SSIM matrix into initial reachability matrix.

Symbol	V	A	X	O
For (i, j) cell	1	0	1	0
For (j, i) cell	0	1	1	0

Based on this conversion, the initial RM is developed as per Table 5. To create the final RM, the transitivity check is applied to the initial reachability matrix following the transitivity rule mentioned in Section 4.1.

Table 5. Initial reachability matrix.

Challenge Code	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
C2	0	1	1	1	1	1	1	0	1	1	1	1	1	1	0
C3	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1
C4	0	0	0	1	0	1	0	0	1	1	1	0	1	1	0
C5	1	0	0	0	1	1	1	0	1	1	1	1	1	1	0
C6	0	0	1	1	0	1	1	0	1	1	1	1	1	1	1
C7	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1
C8	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C9	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1
C10	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1
C11	1	0	1	0	0	0	0	0	0	0	1	1	1	1	1
C12	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Now, there is a need to check the transitivity in the barriers to Industry 4.0. This is because there is a chance that a loop can be created among the variables due to the variable leading to another variable, which circles back to the previous variable. Hence, to overcome this undesirable condition, a transitivity check was made, and wherever transitivity was removed, this place was marked as 1* in Table 6 given below. The final reachability matrix shows all the transitivity checks (Table 6).

Table 6. Final reachability matrix.

Challenge Code	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	Driving Power
C1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1*	15
C2	1*	1	1	1	1	1	1	0	1	1	1	1	1	1	1*	14
C3	1	1*	1	1	1	1	1	1*	1	1	1	1	1	1	1	15
C4	1*	0	1*	1	0	1	1*	0	1	1	1	1*	1	1	1*	12
C5	1	1*	1*	1*	1	1	1	1*	1	1	1	1	1	1	1*	15
C6	1*	0	1	1	1*	1	1	0	1	1	1	1	1	1	1	13
C7	1*	0	1*	1	0	1*	1	0	1	1	1	1	1	1	1	12
C8	1*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
C9	1	1*	1*	1*	1*	1*	1*	1*	1	1	1	1	1	1	1	15
C10	1*	0	1	1*	1*	1*	1*	0	1*	1	1	1	1	1	1	13
C11	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1	1	1	1	1	15
C12	0	0	0	0	0	0	0	0	0	0	0	1	1	1*	0	3
C13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1*	3
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	11	7	11	11	9	11	11	6	11	11	11	12	13	14	14	

This final reachability matrix dependence and driving power were obtained for each challenge, represented in turn by the connection of a given row and column. These acquired powers were used for MICMAC analysis, and the final RM was used for level partitioning, as discussed in the next section (refer to Section 4.3).

4.3. Level Partitions

There is a need to develop an antecedent set and reachability set for every challenge, as defined in the tool methodology based on the final reachability matrix (Satapathy 2017).

A reachability set was formed for each challenge by considering the particular challenge and other challenges that may help facilitate it. Similarly, an ascendant set was developed by considering a specific challenge and other challenges that may enable them. After that, an intersection set was formed for all challenges. The challenge of the reachability set and intersection set being the same is defined as level I and is placed at the acme position in the ISM model structure. After reaching level I, the first iteration is finished, and part of the level I challenges is separated from the rest. The same procedure is followed for finding the level of other challenges. For example, the reachability and intersection sets for challenge 15 are the same. Hence, it is removed at iteration 1; refer to Table 7. Challenge 15 is assigned as level I, and the iteration proceeds to iteration 2; refer to (Table 8).

Table 7. Iteration 1 of level partitions.

Challenge	Reachability Set	Antecedent Set	Intersection Set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 5, 8, 9, 11	1, 2, 3, 5, 9, 11	
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C4	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 5, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	
C6	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 5, 6, 7, 9, 10, 11	
C7	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 3, 5, 8, 9, 11	1, 3, 5, 8, 9, 11	
C9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C10	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C12	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12	
C13	13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	13	
C14	14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	14	
C15	15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15	15	I

Table 8. Iteration 2.

Challenge	Reachability Set	Antecedent Set	Intersection Set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14,	1, 2, 3, 5, 8, 9, 11	1, 2, 3, 5, 9, 11	
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C4	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 5, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	
C6	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 5, 6, 7, 9, 10, 11	
C7	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 3, 5, 8, 9, 11	1, 3, 5, 8, 9, 11	
C9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C10	1, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C12	12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12	
C13	13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	13	
C14	14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	14	II

The reachability and intersection sets for challenge 14 are the same. Hence, it is removed at iteration 2. Challenge 14 is assigned as level II, and the iteration will proceed to iteration 3; refer to Table 9.

Table 9. Iteration 3.

Challenge	Reachability Set	Antecedent Set	Intersection Set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13	1, 2, 3, 5, 8, 9, 11	1, 2, 3, 5, 9, 11	
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C4	1, 3, 4, 6, 7, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 5, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	
C6	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 5, 6, 7, 9, 10, 11	
C7	1, 3, 4, 6, 7, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 3, 5, 8, 9, 11	1, 3, 5, 8, 9, 11	
C9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C10	1, 3, 4, 6, 7, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C12	12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12	
C13	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	13	III

The reachability set and intersection set for challenge 13 are the same. Hence, it is removed at iteration 3. Challenge 13 is assigned as level III, and iteration proceeds to iteration 4. It is observed from iteration 1 that uncertain predicted demand for a product (C15) is obtained at level I in the ISM model's hierarchical structure (Table 7). In iterations 2 and 3, the challenges 'lack of an alternative solution to the technological breakdown (C14)' and 'doubt about the sustainability of I 4.0 (C13)' are placed at level II and level III, respectively (Tables 7 and 8). In iteration 4, the challenge 'leading to unemployment in society (C12)' was placed at level IV (Refer to Table A1 in Appendix A).

After that, in iterations 5, the challenges 'little awareness (C1)', 'little technical knowledge (C3)', 'insufficient funds (C4)', 'lesser resources for research and development (C6)', 'no solid, long-term vision (C7)', 'lack of IT-based infrastructure (software and hardware) (C9)', 'untrained and unskilled personnel (C10)', and 'little coordination and association between SCM members (C11)' were placed at level V (Refer to Table A2 in Appendix A). Further, in iteration 6, the challenges' little managerial support (C2)' and 'no clear government policies (C5)' were placed at level V (Refer to Table A3 in Appendix A).

No similar procedure was repeated for the rest of the partition levels. The remaining iterations are shown in Appendix A, Tables A1–A3. The reachability set and intersection set for challenge 11 are the same. Hence, it is removed at iteration 4. Challenge 12 is assigned as level IV, and the iteration proceeds to iteration 5. The reachability set and intersection set for challenges 1, 3, 4, 6, 7, 9, 10, and 11 are the same. Hence, these are removed at iteration 5. These challenges were assigned as level V, and the iteration proceeds to iteration 6. The reachability set and intersection set for challenges 2 and 5 are the same. Hence, they are removed at iteration 6. These challenges were assigned as level VI, and the iteration proceeds to iteration 7. Lastly, in iteration 7, the challenge 'little enthusiasm from stakeholders (C8)' was set at Level VII.

This study shows that C8 (level VII) is the chief driving force leading to other barriers to the successful implementation of I 4.0 in the SME sector. As we go higher in the hierarchy of understanding the extent of the challenge posed by each barrier (as per Table 10), from level VII to level I, the dependence on the other obstacles mounts, where level I shows the highest amount of dependence on other barriers. So, it can be understood from the above explanation that the role of the primary stakeholder (C8) is maximum in making I 4.0 successful, upon which all other barriers rely. If this stakeholder shows enthusiasm, the result will be different, but, on the contrary, lesser enthusiasm will create more challenges.

Table 10. Final level partitions from all iterations.

Challenge Code	Challenges	Level
C1	Little awareness	V
C2	Little managerial support	VI
C3	Little technical knowledge	V
C4	Insufficient funds	V
C5	No clear government policies	VI
C6	Lesser resources for research and development	V
C7	No solid, long-term vision	V
C8	Little enthusiasm from stakeholders	VII
C9	Lack of IT-based infrastructure (software and hardware)	V
C10	Untrained and unskilled personnel	V
C11	Little coordination and association between SCM members	V
C12	Leading to unemployment in the society	IV
C13	Doubt about the sustainability of I 4.0	III
C14	Lack of alternate solutions to the technological breakdown	II
C15	Uncertain predicted demand for a product	I

4.4. ISM Model Construction

An ISM hierarchy structure model was constructed based on final partition levels from all iterations for each challenge (Table 10), as shown in Figure 3. As obtained from level partitions, the barriers (C15) and (C8) are on the top and bottom level, respectively, in the ISM-based hierarchy structure model. A more detailed view of this model for all challenges is shown in Figure 3.

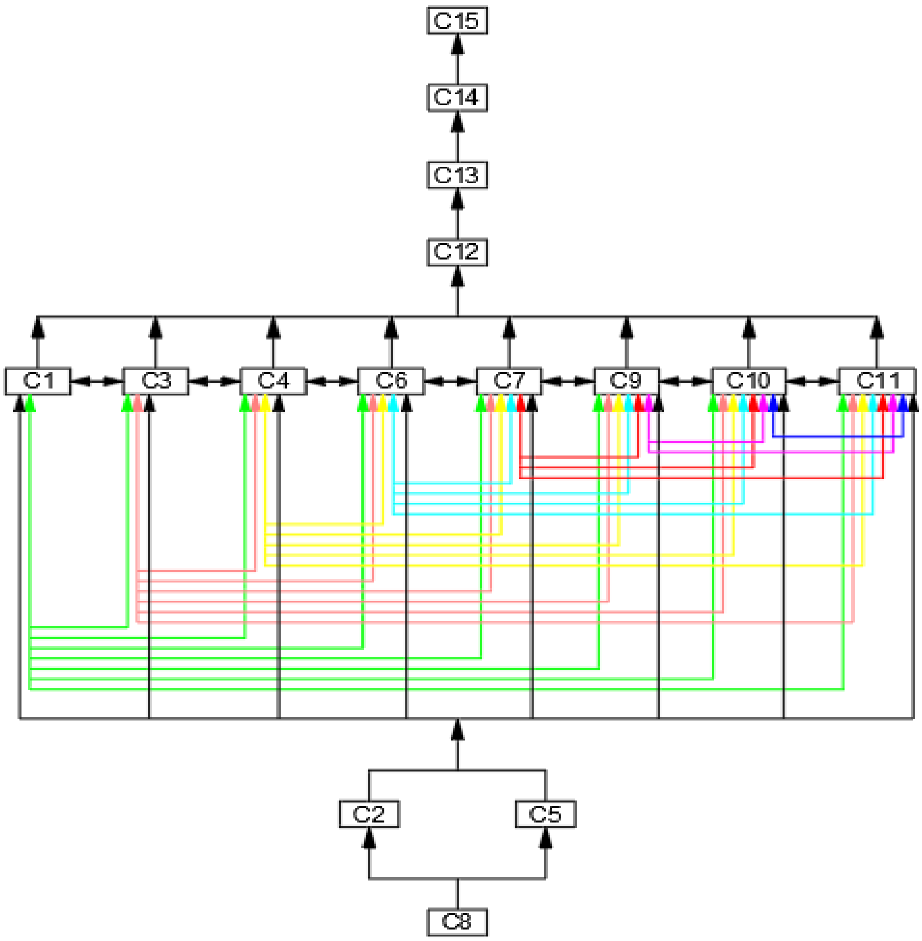

Figure 3. ISM model of challenges in implementing Industry 4.0 in Indian SMEs.

This study shows that uncertain predicted demand for the product (C15, level I) is a major barrier, restricting industrialists from investing and adopting I 4.0 in their units. The systems are so complex that there is no alternative solution once they break down (C14, level II). Hence, this creates doubt among them about the sustainability of I 4.0 (C13, level III). Once adopted, automation and self-production lead to massive unemployment (C12, level IV). These are entirely dependent forces and prove to be major barriers leading to the non-adoption and easy acceptance of I 4.0 in Indian SMEs. Little enthusiasm from stakeholders (C8, level VII) and little managerial support (C2, level VI) are autonomous and driving barriers leading to other barriers. These can be further analyzed with MICMAC analysis, explained in Section 4.5.

4.5. MICMAC Analysis

MICMAC is an acronym for Cross-Impact Matrix Multiplication Applied to Classification. This analysis depends on the multiplication features of matrices. This analysis aims to find the driving power and dependence power of challenges, which helps determine critical challenges or barriers that drive the system (Ahmad et al. 2019; Yadav and Desai 2017). As per the obtained value of driving power and dependence power, the barriers are divided into four main sections: autonomous barriers, dependent barriers, linkage barriers, and driver barriers. In MICMAC analysis, a diagram is constructed, considering barriers' driving and dependence power (Figure 4).

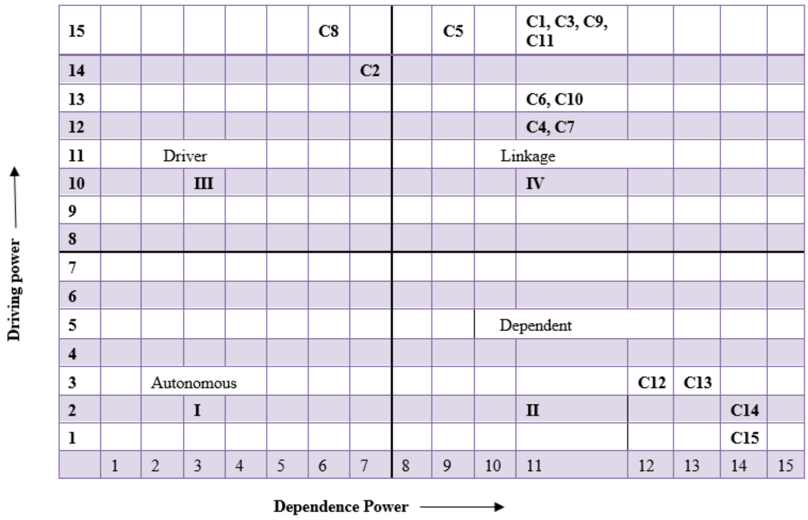

Figure 4. MICMAC analysis representation.

Autonomous Barriers: These barriers have frail driving power and dependence power. They have no relation with the system due to their frail linkage power with other barriers. In this study, there is no autonomous challenge. This means that all the selected barriers in this section are quite significant and help establishments complete I 4.0 as modern-era technology.

Dependent Barriers: These barriers have very weak driving power but strong dependence power. In this study, barriers (C12), (C13), (C14), and (C15) were found to have strong dependence but frail driving power. Therefore, these barriers need more attention.

Linkage Barriers: These barriers have inviolable driving as well as dependence power. In this study, barriers such as (C1), (C3), (C4), (C5), (C6), (C7), (C9), (C10), and (C11) were observed to have inviolable driving and dependence power. However, these barriers showed instability in nature. Therefore, any change in these barriers will affect other barriers, and the reverse may also happen.

Driver Barriers: Driver barriers are also known as independent barriers because they indicate strong driving and weak dependence power. In this study, barriers such as (C2) and (C8) demonstrated robust driving and frail dependence power, driving barriers such as 'key barriers'. The barriers of this category are of prime concern or have great importance over others.

5. Discussion

Modern times are challenging for Indian SMEs on the technology front. They face many barriers to adopting I 4.0 technologies. Observations of research papers show fifteen barriers affecting the adoption of smart technologies in SMEs. The authors' framework helps establish the relationship among these barriers. Therefore, the strategic team of the top management in most Indian SMEs can design effective strategies based on the observations of the current study.

The barriers are grouped into four groups of barriers to MICMAC representation (as shown in Figure 4). Barriers identified as drivers influence the other barriers and need the urgent attention of decision-makers/top management in Indian SMEs.

From ISM analysis, the authors observed that with the absence of autonomous barriers, it could be concluded that all identified barriers significantly influence the implementation of the upcoming I 4.0 in Indian SMEs. Dependence and driving power constituting indirect relationships among these barriers, shown by MICMAC analysis to have high Fisignificance. Little enthusiasm from stakeholders and little managerial support are highly potent barriers to the ISM approach. These barriers prove to be the leading cause of dependent and affected barriers (shown in Figure 4) Little enthusiasm from stakeholders is one of the most affecting challenges, with eminent driving power and frail dependence power; this implies that this challenge strongly influences the adoption of I 4.0 technologies in Indian SMEs. The absence or little managerial support hinders the adoption of I 4.0 and proves to be a significant barrier.

These results are very close to the already published literature detailing that the lack of certainty on future market demand is a major barrier hindering SMEs' progressive inclination. The worries about technical breakdowns and the doubt about the sustainability of I 4.0 are dependent and affected barriers identified by the ISM approach and MICMAC analysis. Scholars and environmentalists spread a common wave and myth that I 4.0 will bring disruption and huge unemployment. Ultimately, the SMEs seem less keen on kicking their labor out and bringing automatic machinery in. Hence, the fear of unemployment depends upon other barriers. Other barriers, such as little awareness, little technical knowledge, insufficient funding to these SMEs, lack of solid vision, lack of IT-based infrastructure, lack of trained staff, and lack of coordination and association between SCM members, have added linkages to the non-adoption of I 4.0 in Indian SMEs. These observations imply that for the effectual promotion of I 4.0 in Indian SMEs, various driving and dependency groups' barriers should be considered an effective priority. To reduce driving and potent barriers, there is a need for Indian SMEs to develop strategies and work in coordination with their supply chain partners. These barriers can impact the other strategic choices for successful I 4.0 implementation. Observations from this study can help decision makers make strategic decisions to manage barriers affecting I 4.0 in Indian SMEs.

6. Managerial Implications, Suggestions, and Future Scope

With the emergence of the Fourth Industrial revolution in 2011 in Germany, enhanced usage of automatic machines, robotics in several manufacturing applications, and digitalization of information, the whole world has completely changed. Almost all the manufacturing and service enterprises around the globe are adopting all of these at a faster pace to tackle sustainability. Initially, there is no doubt that a huge investment outlay is required to transform from the traditional mode to the automation mode. The present research work has theoretically familiarized the need to adopt I 4.0 in SMEs, especially in Indian territory, catering to the mounting aggregate demand of its huge population. However, it is impossible to consider the theoretical findings without understanding their practical implications. This study has shown that practical exertion is required to change the orthodox mindset of management sitting at the top management of these SMEs with continuous spasms of cognizance sessions. There is a need to explain why they should change their vision and mission with the changing business environment.

Finally, this study has made an essential contribution with its appropriate managerial implications and offers sufficient directions for the policymakers, government agencies, stakeholders involved, owners of SMEs, industrial experts, environmental experts, academics, and scholars by creating a relationship between barriers for the adoption of I 4.0 in SMEs. This study, through its findings, helps industry managers and owners in understanding the significant barriers behind their unsuccessful attempts at the adoption of I 4.0 in Indian SMEs. This study suggests that government agencies and the ministry of micro, small, and medium enterprises must help small entrepreneurs enhance their awareness, knowledge, training, and necessary support in adopting I 4.0. Once established in letter and spirit, the problem of sickness in these SMEs can be overcome, and sustainability can be ensured for the long run. This research revealed an extended scope, including other South Asian and developing nations. The present work results can be utilized by adopting dependent and independent variables in further analysis.

7. Conclusions

Indian small and medium manufacturing corporations are the foremost contributors to the manufacturing sector in the modern-day scenario. However, upgrading the applied sciences used through these SMEs is additionally a want of the hour. Therefore, there is a dire need to lay down such sustainable strategies to minimize the challenges affecting I 4.0 in Indian SMEs. This study aimed to identify the major barriers to the successful implementation of I 4.0 in the Indian SME Sector. Hence, through an in-depth literature survey, the authors recognized fifteen key challenges in the present research work and analyzed these challenges with the ISM technique. After identifying the barriers, there is a need to model them in terms of independent and dependent challenges. Hence, the present investigation attempted to optimally utilize the robust technique of ISM and MICMAC analysis to model them. This study segregated these barriers into seven major levels based on their dependency on each other. This study found that the role of the prime stakeholder (C8) is maximum in making I 4.0 successful, upon which all other barriers rely. If this stakeholder shows enthusiasm, the result will be different, but, on the contrary, lesser enthusiasm will create more challenges. This study found that little managerial support makes the program less successful. This means if the management of these organizations is less supportive and is less interested along with other stakeholders, naturally, other barriers will receive more power and create issues. Hence, the ISM diagram was able to model them as per their dependence strength and demonstrated them adequately. In the case of SMEs, the major problem is finance for introductions such as I 4.0 in the modern set ups. A huge contribution still does not ensure a success story for investors. Hence, in developing nations such as India, the management of these organizations is always reluctant to invest or take a big leap. Little managerial support and motivation add fuel to the fire and make such organizations laggard rather than proactive and taking enthusiastic moves.

Even the governments of countries such as India are less-supportive contributors. Here, the role of government in public-private partnership can play a conducive role in uplifting SMEs and making them I 4.0 ready. Thus, there is a need to understand the driving, autonomous, and dependence forces and linkages for the administrative machinery sitting in power in any nation. Herein lies the role of MICMAC analysis, which helped plot these challenges in four quadrants. The present investigation, through MICMAC analysis, divided all these 15 variables into 4 sections, showing the strength and weaknesses of each force. This division will help the government and its concerned ministries to focus according to the power of the challenges posed. This study successfully derived specific valuable suggestions and observations, which are applicable scientifically in Indian scenarios and other developing nations, such as Pakistan, Bangladesh, Sri Lanka, and Nepal, facing similar challenges.

Despite valuable observations and suggestions, this study has shortcomings and limitations. First, this study only observed fifteen challenges, which may have missed some challenges due to the exhaustive survey of the existing published work. Second, the research mainly focused on the Indian scenario and only SMEs. A cross-national study in a similar area can bring better results. Third, biased opinions of the experts may have influenced questionnaire filling while selecting interrelationships between challenges. This is also an inherent limitation of ISM methodology. Finally, this study has a scope including other south Asian and developing nations. The present work results can be utilized with structural equation modeling (SEM) and multiple regression analysis (MRA).

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Appendix A

Table A1. Iteration 4.

Challenge	Reachability Set	Antecedent Set	Intersection Set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12	1, 2, 3, 5, 8, 9, 11	1, 2, 3, 5, 9, 11	
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C4	1, 3, 4, 6, 7, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3, 5, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	
C6	1, 3, 4, 5, 6, 7, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 5, 6, 7, 9, 10, 11	
C7	1, 3, 4, 6, 7, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 3, 5, 8, 9, 11	1, 3, 5, 8, 9, 11	
C9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C10	1, 3, 4, 6, 7, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	
C11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
C12	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12	IV

Table A2. Iteration 5.

Factors	Reachability Set	Antecedent Set	Intersection set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	V
C2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11	1, 2, 3, 5, 8, 9, 11	1, 2, 3, 5, 9, 11	
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	V
C4	1, 3, 4, 6, 7, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	V
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 8, 9, 10, 11	
C6	1, 3, 4, 5, 6, 7, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 5, 6, 7, 9, 10, 11	V
C7	1, 3, 4, 6, 7, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	V
C8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 5, 8, 9, 11	1, 3, 5, 8, 9, 11	
C9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	V
C10	1, 3, 4, 6, 7, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 3, 4, 6, 7, 9, 10, 11	V
C11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	V

Table A3. Iteration 6.

Factors	Reachability Set	Antecedent Set	Intersection set	Level
C2	2, 5	2, 5, 8	2, 5	VI
C5	2, 5, 8	2, 5, 8	2, 5, 8	VI
C8	2, 5, 8	5, 8	5, 8	

Table A4. Iteration 7.

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
C8	8	8	8	VII

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