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Exploring the Lean Implementation Barriers in Small and Medium-Sized Enterprises Using Interpretive Structure Modeling and Interpretive Ranking Process

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Abstract: Past research reveals that many lean implementation barriers hinder lean implementation in small and medium-sized enterprises (SMEs). Among many sectors, the manufacturing sector suffers more as it generates more waste while carrying out manufacturing processes. Many manufacturing units make unsuccessful attempts to implement lean principles in their manufacturing systems. Hence, such units must eliminate the prevailing lean barriers to accomplish successful lean implementation. Moreover, the contextual relationship of lean barriers must be studied to understand the effect of such barriers. This paper uses interpretive structural modeling (ISM) to explore lean barriers, their relationships, and their influence on other lean barriers. The present research also reveals the most significant classification of lean barriers into various categories of independent, dependent, autonomous, and linkage using the (MICMAC) Matrice d'Impacts Croisés Multiplication Appliquée á un Classement analysis. ISM and MICMAC together provide relationship modeling and reveal the interrelationship between each lean implementation barrier and its categories, respectively. The ISM model is validated using the Delphi technique. The interpretative ranking process (IRP) is used to rank the barriers. The three significant lean implementation barriers revealed through the IRP include "lack of lean understanding", "lack of strong quality policy", and "risk of sustainable practice implementation". The present research will help practicing managers of SMEs in the manufacturing sector to understand the mutual influence of lean barriers before introducing lean implementation. It is suggested that SMEs work on independent barriers so that dependent barriers can also be overcome with the least amount of resources and effort.

Keywords: Delphi technique; interpretative ranking process; interpretive structure modeling; lean barrier; MICMAC

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1. Introduction

There is a significant contribution from small and medium-sized enterprises (SMEs) toward a country's sustainable development. SMEs differ from large enterprises in various parameters, such as factory size, manpower involved, yearly turnover, the financial year, size, etc., [1]. The different ways of classifying micro, small, and medium enterprises (MSMEs), and SMEs, vary from country to country [2]. SMEs also differ in terms of the types of skills required, organizational structure, culture, types of resources, total assets involved, etc. SMEs are among the most important economic units globally and contribute more than larger organizations, economically, in terms of providing employment, adding value, and contributing to the GDP of the country [3]. SMEs are attempting to move toward sustainable business practices globally, thus promising profitability, resilience, and positive social and environmental impacts [4]. SME industrial growth boosts a nation's economy. According to a World Bank report, SMEs account for up to 60% of total employment [5]. SMEs, either formal or informal in their structure, contribute to gross domestic product (GDP). Similarly, various Indian enterprises classified as MSMEs also contribute to the national socio-economic development and GDP [6]. In India, MSMEs provide around 8% of the national GDP. They also contribute around 45% of the manufacturing output and approximately 40% of the country's exports [7]. The government's financial help in terms of soft loans and grants appears insufficient to expand MSME operations [8]. SMEs also face slow growth due to the various challenges of insufficient resources, such as skilled manpower, state-of-the-art equipment, revolutionary digital technology, competitive sales and marketing strategies, research and development (R&D) efforts, lack of information technology (IT) infrastructure, etc., [9].

Global challenges and fierce competition force manufacturing industries and organizations to improve their ability to use lean manufacturing [10]. The prevailing stiff competition in the business world is forcing Indian SMEs to look for better management and manufacturing practices to survive [11]. To fight local and global competitiveness and provide long-term sustainability, various strategic approaches are adopted by SMEs. For many probable reasons, lean implementation in SMEs is crucial for waste minimization and value addition. However, without prior knowledge of many lean barriers, lean implementation in SMEs results in unsuccessful attempts. The role of each lean barrier is significant during lean implementations.

The implementation of lean production in SMEs presents many barriers on practical, theoretical, financial, and organizational levels [12]. Hence research on lean barriers (LBs) is essential for successful lean implementation in SMEs [13]. Many SMEs only have a limited understanding and awareness of lean principles and practice [11]. Further, there is a need to understand the importance of understanding LBs so that their respective levels of importance in lean implementation may be evaluated [14]. Researchers should also prioritize and analyze LBs to gain a better understanding and improve interpretation for successful lean implementation [15]. LBs in SMEs must be eliminated for successful lean implementation. Several studies across the globe attempted to identify LBs [10,16,17].

Apart from these several studies, there appear to be no studies suggesting the relationship modeling of lean implementation barriers for SMEs in the manufacturing sector. Further, lean implementation barriers require classification into various categories to help entrepreneurs understand the LBs, and their influence needs further investigation. Hence, it is essential to model lean implementation barrier relationships to provide a good understanding of LBs for successful lean implementation in SMEs. In the present attempt, three well-proven research methods, Interpretive structural modeling (ISM), Matrice d'impacts croisés-multiplication appliquée a un classement (MICMAC) analysis, and Interpretive ranking processes (IRP), are used; these can deliver relationship modeling, categorization of LBs, and ranking of LBs to help in successful lean implementation. Thus, the paper provides LB relationship modeling and ranking based on ISM, MICMAC, and IRP, which will help practicing managers and researchers in LB evaluation. Based on the above, the present research poses the following research questions:

- What are the various LBs for SMEs in the manufacturing sector?
- How may the LBs be classified using MICMAC analysis?
- How can the LBs be modeled using ISM and ranked employing IRP?

The paper is organized as follows: Section 2 documents a literature review to provide the stock of lean implementation barriers for SMEs in the manufacturing sector; Section 3 documents the various research methodologies of ISM, MICMAC, and IRP applied in the present research. Section 4 provides ISM model development and Section 5 provides the discussion of the present research. Section 6 states the limits of the research and potential future directions. Finally, a conclusion is drawn.

2. Literature Review

As per Yadav et al. [16], compared with large enterprises, lean studies in SMEs are often ignored by researchers exploring lean implementation. Therefore, the literature regarding lean implementation in SMEs is not conspicuous. It has also been revealed that many Indian SMEs struggle to adopt lean manufacturing because of their limited understanding and awareness of lean principles. Today, at the global level, lean and its basic principles (flow, value, pull, minimizing waste, etc.) are adopted in many production and service industries. They also became the paradigm for many manufacturing (and service) operations. Lean thinking motivates us to banish waste and create wealth in organizations [18]. Lean is considered to be a management practice that improves organizational performance, ultimately leading to sustainability; hence SMEs adopt lean principles in their operations [16]. Furthermore, while facing new challenges in production processes, companies should adopt lean and green practices in product development [19].

Various lean initiative-based studies using lean, lean with 6σ, lean with green initiatives, and innovation, etc., are found in the literature. These initiatives are equally applicable to SMEs and large enterprises in various sectors. Various mixed approaches alongside lean provide additional benefits. For instance, 6σ with lean leads to process efficiency with a lower defect percentage. Similarly, lean with green boosts environmentally friendly processes.

Various researchers attempted to research various sectors of SMEs to investigate lean implementation barriers. Achanga et al. [20] emphasized financial capabilities, skills and expertise, and organizational culture. Alaskari et al. [21] carried out a study on lean tools employed in SMEs. A lean barrier review-based study was carried out by several researchers [17,22–26]. Bhamu and Sangwan [23] carried out a review of the literature on lean manufacturing challenges. Sahoo and Yadav [24] investigated the lean manufacturing challenges. Similarly, case study-based studies were also conducted to identify LBs [25]. The identification and modeling of employee barriers while implementing lean manufacturing in small- and medium-scale enterprises [26]. Ramadas and Satish [27] worked to identify employee barriers in lean-based SMEs. They later worked on process-related barriers in lean-based SMEs. Khaba and Bhar [28] employed ISM to provide a model for barriers when implementing lean in the construction sector. Later, they used ISM and MICMAC to model lean implementation barriers in coal mines [29].

Shrimali and Soni [30] surveyed India and found eight barriers: resistance to change in middle management, lack of flexible working arrangements, absence of a lean implementation team, lack of reward system, little support from top management, poor lean training, high cost/investment, and absence of a consultant. Shrimali et al. [31] fused ISM modeling of eight lean implementation barriers in SMEs. Sharma et al. [32] carried out research using ISM for lean-based SMEs in the machine tool domain. The research of Salonitis and Tsinopoulos [33] explored the lean-based manufacturing sector of Greek SMEs. Belhadi et al. [34] found the top five barriers to lean implementation in SMEs to be: lack of management involvement, lack of adapted methodology of lean implementation, short-term vision, fear and resistance to change, and lack of understanding of lean. Caldera et al. [4] carried out an exploratory study and investigated manufacturing SMEs in Queensland, Australia, and established six key barriers: lack of financial resources, lack of time, lack of knowledge, risks associated with implementing a sustainable practice, current regulations, and existing organizational cultures that impede sustainable business practice. Sindhwani et al. [35] conducted a study concerning lean-green-agile-based SMEs. Gandhi et al. [36] investigated the applicability of the lean-green-6σ strategies in Indian manufacturing industries. Singh et al. [37] investigated manufacturing systems in the lean-green-agile environment. Jaiswal et al. [38] used available literature and consulted an expert group that identified 16 LM barriers for Indian SMEs. The authors analyzed the interdependencies among the barriers and prioritized them using an integrated grey-decision-making trial and evaluation laboratory (grey-DEMATEL) approach. Puram et al. [39] provided a conceptual framework for lean implementation. Abu et al. [40] prepared structural equation modeling and analyzed the lean implementation barriers in manufacturing industries using SmartPLS. Later, they also studied SMEs belonging to the furniture industry.

Lean implementation-based studies were adopted in various countries and in various sectors of SMEs, such as the manufacturing sector [40], wood and furniture [41], food processing [42], Indian machine tools [43], and the Finnish furniture and boating sectors [22]. Research into lean implementation in SMEs in the Indian context was not yet attempted for the manufacturing sector. The present research uses the combined approach of ISM, MICMAC, and IRP to develop much-needed relationship modeling and subsequent ranking to help practicing managers of SMEs. Several quantitative and qualitative LB identification studies exist in the current literature; however, the studies are limited in their scope. The studies are also restricted to a specific industry or consider a limited sample size. Therefore, there is a need to conduct a research study that provides systematic studies from LB identification through to its ranking.

3. Research Methodology

Mixed approaches-based methodologies are adopted in the research. The LBs to lean implementation were identified through a literature review and their applicability to SMEs in the manufacturing sector in the Indian context was further investigated. The shortlisting of LBs was undertaken based on statistical analysis and expert group consultations. The short-listed LBs were modeled for relationship modeling using ISM. The LBS were further classified using MICMAC and subsequently ranked using IRP. Thus, a combination of research approaches was used. The various research methodologies were used in four different steps, depicted in Figure 1. Further, each step is described in detail as follows:

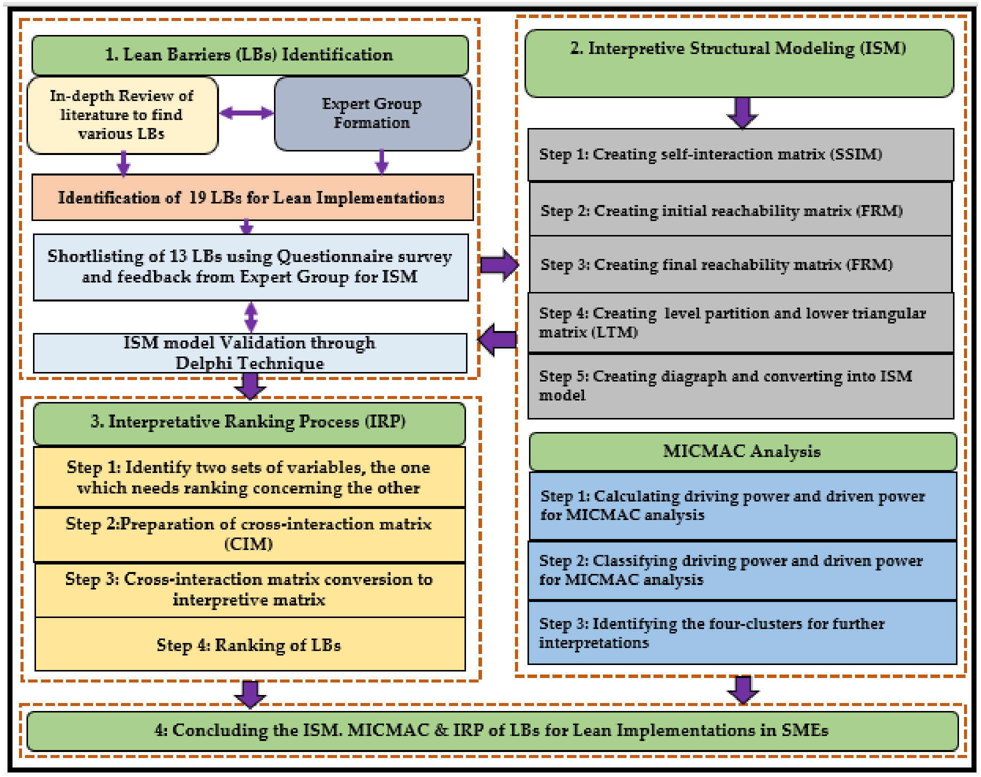

Figure 1. The research methodology.

Step 1: The identification of LBs was carried out through a literature review. Nineteen LBs were short-listed from the review of literature in consultation with an expert group. The expert group was selected based on their experience, qualifications, and willingness to join expert group panels. Five experts working in the manufacturing sector of SMEs showed their willingness to participate in the decision-making without any pre-conditions and binding. All five experts involved were graduates in production engineering with more than five years of working experience in a lean manufacturing setup. The nineteen lean implementation barriers, together with a brief description and references, were prepared and tabulated in Table 1.

Table 1. Brief description and LB references.

LBs Code	LBS	Description	References
B01	Lack of resources to invest	SMEs face insufficient resources while implementing lean.	[44–46]
B02	Current regulations and policies	SMEs find stringent rules and policies to be followed in their production activities.	[44–46]
B03	Lack of empowerment of employees	SMEs could provide employee empowerment, which restricts the effective and efficient decision-making	[22,24]
B04	Lack of machines and plant configuration	SMEs find resources shortage in machine availability and up-to-date plant.	[22,24]
B05	Lack of formal training for workers	SMEs find difficulty in recruiting skilled, well-trained manpower to handle manufacturing challenges.	[32,44,46]
B06	Lack of cooperation and mutual trust between management and employees	SMEs may have a conflict with employees to prevail on mutual trust and a sense of positive cooperation.	[24,44]
B07	Worker resistance	SMEs find worker resistance to establishing the new approach, methodology, etc.	[24,44]
B08	Top management resistance	SMEs suffer from resistance from the top management.	[24,25,33,39]
B09	Poor facilities and layout configuration	SMEs suffer from a shortage of resources, leading to facilities and plant layouts.	[22,24]
B10	Slow response to market	SMEs struggle to meet the pace of the market and find themselves slow in reacting to market changes.	[24,45]
B11	Lack of a strong quality policy	SMEs fear establishing a strong quality policy.	[22,24]
B12	Lack of awareness	SMEs have a wide knowledge gap and find it difficult to remain aware and updated.	[24,45]
B13	Existing organizational culture	SMEs suffer from the existing organizational culture not responding well to new changes.	[24,45]
B14	Risk of sustainable practice implementation	SMEs face the risk of sustainable practices if implemented.	[22,24]
B15	Lack of perseverance	SMEs face the barriers of a lack of perseverance.	[23]
B16	Lack of lean understanding	SMEs feel the barriers of a lack of lean understanding.	[24,45]
B17	Insufficient information system	SMEs have an information gap in their information system.	[45,46]
B18	Manufacturing Process	SMEs have limited access to the most up-to-date manufacturing processes.	[29,45]
B19	Lack of skilled Employees	SMEs have fewer skilled employees to meet the manufacturing demand with the required skills.	[29,33,45]

As per the university guidelines, the Internal Review Board was contacted for the necessary approval. Based on a brief discussion, participants agreed to participate in the study and were given the freedom to leave the study at any moment by signing a permission form. Furthermore, they were permitted to refuse to answer any questions. Participants consented to the confidential use of collected data, with no direct benefit from participation. Participants also consented to audio-recording of the interview, anonymity, and the retention of the original data by the authors. The researchers were further permitted to access collected data at any time, with full freedom to contact any participant.

A questionnaire was prepared using the 5-point Likert scale based on the varying degrees of importance, ranging from not important to extremely important on a scale of 1–5. The questionnaire was tested for its accuracy through pilot testing by administering it to an expert group. Based on their feedback, the questionnaire was approved. The questionnaire was distributed to engineers, senior engineers, and managers of manufacturing units. In total, 120 questionnaires were administered using Google Forms via email and WhatsApp to SME members. The SME members were selected from Gujarat Industrial Development Corporations and the Confederation of Indian Industries. A brief introduction to the research objectives was highlighted at the beginning of the questionnaire. A total of 92 valid responses were received, thus giving an acceptable response rate of 76.66%. The statistical software package SPSS 26.0 was used to analyze the data [47]. Based on the statistical analysis and discussion with the expert group, nineteen barriers were reduced to thirteen. The statistical analysis was carried out in line with the used methodology [10,35,37].

Step 2: ISM methodological steps commonly consist of the preparation of various matrixes: the Structural self-interaction matrix (SSIM), Initial Reachability Matrix (IRM), Final Reachability Matrix (FRM), Level Partition Matrix (LPM), and Lower Triangular Matrix (LTM). The detailed steps may further be found in paper [48]. The following steps comprise the ISM and MICMAC methodology: (a) generating an SSIM; (b) generating the initial and final reachability matrixes; (c) generating the level partition and lower triangular matrixes; (d) generating a digraph and converting it into an ISM model; (e) estimating the driving power and driven power for MICMAC analysis; (f) grouping the driving power and driven power for MICMAC analysis; and (g) assessing four clusters for further interpretation. Further, the structural self-interaction matrix (SSIM) can be formulated using various rules: The contractual relationship is taken into consideration when preparing the SSIM. Let LBs be p and q. To represent the relationship between two LBs, 'V', 'A', 'X', and 'O' may be used to represent their contextual relationship. 'V' may be used if lean barrier p drives or influences barrier q; 'A' may be used if lean barrier p is obtained through barrier q; 'X' may be used if lean barrier p and q help each other; and 'O' may be used if lean barrier p and y do not possess any relation. A contextual link among LBs generates SSIM when the ISM methodological procedures are followed. The expert group identified lean hurdles with a contextual relationship with the SSIM. By transforming SSIM with a binary matrix of 1 and 0, the initial reachability matrix (IRM) is obtained. The following rules can be used to substitute 'V', 'A', 'X', and 'O' with other symbols.

- If the SSIM (p, q) entry is 'V', the reachability matrix (p q) entry becomes 1 and the (q, p) entry becomes 0.
- If the SSIM (p, q) entry is 'A', the reachability matrix (p, q) entry becomes 0 and the (q, p) entry becomes 1.
- If the SSIM (p, q) entry is 'X', the reachability matrix (p, q) entry becomes 1, and the (q, p) entry similarly becomes 1.
- If the SSIM (p, q) entry is 'O', the reachability matrix (p, q) entry becomes 0, and the (q, p) entry similarly becomes 0.

Using SSIM, a reachability matrix can be derived, considering the transitivity among each lean barrier. Thus, the SSIM matrix is transformed into a reachability matrix by replacing the contextual relationship with binary numbers '0' and '1'. Transitivity among LBs may be explained as the influence of one barrier (p) on another barrier (q), and the influence of a lean barrier (q) on another lean barrier (r) may be explored using the rule if $p > q$ and $q > r$ then $p > r$ wherein '>' provides influence or preference.

The FRM can be used to calculate the reachability and antecedent elements for each lean barrier. It consists of the lean barrier itself, as well as a supplementary lean barrier. The antecedent elements have their elements, as well as another lean barrier that influences them. The various lean barriers of the iterative process are obtained using intersections. When an intersection meets such criteria, then the highest level is assigned to the lean barrier, and the lean barrier is removed from the further process. This method results in a classification that ranges from the highest to the lowest level.

The structural model can be built using the final reachability matrix. Following that, a digraph can be created by removing transitivity, as previously discussed. The LTM can be employed to obtain the digraph that will represent the relationship model. The resulting digraph yields a directed graph that aids in understanding the function of each lean barrier. The digraph is used to create an ISM model of the lean barrier.

Each lean barrier is graphically represented in the MICMAC analysis. It provides a good opportunity to research and assess the relative impact of each lean implementation hurdle. The MICMAC analysis aids in the classification of lean implementation barriers into four categories. The driving and dependency force of the lean implementation barriers also has an impact on the categories. As a result, numerous categories, such as autonomous, dependent, linkage, and independent are formed. Clusters I to IV are the four groupings obtained by the MICMAC analysis.

Step 3: IRP (evolved by Sushil [49]) was used to rank the barriers to lean implementation in SMEs. IRP employs an interpretative matrix with a paired comparison matrix. IRP can counteract the effects of the analytic hierarchy process, where expert judgmental bias may exist, or it is often difficult to make a clear decision in the case of a complex hierarchy. Furthermore, the IRP procedure necessitates the use of interpretive logic for each comparison's requisite preponderance of elements. To carry out such a comparison, further information about dominance is not necessarily required. IRP also provides a system for ranking LBS depending on their results. The steps of the IRP are briefly discussed [48–50]: (a) Two sets of variables, one of which requires ranking in relation to the other, are determined. The barriers to lean implementation for SMEs in the manufacturing industry are ranked here; (b) A cross-interaction matrix (CIM) between lean implementation hurdles and lean performance indicators is created; (c) Cross-interaction matrices are converted to interpretive matrices; (d) To obtain the dominating interactions matrix, pairwise comparisons are formed based on the interpretation matrix; (e) dominance and its rating after the ranking of LBs are examined.

Step 4: This step deals with the interpretations of LB rankings derived from ISM and IRP. The conclusion, derived from the ISM, MICMAC, and IRP ranking, will be the significant research outcome.

4. Results

The results of each step are derived and documented below.

4.1. Step 1

The mean and standard deviation (SD) of LBs for lean implementation were calculated. To maintain the reliability of the questionnaire and simultaneously measure the internal consistency, Cronbach's alpha values were calculated for feedback. The Cronbach's alpha was found to be within the acceptable limit. Cronbach's alpha > 0.7, providing acceptable internal consistency (Flynn et al., 1994). The corrected item-total correlation was tested using SPSS 26.0. The thirteen LBs had a mean value ranging between 3.3 and 4.4, and a standard deviation (σ) ranging between 0.42 and 0.97. The Cronbach's alpha (α) observed was 0.83. The six LBs, namely "current regulations and policy", "lack of machines and plant configuration", "poor facilities and layout configuration", "existing organizational culture", "manufacturing process", and "lack of skilled employees" were dropped based on their mean values, statistical results, and consultation with an expert group. The mean value of the dropped LBs ranged between 3.0 and 3.2. The shortlisted barriers were then assigned codes from LB1 to LB13, which are presented in Table 2. The expert group evaluated the six LBs and dropped them from further analysis, based on their applicability in the present study. Further, the bivariate Pearson correlation was conducted to investigate whether a statistically significant linear relationship exists between two LBs. Management will find it easier to develop a strategy for their control if LBs are further categorized into distinct groups based on the correlation coefficient. Table 3 provides the Pearson's bi-variate two-tailed correlation among the 13 LBs. There is a positive correlation between the LBs, which shows that more research is required to discover how the LBs relate to each other in the real world.

Table 2. LBs identified for the present studies.

LBs Code	LBs	Mean	Standard Deviation (σ)
LB01	Lack of resources to invest	4.8	0.42
LB02	Slow response to market	4.7	0.48
LB03	Lack of awareness	4.6	0.52
LB04	Lack of formal training for workers	4.2	0.63
LB05	Top management resistance	4.1	0.57
LB06	Lack of empowerment of employees	4.0	0.47
LB07	Lack of perseverance	4.0	0.80
LB08	Worker resistance	3.9	0.74
LB09	Lack of strong quality policy	3.9	0.74
LB10	Lack of cooperation and mutual trust between management and employees	3.8	0.92
LB11	Lack of lean understanding	3.7	0.95
LB12	Insufficient information system	3.6	0.97
LB13	Risk of sustainable practice implementation	3.3	0.67

Table 3. Pearson's bi-variate two-tailed correlation.

LBs Code	LB01	LB02	LB03	LB04	LB05	LB06	LB07	LB08	LB09	LB10	LB11	LB12	LB13
LB01	1	0.636 ** 0.000	0.716 ** 0.000	0.627 ** 0.000	0.385 ** 0.000	0.394 ** 0.000	0.359 ** 0.001	0.383 ** 0.000	0.399 ** 0.000	0.420 ** 0.000	0.352 ** 0.001	0.367 ** 0.001	0.275 * 0.011
LB02	0.636 ** 0.000	1	0.693 ** 0.000	0.626 ** 0.000	0.514 ** 0.000	0.519 ** 0.000	0.433 ** 0.000	0.530 ** 0.000	0.454 ** 0.000	0.515 ** 0.000	0.283 ** 0.009	0.409 ** 0.000	0.319 ** 0.003
LB03	0.716 ** 0.000	0.693 ** 0.000	1	0.681 ** 0.000	0.411 ** 0.000	0.385 ** 0.000	0.403 ** 0.000	0.415 ** 0.000	0.460 ** 0.000	0.454 ** 0.000	0.321 ** 0.003	0.376 ** 0.000	0.334 ** 0.002
LB04	0.627 ** 0.000	0.626 ** 0.000	0.681 ** 0.000	1	0.446 ** 0.000	0.446 ** 0.000	0.365 ** 0.001	0.464 ** 0.000	0.445 ** 0.000	0.472 ** 0.000	0.295 ** 0.006	0.333 ** 0.002	0.401 ** 0.000
LB05	0.385 ** 0.000	0.514 ** 0.000	0.411 ** 0.000	0.446 ** 0.000	1	0.600 ** 0.000	0.645 ** 0.000	0.694 ** 0.000	0.650 ** 0.000	0.679 ** 0.000	0.421 ** 0.000	0.355 ** 0.001	0.423 ** 0.000
LB06	0.394 ** 0.000	0.519 ** 0.000	0.385 ** 0.000	0.446 ** 0.000	0.600 ** 0.000	1	0.634 ** 0.000	0.668 ** 0.000	0.668 ** 0.000	0.625 ** 0.000	0.445 ** 0.000	0.403 ** 0.000	0.419 ** 0.000
LB07	0.359 ** 0.001	0.433 ** 0.000	0.403 ** 0.000	0.365 ** 0.001	0.645 ** 0.000	0.634 ** 0.000	1	0.726 ** 0.000	0.746 ** 0.000	0.618 ** 0.000	0.386 ** 0.000	0.349 ** 0.001	0.364 ** 0.001
LB08	0.383 ** 0.000	0.530 ** 0.000	0.415 ** 0.000	0.464 ** 0.000	0.694 ** 0.000	0.668 ** 0.000	0.726 ** 0.000	1	0.714 ** 0.000	0.689 ** 0.000	0.444 ** 0.000	0.418 ** 0.000	0.433 ** 0.000
LB09	0.399 ** 0.000	0.454 ** 0.000	0.460 ** 0.000	0.445 ** 0.000	0.650 ** 0.000	0.668 ** 0.000	0.746 ** 0.000	0.714 ** 0.000	1	0.716 ** 0.000	0.379 ** 0.000	0.381 ** 0.000	0.393 ** 0.000
LB10	0.420 ** 0.000	0.515 ** 0.000	0.454 ** 0.000	0.472 ** 0.000	0.679 ** 0.000	0.625 ** 0.000	0.618 ** 0.000	0.689 ** 0.000	0.716 ** 0.000	1	0.473 ** 0.000	0.389 ** 0.000	0.349 ** 0.001
LB11	0.352 ** 0.001	0.283 ** 0.009	0.321 ** 0.003	0.295 ** 0.006	0.421 ** 0.000	0.445 ** 0.000	0.386 ** 0.000	0.444 ** 0.000	0.379 ** 0.000	0.473 ** 0.000	1	0.625 ** 0.000	0.661 ** 0.000
LB12	0.367 ** 0.001	0.409 ** 0.000	0.376 ** 0.000	0.333 ** 0.002	0.355 ** 0.001	0.403 ** 0.000	0.349 ** 0.001	0.418 ** 0.000	0.381 ** 0.000	0.389 ** 0.000	0.625 ** 0.000	1	0.639 ** 0.000
LB13	0.275 * 0.011	0.319 ** 0.003	0.334 ** 0.002	0.401 ** 0.000	0.423 ** 0.000	0.419 ** 0.000	0.364 ** 0.001	0.433 ** 0.000	0.393 ** 0.000	0.349 ** 0.001	0.661 ** 0.000	0.639 ** 0.000	1

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

4.2. Step 2: Interpretive Structure Modeling (ISM) and MICMAC Results

The identified LBs may have different degrees of contextual relationships. Such relationships may be identified by employing ISM, and thus a relationship model may be derived. The ISM model development considers the feedback from the expert group. Following the ISM methodological steps, a contextual relationship among LBs yields SSIM. The contextual relationship is prepared, based on the influence of each barrier on another using feedback from experts. For LB01, "lack of resources to invest", when compared with lean barrier LB05, "top management resistance", it was found that LB01 influences LB05; hence, 'V' is placed in a contextual relationship. Thus, the "lack of resources to invest" influences the "top management resistance", while implementing lean. Similarly, other contextual relationships may be derived when comparing lean implementation barriers LB01–LB13 to each other, and a subsequent matrix can be completed. Table 4 shows the structural self-interaction matrix (SSIM).

Table 4. Structural self-interaction matrix (SSIM).

LBs Code	LBs	13	12	11	10	9	8	7	6	5	4	3	2
LB01	Lack of resources to invest	V	V	V	V	V	V	A	V	V	V	V	V
LB02	Slow response to market	V	A	A	A	O	A	A	O	A	A	A	
LB03	Lack of awareness	V	V	V	V	V	V	O	V	A	X		
LB04	Lack of formal training for workers	V	X	V	V	V	V	V	O	A			
LB05	Top management resistance	V	V	V	V	V	V	V	V				
LB06	Lack of empowerment of Employees	V	O	V	A	V	A	O					
LB07	Lack of perseverance	V	A	V	A	O	A						
LB08	Worker resistance	V	A	V	V	V							
LB09	Lack of strong quality policy	V	O	A	A								
LB10	Lack of cooperation and mutual trust between management and employees	V	A	V									
LB11	Lack of lean understanding	V	A										
LB12	Insufficient information system	V											
LB13	Risk of sustainable practice implementation												

The formation of the initial reachability matrix (IRM) and final reachability matrix (FRM) was carried out using binary digits '1' and '0'. Various symbols ('V', 'A', 'X', and 'O') used to represent contextual relationships may be replaced with 1 and 0, as per the rules discussed earlier. IRM may be transformed to FRM by considering the transitivity among the LBs as explained in Step 2. The difference between IRM and FRM is the additional transitivity (represented by an asterisk in Table 5). To avoid duplication of the matrix, IRM is not shown. Table 5 shows the FRM.

Table 5. Final reachability matrix (FRM).

LBs Code	LBs	1	2	3	4	5	6	7	8	9	10	11	12	13	DP#
LB01	Lack of resources to invest	1	1	1	1	1	1	1	1	1	1	1	1	1	13
LB02	Slow response to market	0	1	0	0	0	0	0	0	0	0	0	0	1	2
LB03	Lack of awareness	0	1	1	1	0	1	1 *	1	1	1	1	1	1	11
LB04	Lack of formal training for workers	0	1	1	1	0	1 *	1	1	1	1	1	1	1	11
LB05	Top management resistance	0	1	1	1	1	1	1	1	1	1	1	1	1	12
LB06	Lack of empowerment of employees	0	1 *	0	0	0	1	0	0	1	0	1	0	1	5
LB07	Lack of perseverance	0	1	0	0	0	0	1	0	1 *	0	1	0	1	5
LB08	Worker resistance	0	1	0	0	0	1	1	1	1	1	1	0	1	8
LB09	Lack of strong quality policy	0	0	0	0	0	0	0	0	1	0	0	0	1	2
LB10	Lack of cooperation and mutual trust between management and employees	0	1	0	0	0	1	1	0	1	1	1	0	1	7
LB11	Lack of lean understanding	0	1	0	0	0	0	0	0	1	0	1	0	1	7
LB12	Insufficient information system	0	1	1 *	1	0	1 *	1	1	1 *	1	1	1	1	11
LB13	Risk of sustainable practice implementation	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Dependence	1	11	5	5	2	8	8	6	11	7	10	5	13	

DP#: Driving Power, *: Barriers having transitivity.

The matrix for FRM shows the driving power (row-wise total) and dependence (column-wise total) of each lean barrier. The driving power of each lean barrier is obtained by summing up all values in the row, including itself. The dependence of each lean barrier is obtained by summing up the column value. The values of driving power and dependence are further used in the MICMAC analysis.

4.2.1. Level Partitions

The reachability and antecedent sets can be derived from FRM. This uses the lean barrier itself and another lean barrier, which it influences, to achieve its goal. The antecedent set will have itself and other LBs that drive its achievement. The intersection of reachability and the antecedent is derived. The common entry in reachability and the intersection leads to taking top priority and removing further iterations. The various iterations lead to accomplishing the lowest level. In the first iteration, LB13 "risk in sustainable practice implementations" is found at level I, thereby taking the top spot in the ISM hierarchy. Similarly, repeating the same process can provide various levels of iteration results. Iterations ii–ix are shown in Table 6.

Table 6. Final iterations of lean implementation barriers level.

Iteration	LBs	Reachability Set	Antecedent Set	Intersection Set	Level
ii	2	2	1, 2, 3, 4, 5,6, 7, 8, 10, 11, 12	2	II
ii	9	9	1, 3, 4, 6, 8, 9, 10, 11, 12	9	II
iii	11	11	1, 3, 4, 5, 6, 7, 8, 10, 11, 12	11	III
iv	6	6	1, 3, 4, 5,6, 8, 10, 12	6	IV
iv	7	7	1, 3, 4, 5, 8, 10, 12	7	IV
v	10	10	1, 3, 4, 5, 8, 10, 12	10	V
vi	8	8	1, 3, 4, 5, 8, 12	8	VI
vii	3, 4, 12	3, 4, 12	1, 3, 4, 5, 12	3, 4, 12	VII
viii	5	5	1, 5	5	VIII
ix	1	1	1	1	IX

4.2.2. Interpretive Structure Modeling (ISM)

The structure model can be derived using the final reachability matrix (FRM). Subsequently, a digraph can be prepared by eliminating transitivity as discussed earlier. The LTM may be used to obtain a digraph that represents the relationship modeling. The digraph thus obtained provides a directed graph that helps in understanding the role of each lean barrier. The ISM model of LBs was prepared from the digraph presented in Figure 2. The figure shows that LB01, "lack of resources", affects LB05, "resistance from top management", which in turn affects LB08, "resistance from workers", through other LBs (LB12, "insufficient information systems", LB04, "lack of formal training for workers," and LB03, "lack of awareness"). The digraph shown in Figure 2 can also be made with other contextual relationships.

4.2.3. Matrice D'impacts Croisés Multiplication Appliquée á un Classment (MICMAC) Analysis

MICMAC analysis provides a graphical representation of each lean barrier. It offers a good opportunity to study and investigate the relative importance of each lean implementation barrier to establish its role in lean implementation. MICMAC provides a four-way classification dependent on driving power and dependence. Thus, the categories generated are autonomous, dependent, linkage, and independent or driver. The four categories generated by MICMAC analysis may also be termed Clusters I to IV, respectively. Each cluster represents driving power and dependence. Clusters I to IV represent the various degrees of driving power and dependence. Since both driving power and dependence are represented by the number 1, their summation will show driving power horizontally and dependence power vertically.

The MICMAC plot is drawn based on the driving power and dependence of each lean barrier. Figure 3 shows the results of MICMAC analysis based on how much each lean barrier drives and how much it depends on other barriers.

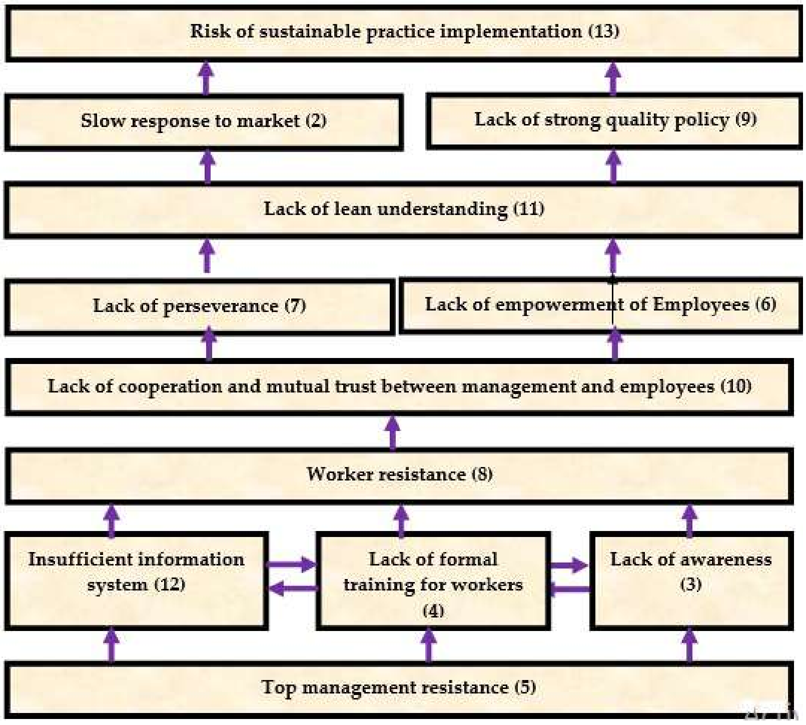

Figure 2. ISM for LBs.

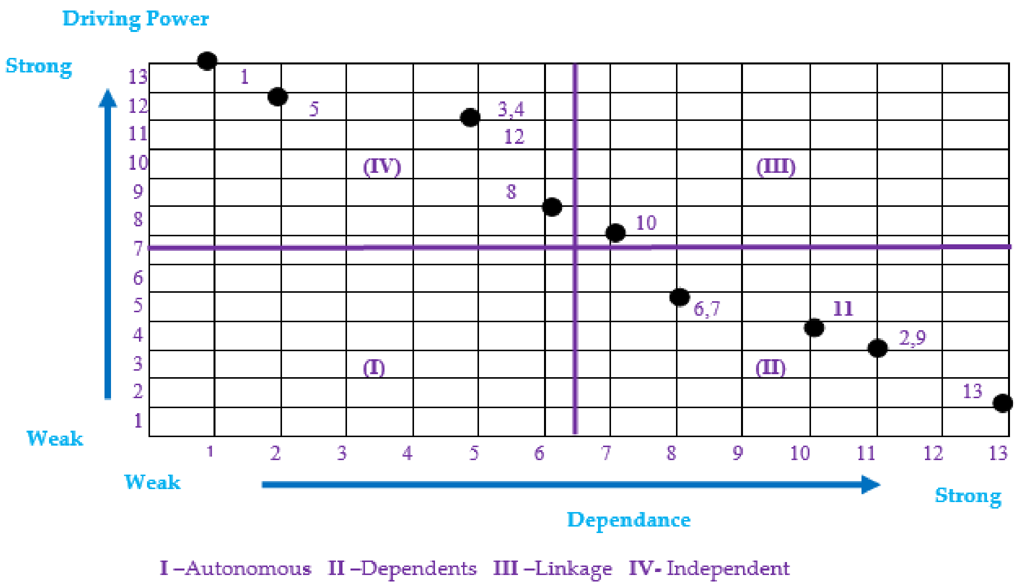

Figure 3. Classification of LBs using MICMAC analysis.

4.2.4. Model Validation

The contextual relationship between lean implementation barriers is the basis for the ISM model development. The formulated model was reviewed and validated using the Delphi technique, as shown in Figure 4. There were three Delphi members, who were not part of the expert group; they were from the piston manufacturing unit, the connecting-rod manufacturing unit, and the cylinder-casting machining unit. They were approached to take part in the Delphi process, anonymously, and consented to do so.

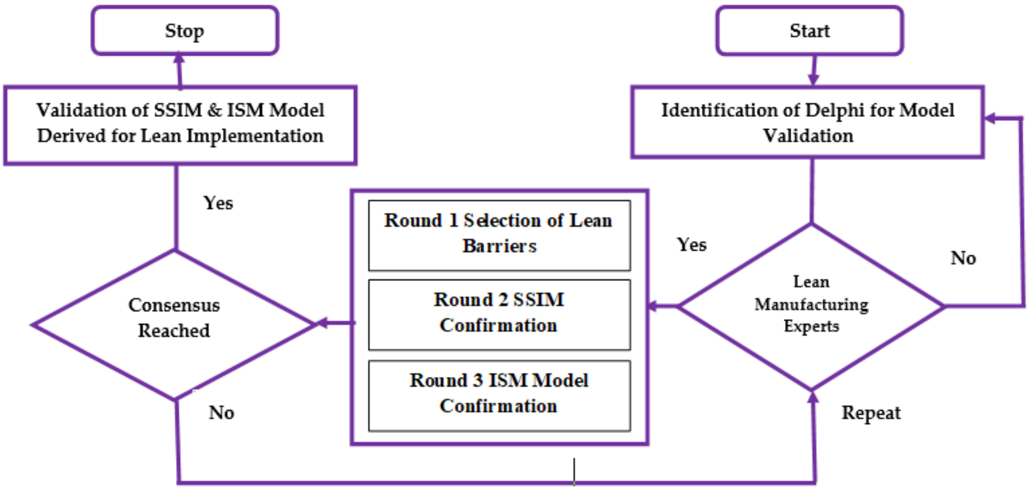

Figure 4. Validation of ISM model through Delphi technique.

The identity of the Delphi group was kept anonymous to avoid any biased decisions. The Delphi members were introduced to the lean implementation barrier identification and ISM methodologies separately. Detailed information on the ISM model with lean implementation barriers was sent to their respective units. Three rounds of Delphi covered validation of the short-listed LBs and ISM results. In round 1, the LB information sheets with the short-listed LBs were sent; a contextual relationship matrix to validate was also sent. In round 2, all team members were sent the contextual relationship matrix for verification. The feedback of the Delphi team was compared to that of the expert group. In round 3, all Delphi members were sent the final ISM model. All the Delphi members agreed to the ISM model, and a consensus was reached.

4.3. Step 3: Interpretive Ranking Process (IRP) Model

To accomplish the IRP of lean implementations, four relevant performance criteria were identified. The four identified criteria were "manufacturing cost" (P1), "service quality" (P2), "volume flexibility" (P3), and "safety" (P4) [10,50]. Reduced manufacturing costs give SMEs a competitive advantage in the face of local and global competition. Improved quality (service/product) is the backbone of the increased market share. Volume flexibility provides demand fulfillment. Safety is one of the most important performance factors to prevent accidents and keep the workplace free of risks.

4.3.1. Cross-Interaction Matrix (CIM)

The CIM produces the relationship between the LBs and lean-based performance criteria. Thus, the interaction matrix is realized using the feedback of the expert team. An expert team critically compares the LBs and their relationships against lean performance criteria. A binary value of '1' or '0' may be used if the relationship between LBs and lean performance criteria exists or otherwise. The cross-interaction matrix so prepared is shown in Table 7.

4.3.2. Interpretive Matrix (IM)

The lean implementation LBs and lean performance criteria are compared using the contextual relationship from the cross-interpretive matrix. Each lean barrier is compared to another lean barrier concerning its dominance on performance criteria, i.e., P1 to P4. Based on such a comparison, the LBs and performance criteria relationship is developed. Such a relationship provides the basis for the further accomplishment of a ranking. Table 8 shows how the lean implementation barriers interact with the lean performance criteria.

Table 7. Cross-interaction matrix (CIM) of LBs and lean performance criteria.

LBs Code	P1	P2	P3	P4
	Manufacturing Cost	**Service Quality**	**Volume Flexibility**	**Safety**
LB 1	1	1	1	0
LB 2	1	1	0	0
LB 3	0	1	1	1
LB 4	1	1	0	1
LB 5	1	0	1	0
LB 6	0	1	1	0
LB 7	1	1	1	0
LB 8	0	1	1	0
LB 9	1	1	0	1
LB 10	0	0	1	1
LB 11	1	1	1	0
LB 12	1	0	0	0
LB 13	1	0	0	1

Table 8. Interpretive matrix.

LBs Code	P1	P2	P3	P4
	Manufacturing Cost	**Service Quality**	**Volume Flexibility**	**Safety**
LB01	Shortages of resources may delay and increase hold-up for the product, people, and machinery during the production process.	Shortages of various resources, e.g., money, skilled workers, and machines affect the quality of the service directly.	Resource shortages may hinder adapting to the changing demands of the customers, which reduces flexibility.	
LB02	Slow response increases manufacturing costs.	A slow response to the market may affect the service quality. Not changing the product according to customer needs, schemes, discounts, or adjusting prices according to the market contributes to it.		
LB03		Being unaware of the current market trends and customer needs leads to a reduction in customer service.	Unawareness of the new technologies, trends, customer demands reduce the flexibility	Unawareness of workplace hazards and unsafe equipment may cause accidents, which is dangerous for the employees.
LB04	The lack of training and ignorant workers leads to poor job performance and hinders progress.	Untrained workers may lead to poor quality of work and service.		Workplace accidents and machine hazards may affect employee health and safety.
LB05	Poor strategies, improper guidelines, and policies escalate the cost.		Not adjusting to uncertain demands reduces flexibility.	

Table 8. *Cont.*

LBs Code	P1	P2	P3	P4
	Manufacturing Cost	**Service Quality**	**Volume Flexibility**	**Safety**
LB06		Lack of empowerment leads to unhappy, demotivated employees, with no sense of responsibility.	Employees are unable to make decisions during critical times because they lack authority.	
LB07	Employees may not take care in their jobs and tasks, making mistakes; wasting time and materials may increase the manufacturing costs.	Due to a lack of perseverance, the employees may not perform their tasks, not pay heed to errors, or have poor-quality finished jobs.	Flexibility is reduced by a lack of willingness to work for the demands.	
LB08		Not caring about the quality of the products, and not being bothered about problems arising in the workplace.	If workers are not committed to their jobs, it reduces the flexibility.	
LB09	The lack of a strong quality policy may increase the number of reworks and decrease the productivity	The lack of strong policies may lead to low-quality products, decreasing productivity and service quality.		This may lead to poor safety conditions, which can cause dangerous accidents to employees.
LB10			Lack of trust between higher-ups and employees, lack of commitment; bad leadership and relationships between employer and employee can all make it harder to change.	Poor leadership may fail to maintain safety standards.
LB11	Lack of lean knowledge may increase the cost, time, and unnecessary task reworks, thus increasing the manufacturing costs.	This affects the quality of the work and increases the non-value-added activities, which cost the customer and the company.	Lack of lean understanding reduces flexibility.	
LB12	This disrupts the flow of the information system and creates communication gaps between the employer and employee.			
LB13	This increases waste diversity and increases the overutilization of resources.			This leads to poor labor conditions.

The lean knowledge base matrix helps in developing dominating and non-dominating lean implementation barriers concerning lean performance criteria, i.e., from P1 to P4. Such a comparison develops the dominance interaction matrix. Table 9 provides the lean implementation barriers dominating the other LBs to provide an interpretive logic lean knowledge base (ILLKB). Each lean barrier is compared to another lean barrier, keeping the performance variable in considering whether it is dominating or not. Further, the Dominance interaction matrix (DIM), as shown in Table 10, may be prepared based on the dominance finalized. Thus, it provides the dominating interaction matrix for understanding the influence of LBs. Table 11 shows the dominance matrix to produce the final ranking of lean implementation barriers. The dominance and dependence of each lean barrier are considered to prepare the final ranking table. Figure 5 shows the dominance of various LBs over each other in pictorial form. Each lean barrier possesses both the dominating and being-dominated characteristics, which are further represented quantitatively for each LB.

Table 9. Interpretive logic lean knowledge base (ILLKB).

Paired Comparison of LBS in Terms of Dominance	Performance Variable (s) for Which the Dominance Holds Good	Paired Comparison of LBs in Terms of Dominance	Performance Variable (s) for Which the Dominance Holds Good
1 Dominating 2	P1,P2,P3	7 Dominating 6	P2,P3
1 Dominating 5	P1,P3	7 Dominating 9	P1,P2
1 Dominating 6	P2,P3	7 Dominating 10	P3
1 Dominating 8	P2,P3	7 Dominating 11	P1,P2,P3
1 Dominating 10	P3,P4	7 Dominating 13	P1
1 Dominating 12	P1,P2,P3	8 Dominating 3	P2,P3
1 Dominating 13	P1,P4	8 Dominating 5	P3
2 Dominating 5	P1,P2	8 Dominating 6	P2,P3
2 Dominating 6	P2	8 Dominating 7	P2,P3
2 Dominating 8	P2	8 Dominating 9	P2
2 Dominating 12	P1	8 Dominating 13	P2,P3
2 Dominating 13	P1	9 Dominating 1	P1,P2
3 Dominating 1	P2,P3,P4	9 Dominating 2	P1,P2
3 Dominating 2	P2	9 Dominating 5	P1
3 Dominating 5	P3	9 Dominating 13	P1,P4
3 Dominating 9	P1,P2	10 Dominating 2	P2
3 Dominating 12	P2,P3,P4	10 Dominating 3	P3,P4
3 Dominating 13	P4	10 Dominating 6	P3
4 Dominating 1	P1,P2	10 Dominating 8	P3
4 Dominating 2	P1,P2	10 Dominating 12	P3,P4
4 Dominating 3	P2,P3	10 Dominating 13	P4
4 Dominating 5	P1	11 Dominating 1	P1,P2,P3
4 Dominating 6	P2	11 Dominating 2	P1,P2
4 Dominating 8	P2	11 Dominating 3	P2,P3
4 Dominating 9	P1,P2,P4	11 Dominating 4	P1,P2
4 Dominating 10	P4	11 Dominating 8	P2,P3
5 Dominating 6	P3	11 Dominating 9	P1,P2
5 Dominating 10	P3	11 Dominating 10	P3
5 Dominating 11	P1,P3	12 Dominating 4	P1
5 Dominating 12	P1	12 Dominating 6	P1
5 Dominating 13	P1	12 Dominating 7	P1,P2
6 Dominating 3	P2,P3	12 Dominating 8	P1,P2,P3
6 Dominating 9	P2	12 Dominating 9	P1
6 Dominating 11	P2,P3	12 Dominating 11	P1
7 Dominating 1	P1,P2,P3	12 Dominating 13	P1,P4
7 Dominating 2	P1,P2	13 Dominating 4	P1,P4
7 Dominating 3	P2,P3	13 Dominating 6	P1,P2,P3,P4
7 Dominating 4	P2	13 Dominating 11	P1,P2,P3,P4
7 Dominating 5	P1,P3		

Table 10. Dominance interaction matrix (DIM).

LBs	LB01	LB02	LB03	LB04	LB05	LB06	LB 07	LB08	LB09	LB10	LB11	LB12	LB13
LB01	-	P3	P1	P3	P2	P1	P1,P2,P3	P1	P3	P1,P2	P1,P2,P3	P2,P3	P2
LB02	P2,P1	-	P1,P3,P4	P4	P2,P3	P2,P3	P3	P1,P3	P4	P1,P2	P1,P2	P2	P1
LB03	P2,P3,P4	P2	-	P1,P3	P1,P2,P4	P4	P4	P4	P3	P2	P4	P2,P3,P4	P2,P3
LB04	P1,P2,P4	P1,P2	P2,P4	-	P2,P4	P1,P4	P4	P1,P4	P1,P2,P4	P1,P2	P4	P2,P4	P2
LB05	P1,P3	P1	P3	P1,P3	-	P1	P2,P3	P1	P3	P1	P1	P3,P4	P3
LB06	P2	P2	P2,P3	P2,P3	P2,P3	-	P2,P3	P2,P3	P3	P2	P2,P3	P2,P3	P2,P3
LB07	P1,P2,P3	P1,P2	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	-	P1	P3	P1,P2	P1,P2,P3	P2,P3	P3
LB08	P2,P3	P2	P2,P3	P2,P3	P2,P3	P2,P3	P2,P3	-	P3	P2	P1	P2,P3	P2,P3
LB09	P1,P2,P4	P1,P2	P1,P2,P4	P1,P2,P4	P1,P2,P4	P1,P2,P4	P1,P2,P4	P1,P2,P4	-	P1	P4	P2,P4	P2
LB10	P3,P4	P3,P4	P3,P4	P3,P4	P3,P4	P3,P4	P3,P4	P3,P4	P3,P4	-	P4	P3,P4	P3
LB11	P1,P2,P3	P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	P1,P2,P3	-	P2,P3	P1
LB12	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	P1	-	P1
LB13	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	P1,P4	-

Table 11. Dominance matrix (DM).

LBs	LB1	LB2	LB3	LB4	LB5	LB6	LB7	LB8	LB9	LB10	LB11	LB12	LB13	Number of Cases Dominating (D)	Net Dominance (D-B)	Rank
LB1		1	1	1	1	1	3	1	1	2	3	2	1	18	−9	11
LB2	2		3	1	2	2	1	2	1	2	2	1	1	20	3	5
LB3	3	1		2	3	1	1	1	1	1	1	3	2	20	−5	10
LB4	3	2	2		2	2	1	2	3	2	1	2	1	23	−1	7
LB5	2	1	1	2		1	1	1	1	1	1	1	1	14	−12	13
LB6	1	1	2	2	2		2	2	1	1	2	2	2	20	−3	9
LB7	3	2	3	3	3	3		1	1	2	3	2	1	27	5	4
LB8	2	1	2	2	2	2	2		1	1	1	2	2	20	−1	7
LB9	3	2	3	3	3	3	3	3		1	1	2	1	28	10	2
LB10	2	2	2	2	2	2	2	2	2		1	2	1	22	3	5
LB11	3	1	3	3	3	3	3	3	3	3		2	1	31	12	1
LB12	1	1	1	1	1	1	1	1	1	1	1		1	12	−11	12
LB13	2	2	2	2	2	2	2	2	2	2	2	2		24	9	3
Number of cases being dominated (B)	27	17	25	24	26	23	22	21	18	19	19	23	15			

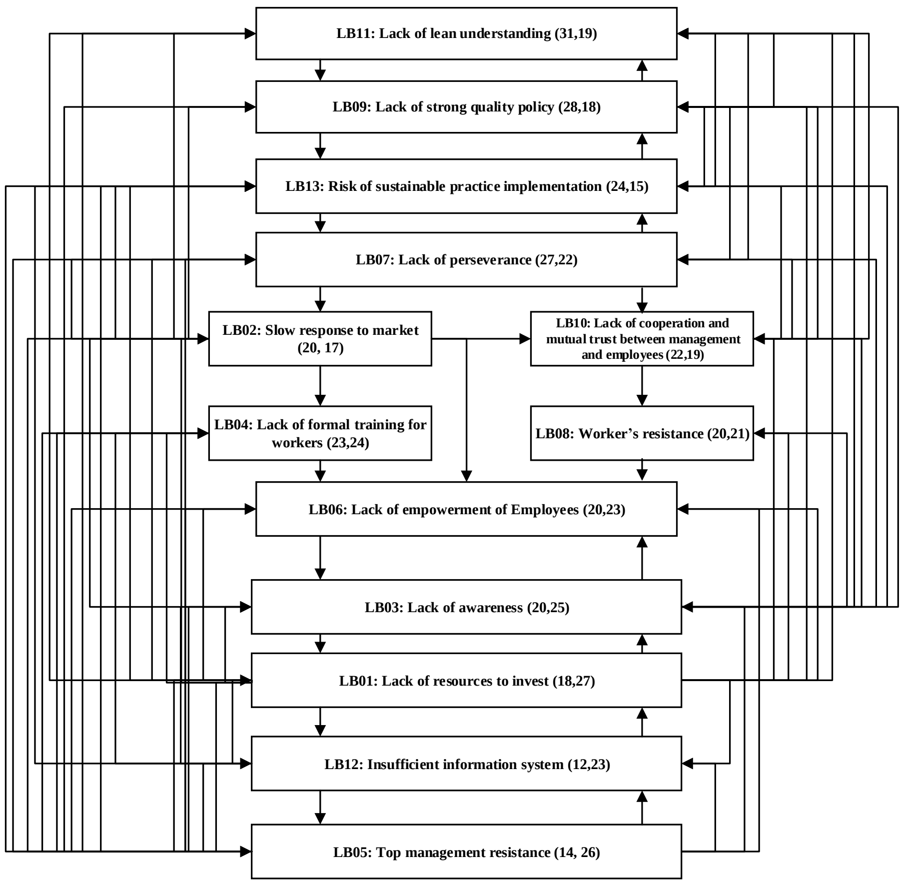

Figure 5. Ranking of LBs using IRP.

5. Discussion

SMEs in various sectors, especially the manufacturing sector, find it difficult to survive in the local and global market because of the tough competition in quality and production costs. The highest level of quality was reached through fast automation and a revolution in machine technology. However, the production system creates a large amount of waste, which raises the cost of production and makes the product expensive. Thus, the manufacturing cost or production cost governs the product price and the market share. By incorporating lean implementation, production costs can be reduced while, simultaneously, adding more value to the product. Lean implementation is hindered by the LBs. To implement the lean successfully, SMEs must implement strategies to control the LBs so that the hindrance of such LBs may be overcome.

The present research helps to evaluate and critically analyze the lean implementation barriers. The ISM digraph helps to understand the level of each barrier that is hindering lean implementations [36,50]. The ISM digraph of lean implementation barriers shows that LB01 "lack of resources to invest"–TLB05 "top management resistance" drives the LB12 "insufficient information system"–LB04 "lack of formal training for workers", and LB03 "lack of awareness" to increase LB08 "workers' resistance". Such an interaction of lean implementation barriers makes it difficult to realize successful lean implementation. It also makes it difficult to implement sustainable lean practices in the organization. The importance of lean implementation barriers [44] in the manufacturing sector of SMEs is also in line with the other lean implementation studies for sustainability in manufacturing [51,52]. Belhadi et al. [34] provide several solutions to overcome the LBs, which include: commitment and participation of management, adoption of simple measurement and key performance indicators, development of an organizational learning culture, and early deployment of lean culture through training and allocation of sufficient time and resources for change.

The MICMAC classifies the LBs into four categories, i.e., dependent barriers, independent barriers, linkage barriers, and autonomous barriers. The classification of LBs helps the organization devise a strategy to control the lean implementation barriers. The independent lean implementation barriers may help in controlling the dependent lean implementation barriers. The manufacturing sector of SMEs should seek to understand the interaction between lean implementation barriers and the hindrance of such barriers, which may be eliminated or minimized.

The rank of lean implementation barriers obtained using IRP also helps in understanding the degree of influence of each lean implementation barrier. Accordingly, the ranking of lean implementation barriers helps to identify suitable strategies. The first three important rankings of lean implementation barriers include LB11 "lack of lean understanding", LB09 "lack of strong quality policy", and LB13 "risk of sustainable practice implementation". The manufacturing sector should adopt a suitable management policy to implement lean in the organization. Lean implementation barriers obstruct the successful implementation of lean to varying degrees of influence. Further, the lean implementation barriers vary from sector to sector in SMEs. Lean implementation barriers are also influenced by various government policies depending upon the country, region, and location of SMEs. Hence, the results obtained may not be generalized. However, ISM, MICMAC, and IRP-based modeling can be altered to suit a sector's needs.

6. Research Limitations and Future Research Directions

Lean barriers provide hurdles to successful lean implementations and, hence, must be studied carefully. The barriers to lean implementation differ from sector to sector and region to region; therefore, a large number of LBs should be included in ISM and IRP modeling so that each barrier can be evaluated and ranked meticulously to avoid any potential hurdle at a later stage. The present study employs limited barriers in its IRP modeling; in future research, therefore, a greater number of LBs should be included. Further, the evaluation of the barriers concerning the region is very crucial to accomplish. The current LBs study was undertaken in the western part of India, where the "financial barrier to resource management" (LB01) is the least important because the state government offers easy loans. Moreover, skill development for workers through Industrial Training Institutes and the National Council of Vocational Training is heavily promoted by the State government and central government. By and large, both programs produce highly skilled workers who need limited training to work in an industrial setup. Hence, "lack of formal training for workers" i.e., LB04, does not pose a greater threat. This may not be true for other parts of the country. Hence, the barrier selection differs from region to region. The same barrier may not pose the same threat in all places during lean implementations. The impact of state and central government laws was not considered in this study. The Indian Factory Act, 1948 was also neglected when considering the barriers in this study. Future studies may consider the impact of prevailing laws when considering the LBs.

7. Conclusions

The present research investigates the lean implementation barriers. Three different methodologies of ISM, MICMAC, and IRP were applied to understand the nature, type, and influence of lean implementation barriers. The ISM provides a model to help visualize and understand the relationship between LBs. The MICMAC analysis helps in classifying the lean implementation barriers so that suitable strategies can be derived to control such LBs. The relation modeling reveals a significant relationship among the LBs. The outcome of this research is significant in lean implementation for SMEs in the manufacturing sector. The understanding of each lean implementation barrier will help the manufacturing industry control and achieve lean implementations. The decision-making in SMEs is simple and fast compared with that in large enterprises, which involve multiple hierarchies. For successful lean implementation, the different sectors can use the ISM, MICMAC Analysis, and IRP to find out which lean implementation barriers are the most important.

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