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Barriers to lean six sigma implementation in the supply chain: An ISM model

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ABSTRACT

Lean six sigma (LSS), a process improvement tool to achieve operational excellence in any industry, has become popular among practitioners over the last few decades. In this study, a framework for identifying barriers to LSS implementation in supply chains has been developed using the interpretive structural modeling (ISM) method. The ISM technique was used to identify the contextual relationships among the barriers. Barriers were classified based on their dependence power and driving power using MICMAC (Matriced Impacts Croisés Multiplication Appliquée á un Classement). This framework will provide a comprehensive understanding of how the barriers of LSS affect each other. The proposed framework has been tested using data from a real-world apparel manufacturing company in Bangladesh. 10 barriers to LSS implementation were identified from a literature review and industrial managers' feedback. This study is expected to guide practitioners in implementing LSS in supply chains by helping to focus their effort on removing the most important barriers.

1. Introduction

In today's world, organizations around the globe are facing increased competition and are looking for ways to reduce costs and lead time while increasing product quality. Lean six sigma (LSS) strategies serve this purpose for manufacturing organizations across the supply chain and can help companies achieve and retain a competitive advantage (Alhuraish, Robledo, & Kobi, 2017; Costa, Godinho Filho, Fredendall, & Ganga, 2020). LSS can be used to gain benefits over competitors by using less wasteful and cost-effective manufacturing processes. In other words, Lean six sigma (LSS) is a methodology to improve efficiency and gain a competitive edge.

To achieve major quality improvement, Motorola introduced the concept of Six Sigma in the mid-1980s. Later, in the 1990s, it was integrated with the lean manufacturing concept known as Lean Six Sigma (LSS). LSS is a method of increasing productivity and performance in a business organization. It also helps in developing leadership skills among managers (Snee, 2010b). The primary focus of LSS is improving bottom-line performance. Currently, six sigma tools and lean management are two continuous improvement tools that companies use widely (Alfaro, Madrigal, & Hernández, 2020; Message Costa, Filho, Fredendall, & Gómez Paredes, 2018; Steere, Rousseau, & Durland, 2018). To take LSS project initiatives in an organization, the current states of the manufacturing or service process of interest are studied, then targets are set for future activities needed to improve the manufacturing or service process. Using LSS strategies, organizations can improve business processes. However, implementing LSS in a manufacturing or service organization and maintaining it is no easy task. Managers have to face a number of challenges and obstacles to complete an LSS implementation. Unfortunately, the literature about these obstacles or barriers is scarce.

Therefore, the aim of this research is to provide comprehensive knowledge about the barriers to LSS implementation and the interrelationships among these barriers. The goal of this study is to introduce a framework of barriers to LSS implementation in supply chains. The research questions are as follows:

1. What are the important barriers to LSS in supply chains?

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2. What are the relationships among the identified barriers to LSS?
3. What are the driving and dependence powers among the barriers to LSS?

To answer the above research questions, an interpretive structural modeling (ISM) framework was proposed. An ISM approach can explore interactions between several factors (Malone, 1975). The proposed framework has been tested using a real-world apparel case study in Bangladesh. Identification and analysis of LSS implementation barriers in an apparel supply chain are essential in an emerging economy, such as exists in Bangladesh (Hodge, Goforth Ross, Joines, & Thoney, 2011; Sreedharan & Raju, 2016). The apparel industry was chosen as the preferred case because it is the largest industry in Bangladesh, contributing 17.86% of the total Gross Domestic Product (GDP) in the 2009–2010 financial year. The industry employs 12.9% of the total manufacturing workforce and 85% of the female manufacturing workforce (Yunus & Yamagata, 2012).

The remainder of this paper is arranged as follows: Section 2 provides a review of the literature on the lean and six sigma process and barriers to LSS implementation in supply chains. The research methodology is presented in Section 3. Section 4 outlines a real-world industrial case with the application of the ISM method. Section 5 provides results and discussions. Section 6 gives conclusions and recommendations for future research.

2. Literature review

This section encompasses the literature review on the lean and six sigma process, followed by barriers to LSS implementation in supply chains. Lean is a systematic method of waste minimization (Thomas, Sherman, & Sawhney, 2018). It is a continuous improvement method that can identify and reduce non-value-added activities or waste by flowing the product at the pull of the customer. Lean philosophy was developed based on the Toyota Production System (TPS) that produces products according to customer requirements with minimum waste (Shingo, 1996).

World-class best practices (e.g. minimum inventories, high production volume, small continuous improvement, etc.) enable reducing waste and maximizing efficiency (Raj & Attri, 2010). Six Sigma improves product quality by reducing variability in processes (Costa, Silva, & Pinto Ferreira, 2017). LSS is an amalgamation of lean manufacturing and six sigma philosophy, can improve quality, reduce process variations, and remove non-value added activities (Alhuraish et al., 2017; de Freitas, Costa, & Ferraz, 2017).

LSS implementation synergizes the strengths of both lean manufacturing and six sigma philosophy. LSS increases revenue and reduces costs. It helps every individual in a company or factory to be successful at work. LSS assists human resources to improve productivity and professional effectiveness. Workforces trained with LSS can identify and systematically remove bottlenecks, waste and process variations from a manufacturing or service system. Hence, implementing LSS facilitates quality assurance and the development of a business. Therefore, LSS can enhance supply chain performance (Ladd, 2013).

LSS implementation requires an integrated approach to achieve the total leanness of the system (Parveen & Rao, 2009). The nature of the market also impacts a lean approach. Lean stabilizes demand by simplifying, optimizing, and streamlining the supply chain. A streamlined supply chain ensures smooth operations and on-time delivery (Vanpoucke, Vereecke, & Muylle, 2017).

There were few extant works of literature on the benefits and limitations of LSS in a supply chain. A formal investigation of the prospective applications and challenges of LSS implementation can help companies to benchmark LSS methodologies, performance metrics, potential failures and savings across the supply chain (Amer, Luong, Lee, Wang, Ashraf, & Qureshi, 2007). Implementing LSS is receiving increased attention among stakeholders in the apparel industry of Bangladesh. It is

Table 1
Barriers to LSS implementation.

No.	Barrier	Sources	Brief Description
1	Lack of information sharing	(Hussain, He, Ahmad, & Iqbal, 2019; Jadhav et al., 2014)	A smooth flow of information allows management to better communicate the benefits of LSS
2	Lack of executive management involvement	(Albliwi et al., 2014; Rodríguez, Pérez, & Gutiérrez, 2008)	Commitment, involvement and support from top management can ensure that all necessary resources are available and LSS implementation is smooth and without obstacles
3	Lack of training	(Chan, Ismail, Ahmad, Zaman, & Lim, 2019)	Education and training are perquisites for any kind of drastic organizational change
4	Insufficient investments	(Bhattacharya & Momaya, 2009; Chan et al., 2019)	Undertaking a major project like implementing LSS requires a considerable amount of monetary investment
5	Poor facility planning and layout	(Arasanipalai Raghavan, Yoon, & Srihari, 2014; Li & Love, 2000).	Poor layout can cost both time and money which is an antithesis to LSS
6	Organizational cultural difference	(Knapp, 2015)	Without understanding cultural differences among organizations, LSS strategies cannot be adapted and will result in inevitable failure
7	Organizational infrastructure	(de Koning, Verver, van den Heuvel, Bisgaard, & Does, 2006; Gutierrez-Gutierrez, de Leeuw, & Dubbers, 2016; Lev, 2002; Pande, Neuman, & Cavanagh, 2000)	Similar to cultural differences, a proper understanding of infrastructure differences is critical in LSS implementation
8	Employee's resistance	(Oreg & Berson, 2009; Shokri et al., 2014; Zhang, Luo, Shi, Chia, & Sim, 2016)	Any change or modification in individual habits needs effort to adapt to change. Employees' attitude, and steps taken by executive management to adapt employees to a new environment, will determine the success of organizational change
9	Lack of LSS knowledge	(Albliwi et al., 2014)	Understanding the basics of LSS and communicating that knowledge to other LSS participants is absolutely necessary
10	Lack of supervision from line managers	(Islam & Adnan, 2016; Moya, Galvez, Muller, & Camargo, 2019; Yadav, Jain, Mittal, Panwar, & Sharma, 2019)	Lack of supervision from line managers has adverse effects on implementing any project in an organization
11	Cross-functional conflict	(Jadhav et al., 2014)	Any gap in communication or poor coordination may lead to conflict among members of cross-functional teams, which may slow down an LSS project
12	Slow response to market	(Jadhav et al., 2014)	In a highly competitive market, some managers may be incapable of responding to market

(continued on next page)

Table 1 (*continued*)

No.	Barrier	Sources	Brief Description
			variations of change in manufacturing technology
13	Poor sales forecasting	(Jadhav et al., 2014)	Poor forecasting and the absence of precise forecasting methods often lead to the incapability of making timely delivery
14	Lack of planning	(Dahlgaard & Mi Dahlgaard-Park, 2006; Snee, 2010a)	Availability of resources of a particular quantity and of particular quality at a particular position is essential for successful LSS implementation in the supply chain
15	Technological barriers	(de Souza & Pidd, 2011; Desale, Devdhar, & Patil, 2013)	Reducing waste and improving product quality requires implementing emerging technologies

Table 2
Comparing the contribution of this study with other relevant literature on LSS.

Source	Contribution
This Study	Using ISM a framework to identifying and ranking the barriers to lean six sigma has been proposed in the apparel manufacturing sector of Bangladesh
Albliwi et al. (2014)	Identified 34 failure factors of LSS. No interrelationships among factors were identified
Alhuraish et al. (2017)	Differentiated between Lean manufacturing and Six Sigma methodologies and identified the critical success factors behind these two methods. It does not consider LSS as a unified methodology
Amer et al. (2007)	Discussed the designing of the supply chain for six sigma implementation. It does not discuss the barriers to LSS implementation
Antony and Banuelas (2002)	Discusses the critical success factors for Six Sigma implementation by conducting a survey in the UK manufacturing and service sector
Desale et al. (2013)	Identifies the barriers in Six Sigma implementation in the construction industry
Gutierrez-Gutierrez et al. (2016)	Discusses the applications of LSS in the logistics of an organization in improving productivity
Jagdish, Shankar, and Santosh (2014)	Identifies 24 barriers in Lean implementation. However, it did not discuss the interrelationships among these barriers
Salonitis and Tsinopoulos (2016)	Discusses the drivers and barriers in Lean Implementation in the Greek manufacturing industry
Kumar et al. (2016)	Identified 21 barriers in implementing Green Lean Six Sigma for product development in Indian automotive industry using ISM and MICMAC analysis
Hussain et al. (2019)	Identified barriers in green, lean and six sigma implementations in Pakistan Construction industry. Considers the 3 concepts individually

crucial to diagnose the barriers to implementing LSS in the supply chain of an enterprise. An ISM can be applied to examine the contextual relationships among barriers (Ali, Arafin, Moktadir, Rahman, & Zahan, 2018). There are a number of barriers that may hinder implementing LSS in supply chains. Implementation is related to various issues, such as planning and decision making, behavioral issues, technical issues, etc. A number of barriers to LSS implementation were identified and are discussed in Table 1. A brief comparison with relevant existing literature is provided in Table 2. In selecting relevant literature, scientific article search engines such as Google Scholar, ScienceDirect and Semantic Scholar were used to find articles related to barriers of Lean Six Sigma. The search space was limited to papers that explicitly discussed about the barriers to implementation of Lean or Six Sigma. Ten such papers were selected for analysis, the contribution and gaps of which were identified and compared to the contribution of the current study.

3. Research methodology

First, the existing literature on LSS implementation in supply chain practices was examined and 10 consultation sessions were arranged with experts using brainstorming and focused group methods to determine the most influential barriers to LSS implementation. The experts consisted of managers of different companies who has been in the manufacturing industry for more than five years. In these sessions, the experts were asked to discuss the criticality of each factor among themselves and rank them in order of preference. By analyzing their responses, 10 barriers were identified from the professionals' feedback. To examine the interrelationships of the selected LSS implementation barriers, an ISM methodology was applied. Using a MICMAC analysis, variables were categorized based on driving and dependence power. Consideration of these variables and appropriate connections can help organizations to make informed decisions. A graphical representation of the methodology is given in Fig. 1.

3.1. Interpretive Structural Modeling (ISM) technique

ISM helps decision-makers by giving a clear picture of the interrelationships among various factors (Mandal & Deshmukh, 1994). It converts unclear and vague models into clearly defined models. ISM is a cooperative education method where a set of different and secondarily connected fundamentals are organized into a complete model. It is a method for classifying interactions among particular objects, which explain a subject or a factor. Multiple factors can be related to a complex problem. The interrelationships among these factors can describe a complex problem far more accurately than considering an individual factor (Mandal & Deshmukh, 1994). Therefore, ISM provides cooperative identifications of these associations. The difficulty of the method is due to the existence of many fundamentals and inherent connections. The existence of openly or indirectly connected fundamentals confuses the assembly of the method, which may or may not be expressed in a pure style. This is problematic to the arrangement of such a method as its construction is not obviously clear. Hence, it requires the progress of a procedure that supports classifying a construction inside a method (Jharkharia & Journal, 2005).

In this approach, concepts of graph theory were used to define the interrelationship among variables (Ravi, Shankar, & Tiwari, 2005). ISM provides a means to impose order on the complexity of such variables (Raj & Attri, 2010). The management of a manufacturing system consists of a large number of factors associated with physical elements and/or decision-making. Interrelationships among factors make the system structure complex and interrelationships may not be articulated clearly. A system with a structure that is not defined clearly is difficult to address. Hence, a model that helps identify the interrelationship of factors within a system was necessary to develop (Pandey, Suresh, & Ravi, 2005). ISM structures interrelated factors into a comprehensive systematic model (Singh, Garg, & Deshmukh, 2007). A multi-objective decision model was created using an ISM-based approach to identify LSS implementation barriers in the supply chain.

An eight-step procedure was used to develop ISM (Ravi et al., 2005). The steps were as follows:

Step 1: The LSS implementation barriers were identified from the literature review and expert feedback. The ISM procedure proposed the practice of several organizational methods, such as brainstorming and focus groups, in developing connections among the variables.

Step 2: The interrelationships among variables from Step 1 were established. To determine those interrelationships, professionals from manufacturing and academia were referred to in order to recognize the nature of the appropriate connections among the issues. For this, brainstorming and focus group techniques were used.

Step 3: A structural self-interaction matrix (SSIM) was developed to indicate pairwise relationships among the variables in the system. To evaluate issues, an appropriate connection of 'leads to' or 'inspires'

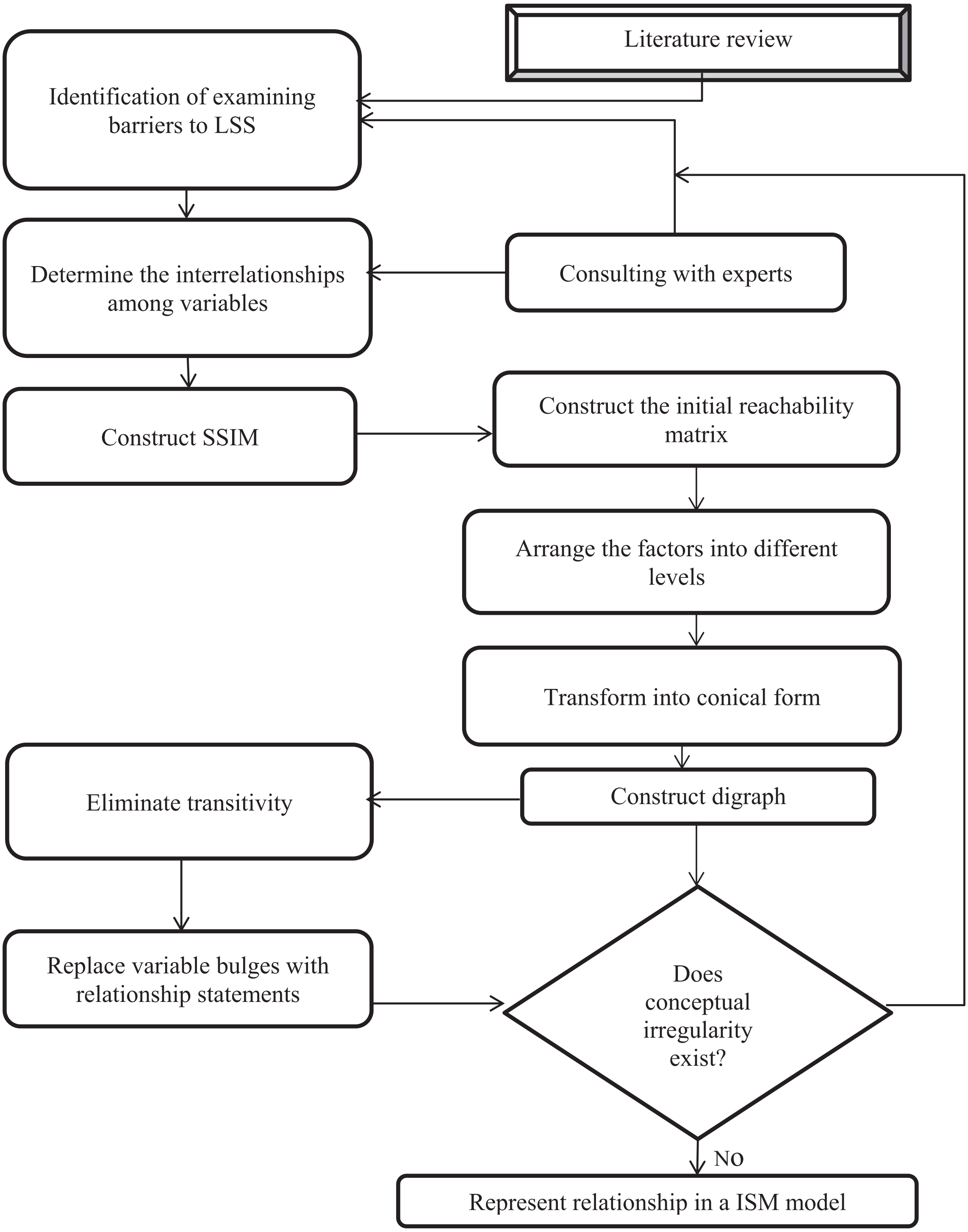

Fig. 1. ISM based methodology (modified from Ali et al., 2018).

needed to be selected. Thus, one issue inspired another issue, for instance. The contextual connections between recognized issues were established. Considering the contextual relationship for each issue and the reality of the connection between any two factors (*a* and *b*), how issues were connected was determined. The four symbols denoting the direction of relationships between two factors (*b* and *b*) were:

Table 3
Rules of substitution.

SSIM	(*a*, *b*) entry	(b, *a*) entry
V	1	0
A	0	1
X	1	1
O	0	0

(a) V indicated the influence of factor *a* on factor *b*
(b) A indicated the influence of factor *b* on factor *a*
(c) X indicated the mutual influence of factors *a* and *b*
(d) O indicated no influence

Based on the contextual relationship, SSIM was developed. It was

Table 4
Experts' feedback on barriers to lean six sigma implementation in supply chains.

Respondent	Barriers														
	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8	EB9	EB10	EB11	EB12	EB13	EB14	EB15
Expert-1	●	●	●	●	●	●	●	●	●	●					
Expert-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Expert-3		●	●	●					●						
Expert-4		●	●			●			●						
Expert-5		●		●					●	●					
Expert-6		●	●	●											
Expert-7		●	●	●						●					
Expert-8	●	●	●	●	●	●	●	●	●	●		●			
Expert-9	●	●	●		●				●						●
Expert-10	●	●		●	●		●	●	●	●					
Expert-11	●	●		●			●		●						
Expert-12		●		●			●		●						
Expert-13		●	●						●					●	
Expert-14		●	●						●						
Expert-15	●	●		●	●		●	●							
Expert-16		●		●					●	●					
Expert-17		●	●	●	●			●							
Expert-18	●	●				●	●		●	●					
Expert-19	●	●							●	●					
Expert-20		●							●	●					
Expert-21		●		●	●		●	●	●	●					
Expert-22		●			●		●	●	●	●					
Expert-23		●			●		●	●	●						
Expert-24		●					●	●	●						
Expert-25		●			●		●	●		●					
Expert-26		●			●			●		●					
Expert-27	●	●		●	●		●	●							
Expert-28	●	●		●			●								
Expert-29		●	●	●		●	●			●					
Expert-30		●	●	●			●								
Expert-31		●	●	●			●								
Expert-32		●		●			●								
Expert-33		●		●			●								
Expert-34		●				●	●	●							
Expert-35		●	●	●			●		●	●					
Total	11	35	15	22	13	7	22	14	21	16	1	2	1	2	1

finalized by obtaining consensus from a group of experts.

Step 4: In this step, an initial reachability matrix was developed. The four symbols (i.e., V, A, X, or O) of the SSIM were converted to one or zero in the initial reachability matrix. The rules for conversion are given in Table 3.

Using these substitution rules, the initial reachability matrix was developed. 1* entries were used to fill the gaps in the expert opinions.

Step 5: The reachability and the antecedent sets were developed from the final reachability matrix. The intersections of these sets were derived for all factors. The levels of the different factors were determined. Factors having the same reachability and intersection occupied the highest level of ISM hierarch. Once identified, top-level factors were removed from further consideration. The procedure was repeated until the level of each factor was found. The digraph and the ISM model were developed using these levels.

Step 6: In this step, by summing the factors of the same level across columns and rows of the final reachability matrix, the conical matrix was developed. Driving power is the summation of 1's in the rows. Similarly, the dependence power is the summation of 1's in the columns. They were ranked according to row and column sums respectively in descending order.

Step 7: The initial digraph with transitive links was developed from the conical matrix. The digraph is a visual representation of the elements and the interdependences. To establish the final digraph, the indirect links were eliminated. The factors were positioned according to level.

Step 8: Replacing the nodes of the factors with statements, the digraph was transformed into an ISM model.

3.2. MICMAC analysis

MICMAC refers to cross-impact matrix multiplication applied for the classification. The objective of MICMAC analysis is to determine the dependence and driving powers of factors. It identifies the key factors that drive the system in different categories. The 'key factor' falls into either an independent or a linkage factor category. Based on their driving and dependence power, the factors are classified into linkage factors, autonomous factors, dependent factors, and independent factors.

Linkage factors: These factors have strong driving power and dependence power. Any actions of these factors will impact other factors and create a feedback effect. Thus, these factors are unstable.

Autonomous factors: These factors are weak in both driving power and dependence power and have few links to the system, but the links are relatively strong.

Dependent factors: These factors are weak in driving power and strong in dependence power.

Independent factors: These factors are strong in driving power and weak in dependence power.

4. Application of ISM method

The proposed methodology has been applied to an apparel manufacturing company named Babylon Garments Ltd. in Dhaka, Bangladesh. Babylon Garments Ltd. is facing numerous obstacles in implementing LSS in its apparel supply chain. This case study demands identification of the major barriers and the ranking of the barriers with strategic action plans for the smooth implementation of LSS practices. The profile of the company is given in Table A1 of Appendix A. In this

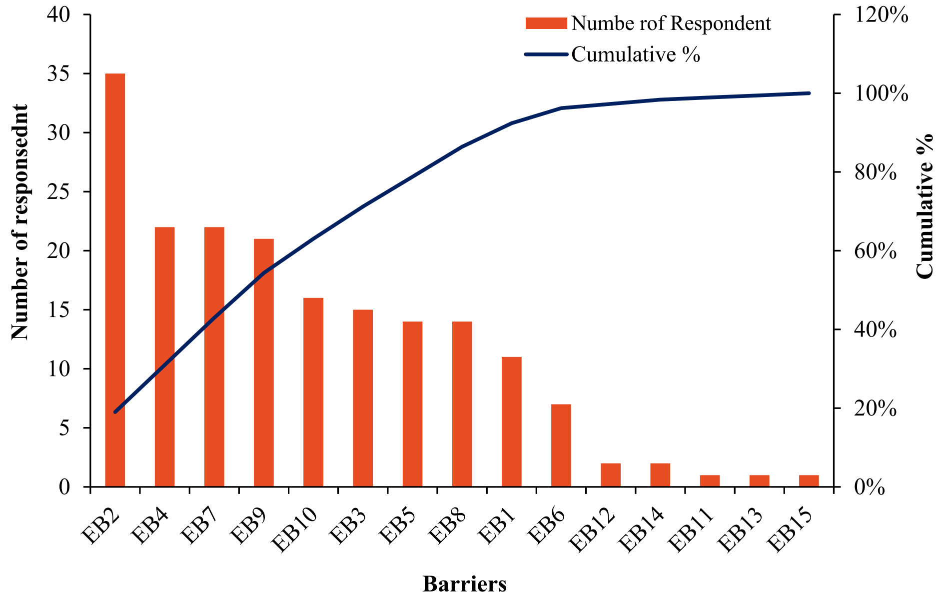

Fig. 2. Pareto Chart of expert feedback based on selected barriers of lean six sigma implementation.

Table 5
Expert feedback based on selected barriers of lean six sigma implementation.

Cause	Number of Respondents	Cumulative	Cumulative %
EB2	35	35	19%
EB4	22	57	31%
EB7	22	79	43%
EB9	21	100	54%
EB10	16	116	63%
EB3	15	131	71%
EB5	14	145	79%
EB8	14	159	86%
EB1	11	170	92%
EB6	7	177	96%
EB12	2	179	97%
EB14	2	181	98%
EB11	1	182	99%
EB13	1	183	99%
EB15	1	184	100%

Table 6
Selected LSS implementation barriers with the identification code.

Notations	Barriers
EB1	Lack of information sharing
EB2	Lack of executive management involvement
EB3	Insufficient investments
EB4	Lack of training
EB5	Poor facility planning and layout
EB6	Organizational cultural differences
EB7	Organizational infrastructure
EB8	Employee resistance
EB9	Lack of LSS knowledge
EB10	Lack of supervision from line managers

study, 15 major barriers were identified from the relevant literature. Based on expert opinions, 10 barriers were selected. The selection criteria for the experts and the questionnaire are provided in Table A2 of Appendix A. Although question no. 1 to 6 were open box questions, question no. 7 provided a list of 15 barriers that were identified using literature review. The experts were asked to rank those in order of importance. This questionnaire was provided during the brainstorming session. The feedback provided by the experts is summarized in Table 4. Using a Pareto chart, 10 barriers from the initial 15 were selected. The Pareto chart is shown in Fig. 2 and the corresponding data is given in Table 5.

4.1. ISM development

The ISM methodology was used to determine the interrelationships among the selected LSS implementation barriers in order to initiate LSS into the apparel supply chain of Bangladesh.

4.1.1. Establishing the contextual relationships between barriers to LSS implementation

Table 6 shows the selected barriers to implementing LSS in the supply chain. The next step was to analyze the interrelationships between the barriers using ISM. Brainstorming and group discussion techniques helped to develop the contextual relationships between barriers. Experts influenced the type of contextual relationship used to analyze barriers to LSS in the supply chain.

4.1.2. Development of a structural Self-Interaction matrix (SSIM)

The next step was to analyze the LSS implementation barriers. To achieve this, a contextual relationship of ‘reaches to’ was chosen (Table 7). The interrelationships were constructed by consulting with experts from various industries. To analyze the barriers for the development of the SSIM, the relation between any two barriers (a and b) and the associated direction of this relation was determined. Singh et al. (2007) suggested four standard symbols to denote the direction of the relationship between the variables, as follows.

V: Criterion a will assist in reaching criterion b
A: Criterion b will assist in reaching criterion a
X: Criterion a and b will assist each other
O: Criterion b and a are unrelated

Based on the contextual relationship between the barriers, the SSIM was developed.

4.1.3. Development of the initial and final reachability matrix

The SSIM was transformed into an initial reachability matrix. The transitivity concept was used to develop the final reachability matrix and some cells of the initial reachability matrix were filled by inference. By applying the transitivity concept to Table 8, the final reachability

Table 7
Structural self-interaction matrix.

Barriers	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8	EB9	EB10
EB1	X	A	A	A	V	V	V	O	V	V
EB2		X	V	V	V	V	V	O	V	V
EB3			X	A	V	V	V	O	V	V
EB4				X	O	O	V	O	V	O
EB5					X	X	V	V	V	V
EB6						X	V	V	V	V
EB7							X	O	O	V
EB8								X	O	V
EB9									X	V
EB10										X

Table 8
Initial reachability matrix.

Barriers	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8	EB9	EB10
EB1	1	0	0	0	1	1	1	0	1	1
EB2	1	1	1	1	1	1	1	0	1	1
EB3	1	0	1	0	1	1	1	0	1	1
EB4	1	0	1	1	0	0	1	0	1	0
EB5	0	0	0	0	1	1	1	1	1	1
EB6	0	0	0	0	1	1	1	1	1	1
EB7	0	0	0	0	0	0	1	0	0	1
EB8	0	0	0	0	0	0	0	1	0	1
EB9	0	0	0	0	0	0	0	0	1	1
EB10	0	0	0	0	0	0	0	0	0	1

Table 9
Final reachability matrix.

Barriers	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8	EB9	EB10	Driver Power
EB1	1	0	0	0	1	1	1	0	1	1	6
EB2	1	1	1	1	1	1	1	0	1	1	9
EB3	1	0	1	0	1	1	1	0	1	1	7
EB4	1	0	1	1	0	0	1	0	1	*1	6
EB5	0	0	0	0	1	1	1	1	1	1	6
EB6	0	0	0	0	1	1	1	1	1	1	6
EB7	0	0	0	0	0	0	1	0	0	1	2
EB8	0	0	0	0	0	0	0	1	0	1	2
EB9	0	0	0	0	0	0	0	0	1	1	2
EB10	0	0	0	0	0	0	0	0	0	1	1
Dependence	4	1	3	2	5	5	7	3	7	10	47

matrix was prepared which is shown in Table 9. Entries marked with * show the transitivity.

4.1.4. Level partitioning the final reachability matrix

The digraph was constructed from the reachability matrix. Based upon the reachability and antecedent sets for each variable, the reachability matrix was split and grouped into different levels through iterations. Based on the suggestions from Farris and Sage (1975) and Warfield (1974), the reachability set and the antecedent set for each barrier were extracted from the conical form of the reachability matrix. The reachability set consisted of the barriers and others that were reachable. Every column that contained a value 1 was considered. The barriers that column represented were included in the reachability set. Similarly, the antecedent set consisted of the barriers and others, which may alleviate the barriers. Every row that contained a value 1 was considered. The barriers that row represented were included in the antecedent set. In this paper, ten barriers were partitioned through seven iterations, which are given below in Table 10.

The final list of level partitions is given in Table 11. The identified levels aided in building the final ISM model. The first level issued was positioned at the top of the model. The final digraph is shown in Fig. 3. The proposed ISM model is shown in Fig. 4.

4.2. MICMAC analysis of obtained results

MICMAC analysis identifies the dependence and driving dependence powers of the barriers to LSS implementation. The challenging issues of the dependence and the driving powers are mentioned in Table 6. An entry of 'one' in the columns and rows identify the dependence and driving power, respectively. The driving power and the dependence diagram is shown in Fig. 5. Based on the dependence and driving powers, barriers were categorized into autonomous issues, dependent issues, linkage issues, and independent issues.

Fig. 4 demonstrates there were no linkage barriers in the driver dependency diagram. If these barriers were improved, LSS implementation would be more effective in the apparel supply chain of Bangladesh. If there were no linkage barriers, then the LSS implementation would be obstruction-free. The next cluster was that of the independent barriers, which contained a lack of information sharing, a lack of executive management involvement, a lack of training, insufficient investments, poor facility planning and layout, and organizational cultural differences. These were the main driving barriers in LSS implementation in the apparel supply chain. Management must pay close attention to these factors to obtain fast and meaningful outcomes. The autonomous barrier contained employee resistance. This factor was reasonably isolated from the system and had few links, but the links may be strong. The last

Table 10
Level identification process for the ten barriers.

Barriers	Reachability Set	Antecedent set	Intersection set	Level
EB1	EB1, EB5, EB6, EB7, EB9, EB10	EB1, EB2, EB3, EB4	EB1	
EB2	EB1, EB2, EB3, EB4, EB5, EB6, EB7, EB9, EB10	EB2	EB2	
EB3	EB1, EB3, EB5, EB6, EB7, EB9, EB10	EB2, EB3, EB4	EB3	
EB4	EB1, EB3, EB4, EB7, EB9, EB10	EB2, EB4	EB4	
EB5	EB5, EB6, EB7, EB8, EB9, EB10	EB1, EB2, EB3, EB5, EB6	EB5, EB6	
EB6	EB5, EB6, EB7, EB8, EB9, EB10	EB1, EB2, EB3, EB5, EB6	EB5, EB6	
EB7	EB7, EB10	EB1, EB2, EB3, EB4, EB5, EB6, EB7	EB7	
EB8	EB8, EB10	EB5, EB6, EB8	EB8	
EB9	EB9, EB10	EB1, EB2, EB3, EB4, EB5, EB6, EB9	EB9	
EB10	EB10	EB1, EB2, EB3, EB4, EB5, EB6, EB7, EB8, EB9, EB10	EB10	I
Iteration 2				
EB1	EB1, EB5, EB6, EB7, EB9	EB1, EB2, EB3, EB4	EB1	
EB2	EB1, EB2, EB3, EB4, EB5, EB6, EB7, EB9	EB2	EB2	
EB3	EB1, EB3, EB5, EB6, EB7, EB9	EB2, EB3, EB4	EB3	
EB4	EB1, EB3, EB4, EB7, EB9	EB2, EB4	EB4	
EB5	EB5, EB6, EB7, EB8, EB9	EB1, EB2, EB3, EB5, EB6	EB5, EB6	
EB6	EB5, EB6, EB7, EB8, EB9	EB1, EB2, EB3, EB5, EB6	EB5, EB6	
EB7	EB7	EB1, EB2, EB3, EB4, EB5, EB6, EB7	EB7	II
EB8	EB8	EB8	EB8	II
EB9	EB9	EB1, EB2, EB3, EB4, EB5, EB6, EB9	EB9	II
Iteration 3				
EB1	EB1, EB5, EB6	EB1, EB2, EB3, EB4	EB1	
EB2	EB1, EB2, EB3, EB4, EB5, EB6	EB2	EB2	
EB3	EB1, EB3, EB5, EB6	EB2, EB3, EB4	EB3	
EB4	EB1, EB3, EB4	EB2, EB4	EB4	
EB5	EB5, EB6	EB1, EB2, EB3, EB5, EB6	EB5, EB6	III
EB6	EB5, EB6	EB1, EB2, EB3, EB5, EB6	EB5, EB6	III
Iteration 4				
EB1	EB1	EB1, EB2, EB3, EB4	EB1	IV
EB2	EB1, EB2, EB3, EB4	EB2	EB2	
EB3	EB1, EB3	EB2, EB3, EB4	EB3	
EB4	EB1, EB3, EB4	EB2.EB4	EB4	
Iteration 5				
EB2	EB2, EB3, EB4	EB2	EB2	
EB3	EB3	EB2, EB3, EB4	EB3	V
EB4	EB3, EB4	EB2, EB4	EB4	
Iteration 6				
EB2	EB2, EB4	EB2	EB2	
EB4	EB4	EB2, EB4	EB4	VI
Iteration 7				
EB2	EB2	EB2	EB2	VII

cluster was dependence barriers that contained organizational infrastructure, lack of knowledge about LSS and a lack of supervision from line managers. This cluster had weak driving power and strong dependence.

From the ISM model and the MICMAC analysis, the lack of executive management involvement was the most independent issue in terms of its ability to drive other factors in achieving the final goal of implementing LSS in the supply chain. This factor appears in the bottom level of the ISM model.

Table 11
Final list of level partitions.

Level	Barriers No.	Barriers
I	EB10	Lack of supervision from line managers
II	EB7	Organizational infrastructure
	EB8	Employee resistance
	EB9	Lack of LSS knowledge
III	EB5	Poor facility planning and layout
	EB6	Organizational cultural differences
IV	EB1	Lack of information sharing
V	EB3	Insufficient investments
VI	EB4	Lack of training
VII	EB2	Lack of executive management involvement

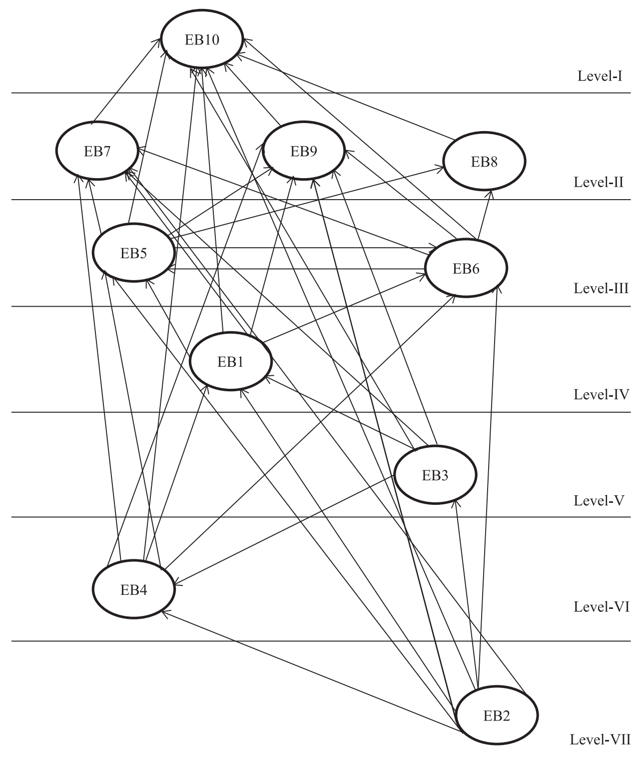

Fig. 3. Final Digraph.

5. Results and discussions

Successful implementation of LSS requires a clear understanding of the barriers in the ISM framework. Lack of executive management involvement (EB2) was found to be the most important barrier. Without the active participation and enthusiasm of senior management, implementing LSS it is impossible as it is an organization-wide cultural change (Antony & Banuelas, 2002). Senior executives must be proactive and progressive. They must be the first to embrace change and adapt to new managerial styles. They must inspire their subordinates to let go of traditional ways of operating. Any organizational change must start with them. Executive management involvement was placed on the lowest level of the ISM model as it had high driving power but low dependence power, which means this barrier drives all other barriers but was unaffected by any other barrier, making it the most critical barrier in the context of the apparel industry. As a result, it was placed on Level VII of the final digraph. This finding is in line with the study of Dede, Lori, and Aaron (2017), who studied the critical success factors of LSS in the context of the global textile supply chain.

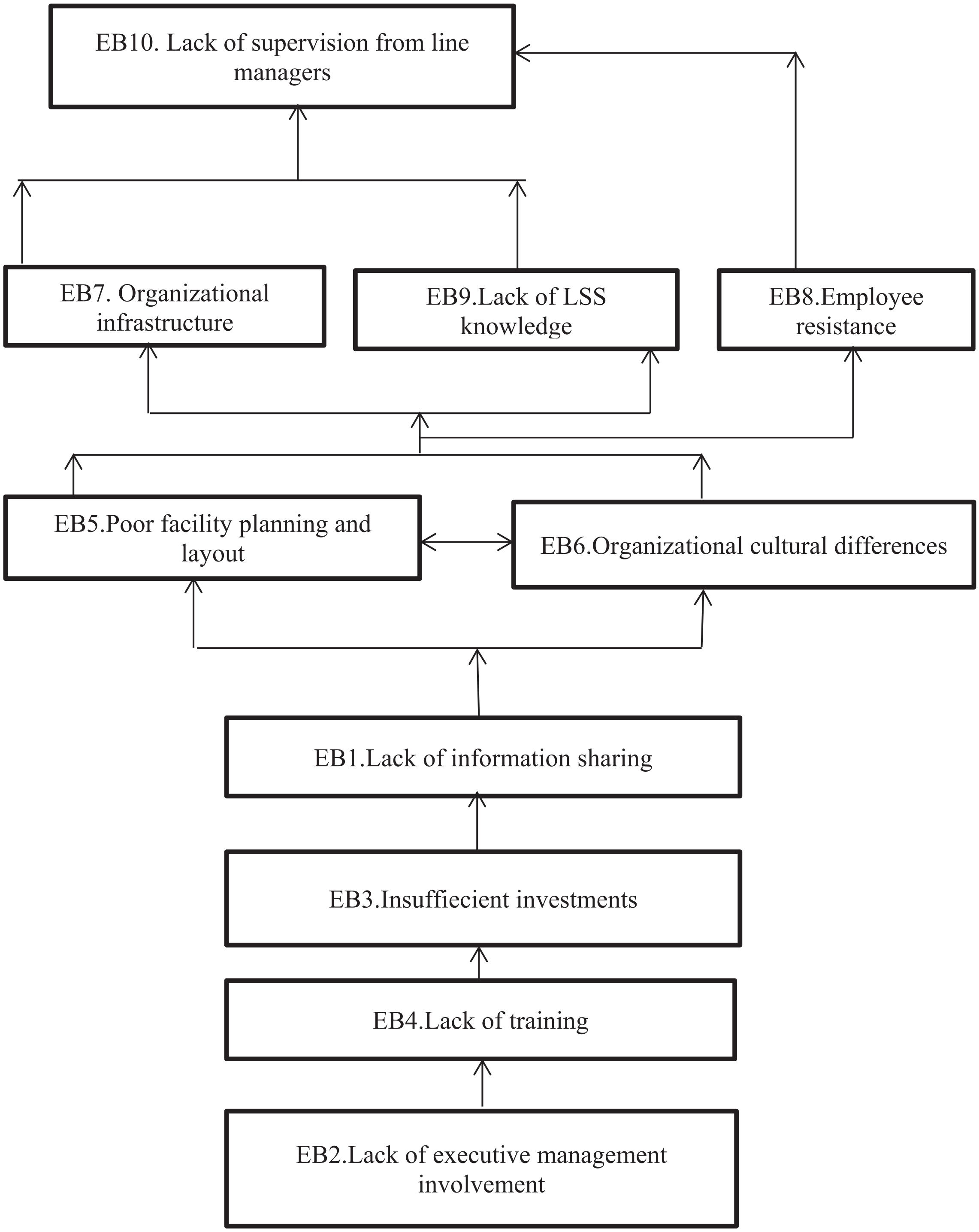

Fig. 4. Proposed ISM model.

Next, Lack of training (EB4) was found to be the next most critical barrier in the ISM hierarchy and, as such, it was placed on Level VI of the final digraph. All employees, from the very top to the very bottom of an organization's structure, must be trained about what LSS is, what it will do, its benefits, and what they need to do to ensure its successful implementation. As mentioned before, LSS involves the cultural overhaul of an organization and this must be carried out by employees. A lack of training means employees will be oblivious to their responsibilities in the successful implementation of LSS. According to Dede et al. (2017), providing ample training about LSS is critical before the implementation of LSS in apparel manufacturing companies. Communicating the importance of LSS and training using a belt system can make the implementation process easier (Antony & Banuelas, 2002).

The next barrier placed in level V was insufficient investments (EB3). As discussed before, investment not only means monetary investments but human resources and technology investment as well. Successful implementation of LSS requires the development of growth and waste reduction strategies. Financial resources enable these strategies to be successfully implemented. Implementing LSS may require technological change, such as new equipment or new methods of production. Technological investment is, therefore, necessary. However, without proper human resources investment, financial and technological resources

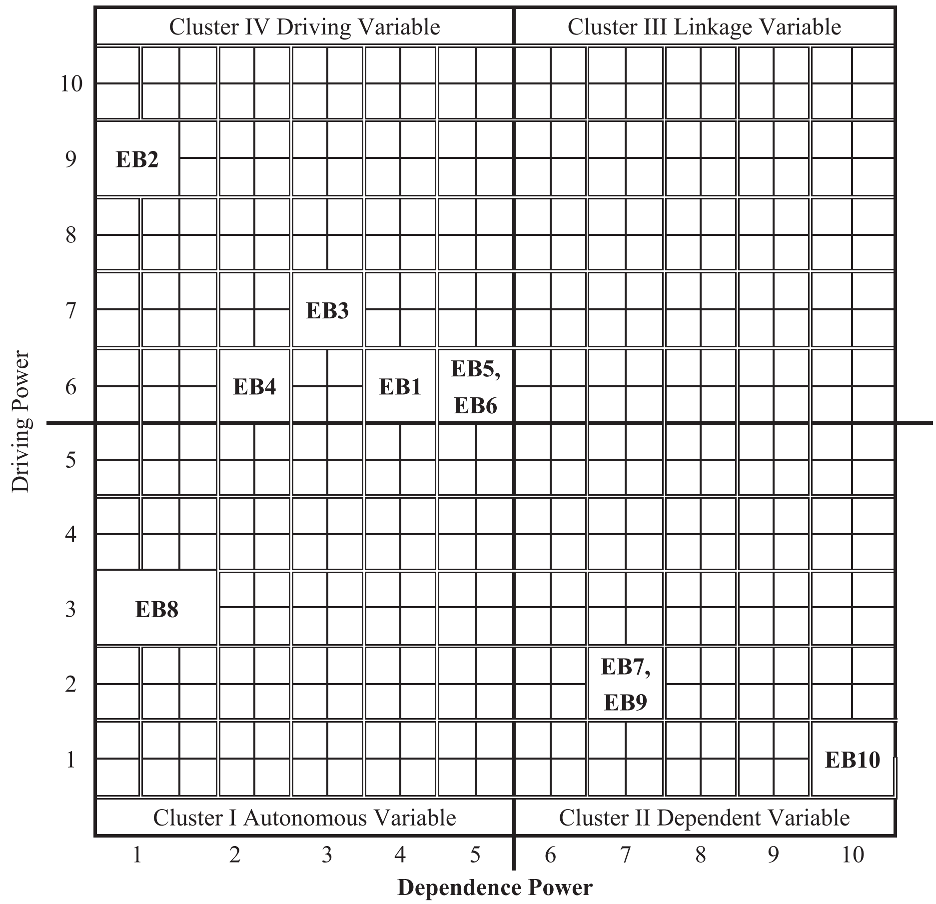

Fig. 5. Driving power and dependence graph for barriers.

cannot be used effectively and efficiently (Bhattacharya & Momaya, 2009). Lack of human, technical, and financial resources is, therefore, one of the most important barriers facing the successful implementation of LSS (Albliwi, Antony, Lim, & van der Wiele, 2014; Gamal Aboelmaged, 2011). In a labor-centric industry such as the apparel industry, training a considerable number of supervisors, line and shift managers, and middle-level managers require a lot of money and resources (Dede et al., 2017; Raj, Ma, Gam, & Banning, 2017).

The barrier in level IV was a lack of information sharing (EB1). Employers must be made aware of the motivations and goals of LSS implementation. They must communicate about the benefits of implementing LSS. Lean wins, such as cost and waste reduction in one department, must be spread throughout the organization (Jadhav, Mantha, & Rane, 2014). Strong information flows are crucial in successfully deploy LSS in the apparel industry (Raj et al., 2017). Coordination at all steps of implementation is necessary (Bharosa, Lee, & Janssen, 2010; Jadhav et al., 2014).

The next two barriers placed in level III were poor facility planning and layout (EB5) and organizational cultural differences (EB6). Optimized facility layout can ensure obstruction-free material flow and, in turn, reduce production time and cost (Li & Love, 2000). It can also help the apparel factories to respond to customer demands quicker and better utilize factory space that is constrained in a densely populated country like Bangladesh (Dai, Lee, & Cheung, 2009). In many cases, employees may fail to cope with the organizational cultural changes brought on by LSS, resulting in poor performance (Knapp, 2015). The six barriers mentioned above have high driving power and low dependence power, as seen in Fig. 5. This means these barriers influence other barriers but are not influenced to the same degree by other barriers. Managers should take extra care in understanding and removing these barriers for a successful implementation of the LSS.

It can be seen from Fig. 5 that there are no linkage variables. There are four variables with low driving power and high dependence power. This means these variables do not influence others and, in turn, are influenced by other variables. These are organizational infrastructure (EB7), employee resistance (EB8), lack of LSS knowledge (EB9), and lack of supervision from line managers (EB10). Ineffective organizational infrastructure can severely hinder the implementation process (Albliwi et al., 2014; Antony & Banuelas, 2002). Top management must take proactive steps to help employees cope with rapid changes in the supply chain process. Otherwise, employee resistance to change can pose a great challenge in implementing LSS (Oreg & Berson, 2011; Shokri, Oglethorpe, & Nabhani, 2014). Lack of LSS knowledge can be a significant barrier, but a hierarchical belt system can circumvent this issue (Antony & Banuelas, 2002). Proper knowledge must be communicated to all stakeholders of LSS in the apparel industry (Dede et al., 2017; Raj et al., 2017). Finally, the bottom level contained a lack of supervision from line managers (EB10). Ineffective and inefficient supervision can have a significant impact on productivity (Islam & Adnan, 2016). This is the least influential barrier in implementing LSS in apparel supply chains. These variables have been placed at level II and level I of the final digraph.

The findings of this study were compared with other research literature related to the barriers in LSS, and although some research agreed with the findings of this study, there were also some discrepancies. For example, Bhattacharya and Momaya (2009), who studied enablers of growth in the construction industry in India, found senior management support to be the most critical enabler. Salonitis and Tsinopoulos (2016) found a lack of executive management support to be a critical barrier in implementing LSS in Greek manufacturing industries. However, Jadhav et al. (2014), who explored the barriers of lean implementation, ranked this factor second. In our study, a lack of training was ranked second in the ISM model. However, this barrier had a lot less driving power than the study by Bhattacharya and Momaya (2009). Shang and Sui Pheng (2014) ranked a lack of training the 7th most critical barrier in implementing lean philosophy in the Chinese construction industry. Insufficient investment was ranked 3rd in our study. This finding seems to agree with Bhattacharya and Momaya (2009), who also ranked this factor 3rd. This study found employee's resistance and lack of LSS knowledge to have low driving power. Shang and Sui Pheng (2014) also ranked these two factors lower in their study. On the other hand, Salonitis and Tsinopoulos (2016) ranked lack of information sharing to be one of the most critical barriers.

From the above discussion, it can be said that, although this study provides a general framework to identify and rank barriers in implementing LSS, there are opportunities for further studies in the context of other industries and countries. The barriers that have been found to be most critical in one industry or one country may not be that influential in other industries or countries.

6. Limitations to this study

In this study, we developed a comprehensive framework to determine the barriers to implementing LSS. The model has been tested and verified using a case study on an apparel company in Bangladesh. A limitation of a study is that the results can be limited in scope in terms of applicability in the context of other industries or other countries. However, as we used the expert opinions about the importance of barriers from 35 professionals in different industries to generate the findings and used the Pareto chart to prioritize the barriers, the results have become quite generalizable. However, some discrepancies can be expected in the findings of other studies conducted in other countries. For example, Kumar, Luthra, Govindan, Kumar, and Haleem (2016) identified twenty-one barriers in implementing six sigma in the Indian construction industry. Although they found a lack of top management support to be the most important barrier similar to our studies, dissimilarities in other barriers are present. Discrepancies in identifying the barriers from our study can also be seen. Similarly, Salonitis and Tsinopoulos (2016) studied barriers of lean implementation in the Greek manufacturing industry found workforce-related issues such as lack of LSS knowledge and lack of communication (lack of information sharing) to be the most critical barriers whereas workforce-related barriers ranked lower in our study.

However, the framework we developed can be applied to identify the LSS barriers in any context. Future research studies can use the framework we presented to identify and rank the barriers in other industries and/or other countries. Future studies can also enhance the results of this study with the development of a more comprehensive model with the collaboration of multiple stakeholders involved in the implementation of LSS with diverse disciplines of knowledge. Furthermore, multiple companies from different manufacturing industries can be studied to see how barriers differ between different industries.

7. Conclusions

LSS is a powerful approach that aims to reduce waste in manufacturing organizations across the supply chain. This study developed an ISM model to examine key barriers to LSS implementation. This study provides several theoretical contributions in the field of lean six sigma, such as:

1. A framework for identifying and ranking barriers to lean six sigma implementation. This framework can be used to identify barriers to LSS in other industries and other countries.
2. The driving and dependence powers of the barriers to LSS implementation using MICMAC analysis.
3. Identification of critical barriers to LSS implementation in the Apparel Industry of Bangladesh.

The findings of this study can guide managers in the manufacturing industry to focus on issues essential to supporting the implementation of LSS concepts across the supply chain. Managers usually have limited resources to work with. Removing barriers requires a financial investment. Thus, focusing on all barriers is not possible. This study informs managers about the criticality of each barrier. Classifying barriers by their driving and dependence power means that managers only need to focus on barriers with high driving power and low dependence power. Focusing on these barriers and working to remove them will automatically affect other barriers, ensuring efficient use of financial resources.

The ISM model provides contextual relationships among barriers to LSS implementation. The ranking of barriers is significant for LSS implementation in an emerging economy. Lack of executive management involvement was the most significant barrier found in this study. Lack of information sharing, lack of training, and insufficient investments were also important barriers requiring attention in order to implement LSS. All barriers mentioned in the ISM model must be addressed by managers.

A valuable addition to the current work would be the addition of a Total Interpretive Structural Modeling (TISM) which clarifies both nodes and relations in a digraph. TISM can provide a better indication of related factors when theory building. Besides using the TISM method in examining the barriers to LSS implementation, other methods such as the analytic network process or decision-making trial and evaluation laboratory may be applied. The model developed in this work can be used for the analysis of LSS implementation barriers in other industrial sectors, such as automotive, manufacturing, pharmaceuticals, leather and cement. Future studies can address this issue by studying the barriers of LSS in other industries and other countries.

Table A1
Profile of the Babylon group.

Factory Name	Babylon Garments Ltd.
Head office Address	Babylon Group, 2-B/1, Darussalam Road, Mirpur, Dhaka-1216, Bangladesh
Factory Type	Woven Garments (Top)
Factory space	Total 1,63,000 SFT
Production area	Total 1,03,000 SFT
Total worker Strength	Total:- 2011; Male: 913; Female: 1198
No. of Production lines	15 lines
Products	Men's Shirt, Ladies Blouse and Boys' Shirt
Production Capacity	35,000 Dozen / Month
Main Buyers	ASDA (George), TARGET AUS, Cherokee, Topman, s. Oliver, VF Asia (Nautica), PVH, PERRY ELLIS, H and M, Debenhams
Buyers name with % of production	ASDA (George) – 25%, H and M – 15%, Tesco – 10%, Target AUS–10%, Debenhams – 10%, s. Oliver – 10%, VF Asia-10%, Others-10%
Production process	Cutting, Sewing, Finishing and packing
Business %	USA:- 20%, Europe:-50%, Others:- 30%
Total Machinery	Sewing – 940; Others – 125. Total: 1065
Export Market	U.S.A., Europe, Canada, South Africa, Japan, Australia

Table A2
Questionnaire Format for Data Collection.

Q1: What is your educational background & institution name?
Q2: What is your working experiences?
Q3: What is the company's main area of activity?
Q4: Is your factory certified by accord/alliance?
Q5: Do you have any professional training on lean/lean six sigma?
Q6: Was the lean six sigma implementation done by your company?
Q7: What are the barriers do you think about the implementation of lean six sigma in the supply chain?

Authors contribution

All the authors contributed in this article.

Appendix A

See Tables A1 and A2

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