Examining Barriers to Lean Six Sigma Implementation in Supply Chain: A Case Study

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CERTIFICATE OF APPROVAL

The project titled "Examining Barriers to Lean Six Sigma Implementation in Supply Chain: A Case Study" submitted by Md. Anwar Hossen, Student No. 0412082120, Session - April 2012, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management on September 19, 2018.

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CANDIDATE'S DECLARATION

It is hereby declared that this project or any part of this has not been submitted elsewhere for the award of any degree or diploma.

Md. Anwar Hossen

This Work is Dedicated to My Parents

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List of Abbreviations

LSS	: Lean Six Sigma
RMG	: Ready Made Garment
TPM	: Total Productive Maintenance
ISM	: Interpretive Structural Modeling
TISM	: Total Interpretive Structural Modeling
SSIM	: Structural Self Interaction Matrix
TQM	: Total Quality Management
CI	: Continuous Improvement
RM	: Reachability Matrix
MICMAC	: Cross Impact Multiplication Applied to Classification
SME	: Small Medium Entrepreneur
FMEA	: Failure Mode Effective Analysis
SWOT	: Strength Weakness Opportunity Threat
SC	: Supply Chain
JIT	: Just In Time
CM	: Cellular Manufacturing
5S	: Five 'S'
VSM	: Value Stream Mapping
EB	: Examining Barrier
DMAIC	: Define Measure Analyze Improve Control
TPS	: Toyota Production System

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Abstract

The readymade garment industry is the main dominating business sector of Bangladesh. To achieve operational excellence in the readymade garment industry, lean six sigma (LSS), a process improvement tool, has become popular among practitioners. In this thesis, barriers to LSS the apparel supply chain of Bangladesh have been addressed. Ten barriers to LSS were identified from the review of literature and managers' feedback. The interpretive structural modeling (ISM) technique was used to examine the contextual relationships among the barriers. MICMAC (Matriced' Impacts Croise´s Multiplication Applique´e a´ unClassement) analysis was also conducted to classify the barriers based on the driving power and dependence among them. The findings reveal that a lack of top management commitment and support and lack of training and education are the most significant barriers to LSS implementation in the apparel industry context. This study is expected to guide practitioners in implementing LSS in the apparel supply chain of Bangladesh.

Chapter 1
Introduction

1.1 Introduction

In modern business world, companies around the globe are facing increased competition, and are looking ways to reduce cost, lead time and to increase the product quality. LSS strategies can serve this purpose for manufacturing organizations across the supply chain, and can help acquire and retain competitive advantage (Alhuraish et al., 2017). LSS approaches to business process improvement help companies distinguish themselves from competitors by manufacturing products with less waste and at the lower cost. LSS is a methodology to improve efficiency and gain the competitive edge. Today, organizations are using different tools and techniques sustain local and global competition.

Currently, six sigma tools and lean management are recognized as the most popular continuous improvement initiatives and companies are using them widely (Costa et al., 2018; Steere et al., 2018). LSS project initiatives start with understanding the current state of the business processes in the organization, and then setting up targets for the future state of all activities. Six sigma uses DMAIC (define, measure analyze, improve, and control) framework and lean uses tools like value stream mapping, 5S program, single piece flow. Using these tools and techniques, organizations can improve their business processes. The obstacles to achieving these improvements can be addressed by kaizen event (Chalamcharla & Kunte, 2012).

With an aim to increase productivity in a manufacturing environment, LSS is gaining popularity among Bangladeshi industrial practitioners. The goal of this thesis is to introduce a framework of barriers to LSS implementation for the readymade garment industry of Bangladesh.

Identification and analysis of LSS implementation barriers in the textile and apparel supply chain (Sreedharan and Raju, 2016; Hodge et al., 2011) are essential. In this research, the interpretive structural modeling (ISM) approach has been used to explore the interactions among most significant LSS implementation barriers in supply chains. This study will deliberately select a case company from Bangladesh for testing the ISM framework of barriers to LSS in the apparel supply chain.

1.2 Objectives of the Present Work

The purpose of this thesis is to examine barriers to LSS implementation in the apparel supply chain of a company of Bangladesh. The objectives of this study are:

1. To identify barriers to implementation of LSS in supply chains.
2. To investigate the causal relationships among barriers through formulating an ISM model.

1.3 The organization of the Thesis

This thesis consists of six chapters including this one. The chapters are structured in the following way:

Chapter 1 gives the motivation and objectives of this thesis.

Chapter 2 illustrates the literature review of lean six sigma and supply chain management, barriers to LSS implementation in supply chains, and an overview of the apparel sector of Bangladesh.

Chapter 3 gives the research methodology. Also, an overview of ISM method and MICMAC methods is illustrated.

Chapter 4 presents an industrial case study with the application of interpretive structural modeling (ISM) method.

Chapter 5 provides results and discussions.

Chapter 6 gives conclusions and recommendations for the future research.

Finally, references and appendix are presented at the end of the thesis.

Chapter 2
Literature review

2.1 Lean six sigma and supply chain

Lean is a systematic method of waste minimization (Thomas, Sherman, & Sawhney, 2018). A lean system can be defined as "a systematic approach to identify and eliminate waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection". It is based on the Toyota Production System (TPS) that produces products according to the customer requirements with minimum waste (Shingo, 1996). World class best practices (e.g. minimum inventories, high production volume, small continuous improvement etc.) enable reducing wastes and maximizing the efficiency (Raj & Attri, 2010). On the other hand, the six-sigma improves product quality by reducing variability in the processes (Costa, Silva, & Ferreira, 2017). Combining lean and six-sigma technique, known as lean six sigma (LSS), can contribute to improve quality, reduce process variations, and remove non-value added activities (Alhuaish, Robledo, & Kobi, 2017;de Freitas, Costa, & Ferraz, 2017).

LSS implementation synergizes the strengths of both Lean and Six-sigma. LSS increases revenue as well as reduces costs. It helps every individual of a company or factory to make them successful at their work. LSS develop human resources to improve the productivity and professional effectiveness. Workforces trained with LSS can identify and systematically remove bottlenecks, wastes (e.g., non-value-added activities), and process variations of the system. Hence, implementation of LSS facilitates quality assurance and developments of the business. Therefore, LSS can enhance supply chain performance (Lad 2013).

LSS implementation requires an integrated approach to achieve the total leanness of the system (Parveen and Rao (2009)). The nature of the market also impacts the lean approach. Lean tends to increase demand stability by simplifying, optimizing and streamlining the supply chain. A streamlined supply chain ensures smooth operations and on-time delivery (Gunasekaran et al., 2001).

Nevertheless, there are few researches in the literature describing the benefits and limitations of six-sigma applications in a supply chain. A formal investigation of the prospective applications and challenges of LSS implementations can help companies to benchmark LSS tools and techniques, fundamental metrics, potential savings and reasons for potential failures etc. (Amer et al., 2007). Implementing LSS is recently getting increased attention among stakeholders in the apparel industry of Bangladesh. It is important to recognize barriers to implementing LSS in the supply chain of an enterprise. Interpretive structural model (ISM) can be applied to examine the contextual relationships among barriers (Ali, Arafin, Moktadir, Rahman, & Zahan, 2018). In following sections, the barriers identification and ISM methodology are discussed in details.

2.2 Barriers to LSS implementation in supply chain

There are a numbers of barriers that may hinder implementing LSS in supply chains. Implementing LSS is related to various issues, such as planning and decision making, behavioral issues, technical issues and so on. In doing the literature review, a number of barriers to LSS implementation are identified as discussed below.

- **Lack of information sharing or communication with stakeholders**

Material flow and information flow are the two main flows that need to be studied in LSS implementation. The information flows in the manufacturing process are important considerations for LSS implementation in the supply chain. Sharing and coordination of information are useful for implementing LSS across the supply chain (Jadhav et al. 2014; Bharosa,Lee, & Janssen, 2010).

- **Lack of top management commitment and support**

Top management commitment enhances the importance of effective cross-functional communication flows for new product performance (Albliwi et al., 2014; Rodríguez, Pérez, & Gutiérrez, 2008). Top management commitment and support are crucial when applying LSS in the supply chain.

- **Lack of training and education**

Education and training are important for any organization to incorporate any kind of change, modification, innovation or process improvement (Habib & Wazir, 2012). LSS training and education play a vital role in implementing LSS in organizations. Training is part of the communication process to make definite that leader and staffs work together to implement LSS successfully (Albliwi et al., 2014).

- **The lack of resources to invest/financial constraints**

Financial support in today's business world is a significant issue for the LSS project application. Financing any project is essential for productive and actual application of any industrial engineering tools (Kumar and Kumar, 2014).

- **Poor facility planning and layout**

The facility planning and layout is one of the important parts for LSS implementation in the supply chain (Arasanipalai et al., 2014). The layout of facilities can influence the production time and cost in projects (Li & Love, 2000). Sudden changes of planned layout will cause the feeding problem for producing a new item, which may obstruct in LSS implementation.

- **Organizational cultural difference**

Every organization has a unique culture and work environment. There are cultural factors related to the workplace that impact the implementation of LSS. Advances in culture make a set of performance principles and social environment that set organizational aims. On many occasions, workers fail to adapt to new policies and practices related to LSS implementation (Knapp, 2015).

- **Organizational infrastructure**

The infrastructure required for an LSS development usually contains a team, a LSS leader, and a standard operating procedure (De Koning et al., 2006; Pande et al., 2000). The six sigma administrative team is usually established in the existing organizational structure. With such basis, the application of any quality development instrument can take place inside the usual regular procedure of the organization. Organizational infrastructure managerial processes can enable management to manufacture excess product out of invested resources (Gutierrez-Gutierrez et al., 2016; Lev, 2002).

- **Employee's resistance**

Any change or modification in individual habits needs efforts to adapt to the change and therefore fall out of the individual's comfort area. Employees' attitude and the steps taken by the top management to adapt the employees to the new environment determines the success of an organizational change (Shokri et al., 2014; Zhang et al., 2016; Oreg & Berson, 2009). During change in management, a regularly encountered difficulty is the absence of employees' interest to the change. Therefore, addressing employees' resistance is critical to LSS implementation in the supply chain system.

- **Lack of knowledge about lean six sigma**

In practice, the understanding of how the LSS works is an important factor to implement LSS in any organization. LSS reduces the cost due to poor quality products, improves the bottom line results and creates value for both customers and stakeholders through continuous improvement (Albliwi, Antony, Abdul Halim Lim, van der Wiele, & Management, 2014). To apply the LSS, it is absolutely vital to have an in-depth understanding of the ideas related to LSS.

- **Lack of supervision from line managers**

Lack of supervision from line managers has different and adverse effects on implementing any project in an organization. Ineffective supervision from line managers is one of significant factor that has significant impact on productivity (Islam & Adnan, 2016). Strict supervision and guidance from line managers are crucial for implementing lean six sigma across the supply chain.

- **Cross-functional conflict**

Constructive conflicts may sometimes result in manufacturing process improvements. However, any gap in communication or poor coordination may lead to conflict among cross-functional team members, which may slow down the LSS implementation for an organization.

Poor coordination between the functional departments is one of the most important barriers that should be properly addressed (Jadhav, Mantha, Rane, 2014).

- **Slow response to market**

Current business market is competitive. Some managers may be incapable to responses to variations in product design, product mix, or large demand volumes, customer planning changes, incapability to meet the plan and unbalanced demand. These factors lead to slow response to market (Jadhav et al., 2014).

- **Poor sales forecasting**

Sales forecasting has now become backbone of business industry due to change in the nature of business operations (Abbas, Shahzad, & Sarwar, 2017). Poor forecasting and the absence of a precise forecasting are method might result in the incapability of the company to make delivery to customers as required.

- **Absence of a sound action or planning system**

Availability of resources with a particular quantity and of particular quality at particular position is essential for successful LSS implementation in the supply chain. Written action plan and clearly defined roles and responsibilities of managers and workers on LSS implementation may help to smooth out the LSS journey across the supply chain (Snee, 2010; Dahlgaard and Daghlgaard, 2006).

- **Technological barriers**

Modern technology characterizes the high-end fashion market. In the apparel industry, technology is updating day by day. The use of manual process and machinery in factories results in low productivity and poor quality. High technology and modern machinery results in higher productivity. However, the high cost of advanced technology is a barrier to lean or six sigma implementation in an enterprise (De Souza and Pidd, 2011; Desale et al. 2013).

Chapter 3
Methodology

3.1. Proposed Research Methodology

To fulfill the objectives of this study, at first the existing literature on LSS implementation in supply chain practices was examined and a number of consultation sessions were arranged with experts from the apparel supply chain of Bangladesh. From the outcomes of reviewing the current literature and opinions from the experts of the apparel supply chain of Bangladesh, the most influential barriers to LSS implementation practices were selected in the field of the apparel supply chain of Bangladesh. In this work, ten barriers were identified from the professionals' feedback. The selected LSS implementation barriers for examining interrelationship, we applied ISM methodology. MICMAC examination has been used to bring out the cataloging of variables created on their driving power and dependence power. Considerate of these variables and their appropriate connection can help organizations to make calculated and planned decisions further helping in formula construction.

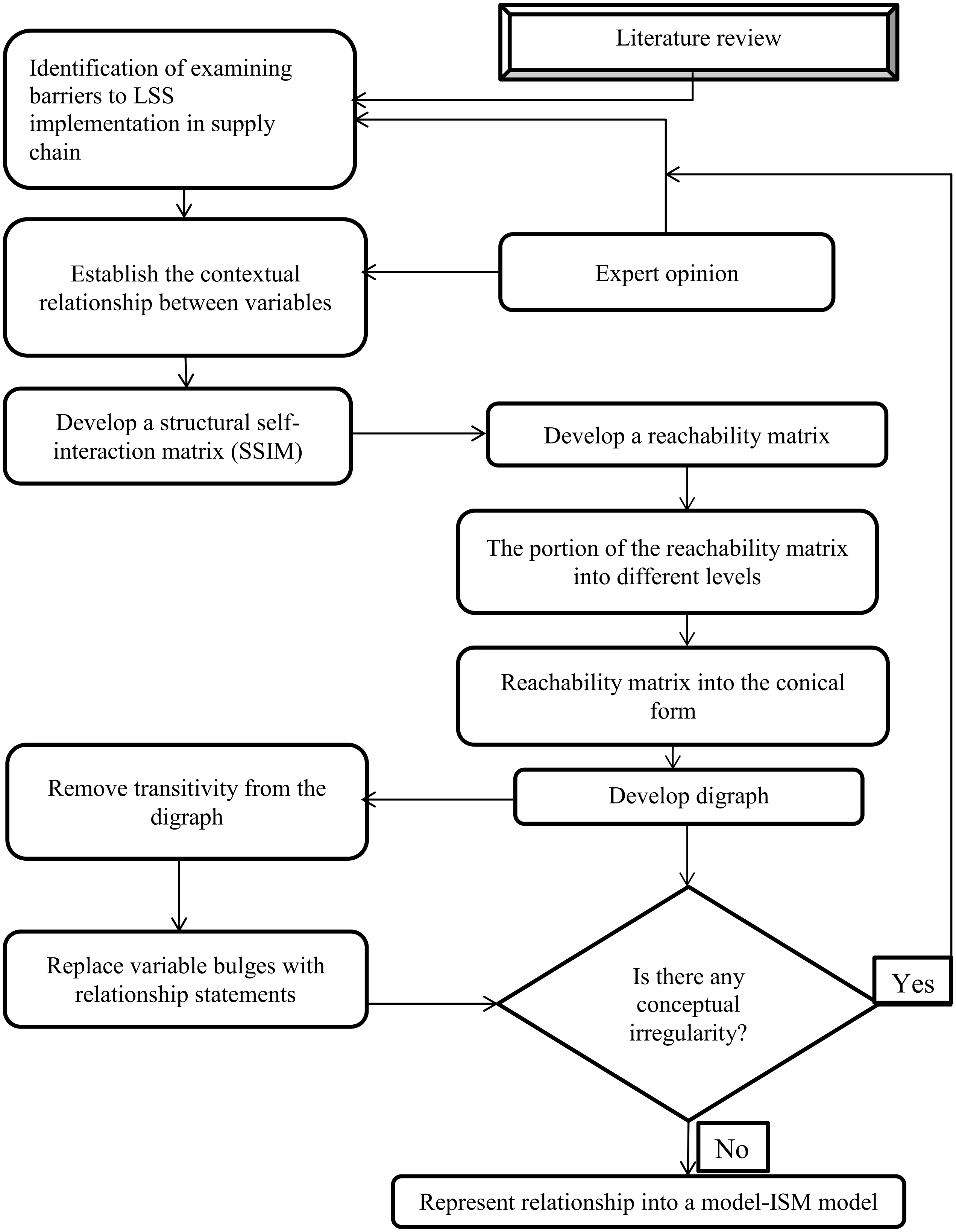

Fig 3.1 ISM based methodology

3.2 Interpretive Structural Modeling (ISM) Methodology

3.2.1 ISM

ISM is a process aimed at supporting the human being to better understand what he/she trusts and to identify obviously what he/she does not know (Attri, Dev, & Sharma, 2013). Its necessary function is organizational. The ISM process changes unclear, unwell expressed emotional models of systems into evident and well-defined models. ISM is a cooperative education method where a set of dissimilar openly and secondarily connected fundamentals are organized into a complete organized model. ISM is a firm method for classifying interactions among particular objects, which explain a subject or a factor. For any complex problem under consideration, a number of factors may be related to an issue or problem. However, the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor taken into isolation (Attri, Dev, & Sharma, 2013).

Therefore, ISM progresses visions into cooperative identifications of these associations. The difficulty of the matters or methods is due to the existence of a huge amount of essentials and connections among these fundamentals. 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. It develops problematic to the arrangement with such a method in which construction is not obviously clear. Hence, it requires the progress of a procedure which supports in classifying a construction inside a method. Interpretive structural modeling (ISM) is a well-established methodology that identifies relationships among items that define a problem or an issue (Sanjay & Ravi, 2005).

In this approach, some notions of graph theory is used to explain complex relationships among a set of variables. (Ravi, Shankar, Tiwari, & Management, 2005). ISM provides a mean 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. The presence of directly or indirectly related factors complicates the structure of the system, which may or may not is articulated in a clear manner. A system whose structure is not defined clearly is difficult to deal with. Hence, the development of a methodology that aids in identifying an inter-relationship structure within a system is necessary

(Pandey, Suresh, & Ravi, 2005). ISM is an interactive process that structures the set of related factors into a comprehensive systematic model (Singh, Garg, Deshmukh, & Management, 2007). Provided a multi-objective decision model using interpretive structural modeling (ISM) based approach to enrich and initiate LSS implementation barriers in the apparel supply chain of Bangladesh.

A 8 step procedure is used to develop a model using ISM (Ravi et al., 2005). The steps are:

Step 1: The barriers to LSS implementation in the supply chain are listed from literature review and industrial experts' feedback. ISM procedure proposes the practice of several organization methods such as brainstorming, insignificant group method, etc. in developing the relative connection among the variables.

Step 2: A contextual relationship is established among the variables identified in step 1. For this determination, professionals from the manufacturing and academia should be referred in recognizing the nature of appropriate connection among the issues. Through brainstorming and group discussion technique, which is a process of ISM methodology helps to develop the contextual relationship between barriers.

Step 3: A structural self-interaction matrix (SSIM) is developed for variables to indicate pairwise relationships among the variables of the system. These professionals from the manufacturing and academia would be found familiar with the difficult less attention. For evaluating the issues, an appropriate connection of 'leads to' or 'inspirations' type need be selected. This means that one issue inspires another issue. On the basis of this, the contextual connections between the recognized issues are established. Keeping in mind the contextual relationship for each issue and the reality of a connection between any two factors (i and j), the ways the issues are connected are determined. The four symbols denoting the direction of relationship between two factors (i and j) are:

(a) V indicates the influence of factor in factor j

(b) A for the influence of factor j in factor i

(c) X for mutual influence of factors i and j.

(d) O for no influence

SSIM is developed based on the contextual relationship. SSIM must be finalized by obtaining consensus from a group of experts.

Step 4: In this step and initial reachability matrix is developed. The four symbols (i.e., V, A, X or O) of SSIM is converted to 1s or 0s in the initial reachability matrix. The rules of conversion are given in table 3.1.

Table 3.1: Rules of substitution

SSIM	(i, j) entry	(j, i) entry
V	1	0
A	0	1
X	1	1
O	0	0

Using these substitution rules the initial reachability matrix is prepared. 1* entries are included to filling the gaps in expert opinions in development of SSIM matrix.

Step 5: Reachability set and antecedent sets are developed from the final reachability matrix. The intersections of these sets are derived for all the factors. The levels of the different factor are determined. The highest level in ISM hierarchy are occupied by the factors for which the reachability and the intersection sets are the same. Once identified, top level factors are removed from further consideration. The same process is repeated until the level of each factor is found. The digraph and the ISM model are developed using these levels.

Step 6: In this step, by summing the factors of the same level across rows and columns of the final reachability matrix, the conical matrix is developed. The summation of 1's in the rows are the driving power and summation of 1's in the columns are the dependence power. Then driving power and dependence power are ranked by giving the highest rank to the factors with the highest sum in the rows and columns respectively.

Step 7: Using the conical matrix, the preliminary digraph including the transitive links is developed. By removing the indirect links, a final digraph is established. The digraph is a visual representation of the elements and their interdependences. The factors are positioned according to their level. .

Step 8: Digraph is converted into an ISM model by replacing nodes of the factors with statements.

3.2.2 MICMAC Analysis

Matrice d'Impacts Croisés Multiplication Appliquée á un Classeement (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MICMAC analysis is to analyze the driving power and dependence power of factors. MICMAC principle is based on the multiplication properties of matrices (Bhattacharya & Momaya, 2009). It is done to identify the key factors that drive the system in various categories.

The 'key factor' falls into the category of either independent or linkage factors. Based on their driving power and dependence power, the factors have been classified into four categories i.e. autonomous factors, linkage factors, dependent and independent factors.

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.

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

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

Independent factors: Exact opposite of dependent factors. These factors are strong in driving power and weak in dependence power.

Chapter 4
A Case Study

4.1. Application of Interpretive Structural Modeling (ISM) Method

The developed methodology has been applied to a real industrial case study and used to rank the major barriers to LSS implementation. The garments manufacturing factory, "Babylon Garments Ltd" is facing numerous obstacles to implementing LSS in the apparel supply chain. The case organization demands the identification of major barriers and the ranking of the barriers with strategic action plans for the smooth implementation of LSS practices. In this study, the major barriers are identified by the relevant literature and the previous studies. Using expert opinions ten barriers were selected. Then, the ISM methodology was applied for examining interrelationship among the selected LSS implementation barriers, provided a multi-objective decision model using interpretive structural modeling (ISM) based approach to enrich and initiate LSS implementation in the apparel supply chain of Bangladesh.

4.2 Interpretive Structural Model (ISM) Development

4.2.1 Establishing the Contextual Relationship between LSS Implementation Barriers in the Supply Chain

Ten barriers to LSS in the supply chain were identified through literature review and manager's feedback Table 4.1. The next step is to analyze the interrelationship between these barriers using ISM. Brainstorming and group discussion techniques, which are the processes of ISM methodology helps to develop the contextual relationship between barriers. Experts' choice leads to or influence the type of contextual relationship for analyzing barriers to LSS in the supply chain.

Table 4.1 Selected LSS implementation barriers with the identification code

Identification Code	Barriers
EB1	Lack of information sharing or communication with stakeholders
EB2	Lack of top management commitment and support
EB3	The lack of resources to invest/financial constraints
EB4	Lack of training and education
EB5	Poor facility planning and layout
EB6	Organizational cultural difference
EB7	Organizational infrastructure
EB8	Employee's resistance
EB9	Lack of knowledge about lean six sigma
EB10	Lack of supervision from line managers

4.2.2 Development of a Structural Self- Interaction Matrix (SSIM)

After identifying and enlisting the ten LSS implementation barriers in supply chain shown in Table 4.1. Through the literature review, and expert opinion on criteria survey sheet implementing LSS is getting attention to Bangladeshi industrial practitioners. This study will deliberately select a case company from Bangladesh for examining barriers to LSS implementation in the apparel supply chain of Bangladesh; the next step is to analyze the LSS implementation barriers. For this purpose, a contextual relationship of 'reaches to' type is chosen. This means that one objective reaches to another chosen. Based on this principle, a contextual relationship is developed Table 4.2. Some experts, from various industries, were consulted to assist in developing the contextual relationships between the objectives. Keeping in mind the contextual relationship for each, the existence of a relation between any two objectives (i and j) and the associated direction of this relations decided to analyze the objectives for the development of the SSIM. Singh et al. (2007) suggested four standard symbols, given below, to denote the direction of the relationship between the variables.

V: Criterion i will assist to reach criterion j

A: Criterion j will assist to reach criterion i

X: Criterion i and j will assist to reach each other

O: Criterion j and i are unrelated

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

Table 4.2 Structural self-interaction matrix (SSIM)

Objective Code	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

4.2.3 Development of the Initial and Final Reachability Matrix:

The SSIM was converted to initial reachability matrix. We used transitivity concept to get final reachability matrix and some of the cells of the initial reachability matrix are filled in by inference. If a variable 'i' is related to 'j' and 'j' is in turn related to 'k', then transitivity implies that variable *'i'* is related to *'k'*. The final reachability matrix is developed after incorporating the transitivity concept in Table 4.4 and is presented in Table 4.5 wherein entries marked with † show the transitivity.

Table 4.3 Initial reachability matrix

Objective Code	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 4.4 Final reachability matrix

Objective Code	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

4.2.4 Level Partitioning the Final Reachability Matrix

Once the reachability matrix has been created, it must be processed to extract the digraph (structural model). The reachability matrix is partitioned on the basis of the reachability and antecedent sets for each of the variables, and, through a series of iterations, these were grouped into various levels. Warfield & Cybernetics (1974) presented a series of partitions induced by the reachability matrix on the set and subset of different elements.

From these partitions, many properties of the structural model can be identified (Farris, Sage, & Engineering, 1975). Based on the suggestions (Farris et al., 1975; Warfield & Cybernetics, 1974) the reachability set and antecedent set for each objective were extracted from the conical form of the reachability matrix. The reachability set consists of the objectives, itself and the other which are reachable from those particular. For every column which contains 1 in the row is considered. The objectives that column represents is included in the reachability set. Similarly, the antecedent set consists of the objectives itself and the other which may reach the objectives. For every row which contains 1 in the column of considered. The objectives that row represents are included in the antecedent set. In the present case, the level identification process for the ten objectives was completed in seven iterations which are given below by the following Tables (Table 4.6, Table 4.7, Table 4.8, Table 4.9, Table 4.10 and Table 4.11).

Table 4.5: Level partition iteration 1

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	

Table 4.5 continued

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

Table 4.6: Level partition iteration 2

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
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	
EB9	EB9	EB1,EB2,EB3,EB4,EB5,EB6,EB9	EB9	

Table 4.7 : Level partition iteration 3

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
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	

Table 4.8 : Level partition iteration 4

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
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	

Table 4.9 : Level partition iteration 5

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
EB2	EB2,EB3,EB4	EB2	EB2	
EB3	EB3	EB2,EB3,EB4	EB3	V
EB4	EB3,EB4	EB2,EB4	EB4	

Table 4.10: Level partition iteration 6

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
EB2	EB2,EB4	EB2	EB2	
EB4	EB4	EB2,EB4	EB4	VI

Table 4.11 : Level partition iteration 7

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
EB2	EB2	EB2	EB2	VII

The final list of level partitions is given in Table 4.13. The identified levels aids in building the final ISM model. The first level issue is positioned at the top of the model and so on.

Table 4.12 Final list of level partitions

Level	Barriers No.	Barriers
I	EB10	Lack of supervision from line managers
II	EB7	Organizational infrastructure
	EB8	Employee's resistance
	EB9	Lack of knowledge about LSS
III	EB5	Poor facility planning and layout
	EB6	Organizational cultural difference
IV	EB1	Lack of information sharing or communication with stakeholders
V	EB3	The lack of resources to invest/financial constraints
VI	EB4	Lack of training and education/
VII	EB2	Lack of top management commitment and support

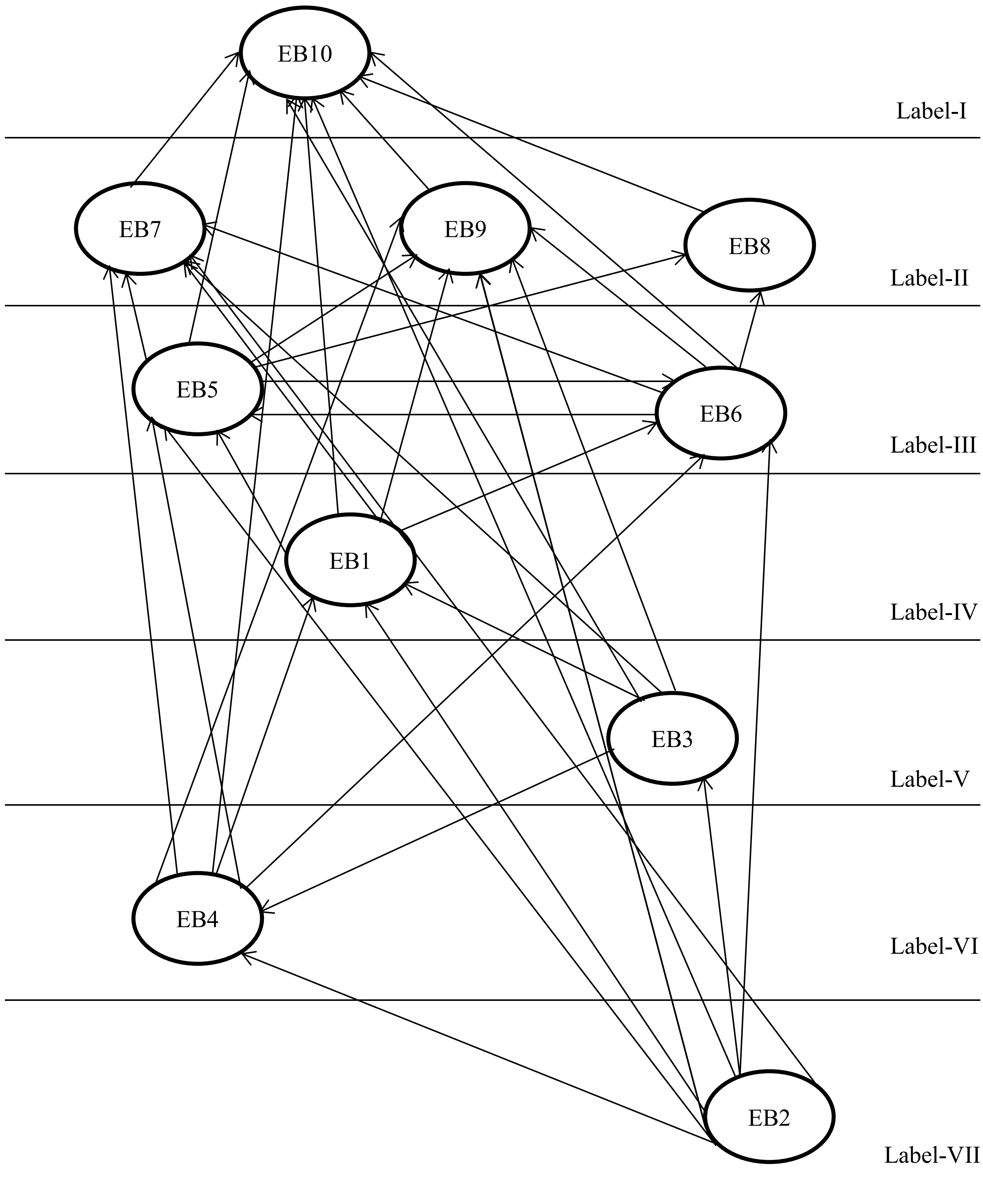

Fig.4.1 Final digraph

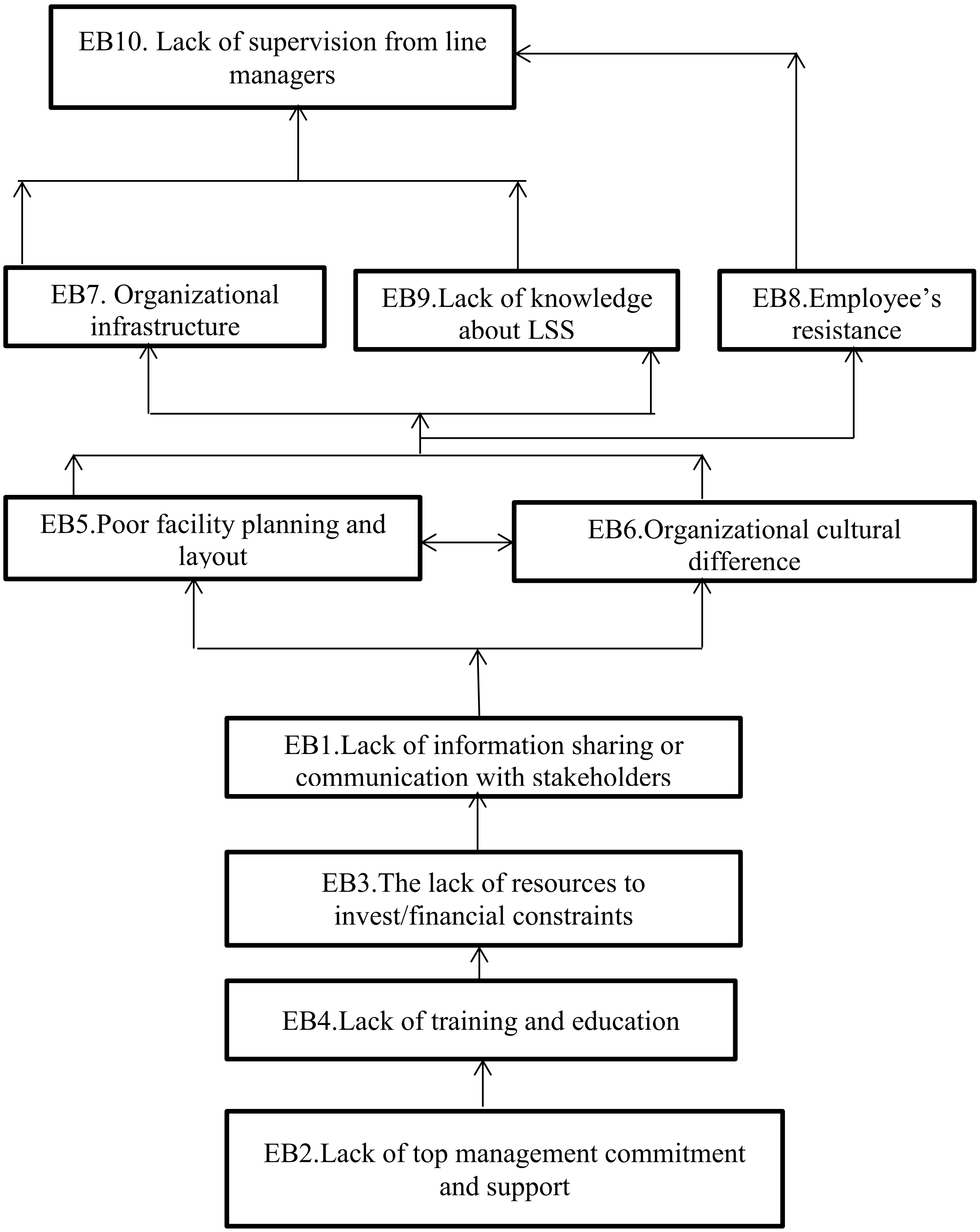

Fig.4.2 Proposed ISM model

4.3 MICMAC Analysis of Obtained Results

The MICMAC principle is based on the multiplication properties of matrices. The purpose of a MICMAC analysis is to analyze the driving and dependence power of the barriers to LSS implementation in the apparel supply chain of Bangladesh. The challenging issues of the dependence and the driving power mentioned in Table 4.5, an entry of '1' along the columns and the row identifies the dependence and the driving power, respectively. The driving power and dependence diagram is constructed as shown in Figure 4.3 Based on their driver and dependence power, the barriers, in this case, have been classified into four categories as follows:

- Autonomous issues
- Dependent issues
- Linkage issues
- Independent issues

Figure 4.3 shows that there is no linkage barrier seen in the driver dependence diagram. If these barriers are improved LSS implementation are will be more effective in the apparel supply chain of Bangladesh. If there are no linkage barrier then the LSS implementation will be obstruction free.

The next cluster is that of independent barriers that contain lack of information sharing or communication with stakeholders, lack of top management commitment and support, lack of training and education, the lack of investment and financial constraints, poor facility planning and layout and organizational cultural differences. These barriers are the main drivers for barriers in LSS implementation in the apparel supply chain. Management has to pay close attention to these factors to get fast and meaningful outcomes. The autonomous barrier contains employee resistance. These factors are reasonably isolated from the system and have few links, but those links may be strong. The last cluster is that of dependence barriers that contain organizational infrastructure, lack of knowledge about lean six sigma and Lack of supervision from line managers. This driver has weak driving power and strong dependence.

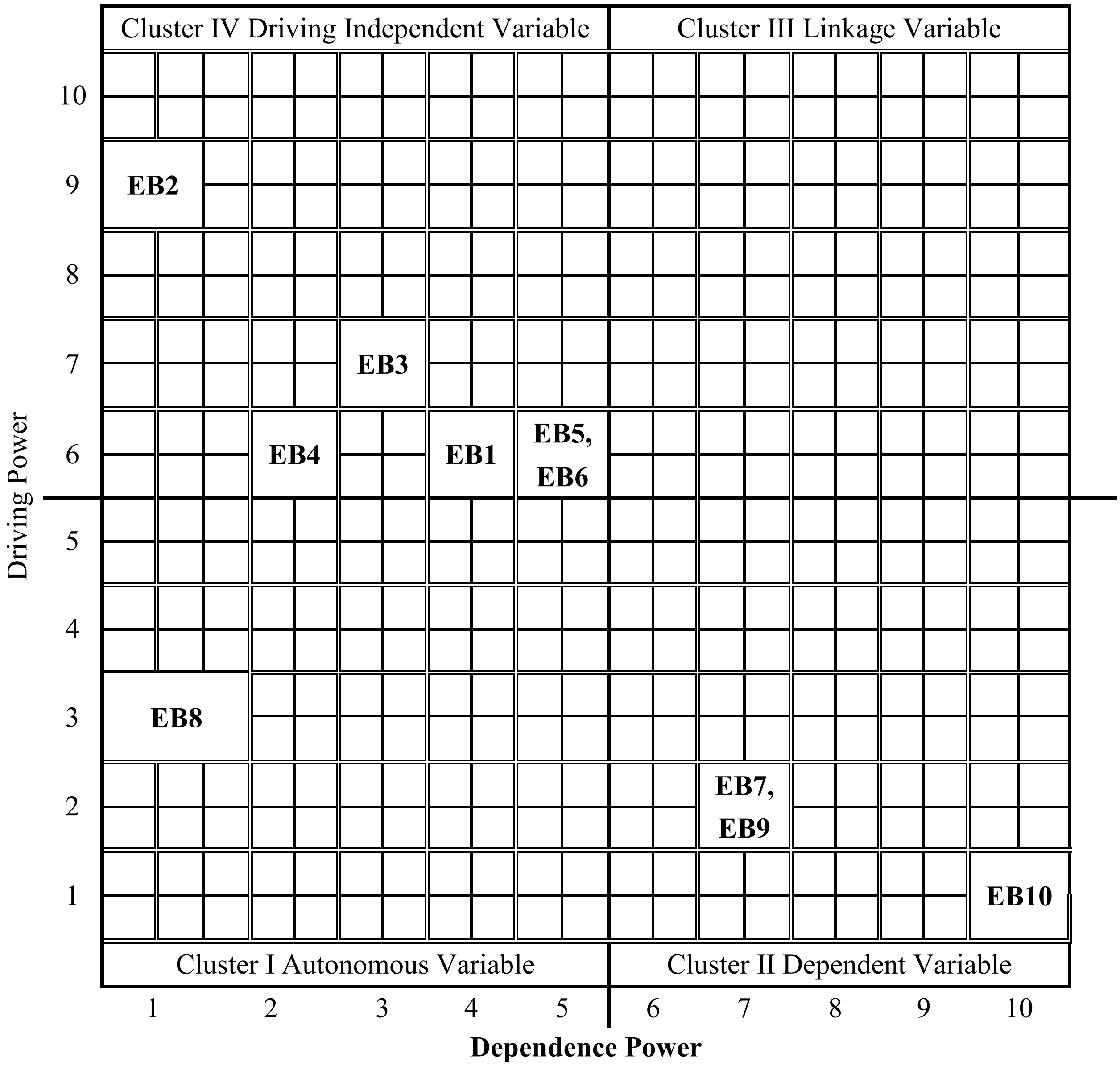

Figure 4.3 Driving power and dependence graph for barriers

It is observable from the ISM model and MICMAC analysis that, lack of top management commitment and support is the most independent issue in terms of its ability to drive other factors for achieving the final goal of implementing LSS in the supply chain. This factor appears in the bottom level in the ISM model.

Chapter 5
Results and Discussions

5.1 Results and Discussions

Successful implementation of LSS requires the proper and clear understanding of the barriers in the ISM framework. Lack of top management commitment and support (EB2) were found to be the most important barrier among all the selected barriers. Lack of top management commitment and support (EB2) showed high driving and low dependence power. Therefore, this barrier was leveled at the bottom of the hierarchical structure of the ISM framework. Lack of top management commitment and support (EB2) along with Lack of training and education (EB4) was positioned in level II and could play the role of key variables for implementation of LSS the apparel supply chain of Bangladesh.

These two barriers essential to be addressed in the first place to implement LSS. The next barrier placed in the level III is the lack of resources to invest/financial constraints (EB3). The barrier in the level IV is the lack of information sharing or communication with stakeholders (EB1). The next two barriers placed in the level V are poor facility planning and layout (EB5) and organizational cultural difference (EB6). The next three barriers placed in the level VI are organizational infrastructure (EB7), employees' resistance (EB8) and lack of knowledge about LSS (EB9). These barriers may hinder the implementation of LSS method. Finally, the bottom level discloses that barrier lack of supervision from line managers (EB10). This is the least influential barrier compared to other barriers in implementing LSS in the apparel supply chains.

Using MICMAC analysis, the barriers have been examined on the four boundaries based on driving power and dependence power. There are six barriers (EB2, EB3, EB4, EB1, EB5, EB6) under the independent barrier category. These barriers should be given utmost attention to implement LSS practices because the independent barriers have high driving power and low power. There was no linkage barrier in the system. There is one barrier (EB8) found under autonomous barrier in the system. These barriers are generated because of the autonomous drivers as dependent barrier are low in dependence and driving power. There are three barriers (EB7, EB9, E10) found under dependent barriers. These barriers are due to independent drivers as independent barriers are high in dependence and driving power. The proposed ISM model in this study will give managers a clear picture of the barriers that obstruct successful implementation of LSS in the apparel supply chain of Bangladesh.

Chapter 6
Conclusions and Recommendations

6.1 Conclusions

LSS is a powerful approach that shares common features aiming to waste reduction in the manufacturing organizations across the supply chain. This thesis has developed an ISM model to examine key barriers to LSS implementation in the apparel supply chain of a readymade garment company.

The ISM model has provided the contextual relationships among barriers to LSS implementation in the apparel supply chain of Bangladesh. The ranks of barriers are significant for LSS implementation in the emerging economy of Bangladesh. A lack of top management commitment and support is the most significant barrier found in this study. Lack of information sharing or communication with stakeholders, lack of training and education and the lack of resources to invest/financial constraints are also important barriers, which need attention to implement LSS in the apparel supply chain. To implement the LSS in the supply chain, all barriers mentioned in the ISM model need to be addressed by managers.

The findings of this study could be used to aid managers in the apparel industry to focus on important issues essential to support the implementation of LSS concepts across the supply chain.

6.2 Recommendations

This study has some limitations. The ISM only clarifies the nodes in a digraph. Further analysis can be conducted to enhance the model using total interpretive structural modeling (TISM), which clarifies both nodes and relations in a digraph. TISM can reflect a better idea of related factors for the purpose of the theory building. Besides using the TISM method in examining the barriers to LSS implementation, other methods such as decision making trial and evaluation laboratory or analytic network process may be applied. The model developed in this work can be used for analysis of LSS implementation barriers in other industrial sectors, such as the automobile, manufacturing, pharmaceuticals, leather, and cement industry.

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Appendix

Profile of the Babylon group

Factory Name	Babylon Garments Ltd.
Location/ Address	2-B/1, Darussalam Road, Mirpur, Dhaka-1216, Bangladesh.
Phone / Fax No.	88-02-9023495-6. Fax:- 88-02-8032949
Head office Address	Babylon Group, 2-B/1, Darussalam Road, Mirpur, Dhaka-1216, Bangladesh.
Phone / Fax No.	88-02-9023495-6. Fax:- 88-02-8032949
Contact Person	Mohammad Hasan Executive Director. Cell # 01713-013331 e-mail: hasan@babylon-bd.com
Phone No.	88-02-9023495-6
Distance from Airport	15 Km.
Year of establishment	1986
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
Seating capacity of the dining area	800
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%.
Weekly holiday.	Friday
No of working shift	1
Working hours	8 am to 5 pm
Lunchtime	1 hour
Pay period	1st to end the month
Payment Date	Within 7 working days of next month
Production process	Cutting, Sewing, Finishing and packing.
No of the building of their factory	1
Number of staircases	3
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.
Traveling time from airport to factory	1.00 Hours

Questionnaire and response:

Selection critraria of interviewers:

- Industrial engineering background
- Working as a manager
- Experience level at least 8 years in relevant field
- manager having at least one professional training an IE/lean

Manager-1	X1
Q-1	What is your educational background & institution name?
Answer:	B.Sc. (IPE),Shahjalal University of Science & technology
Q-2	What is your working experiences?
Answer:	8 years
Q-3	What is the company's main area of activity?
Answer:	Woven & Knit
Q-4	Is your factory certified by accord/alliance?
Answer:	Yes
Q-5	Do you have any professional training on lean/lean six sigma?
Answer:	Yes
Q-6	Was the lean six sigma implementation done by your company?
Answer:	Yes
Q-7	What are the barriers do you think about the implementation of lean six sigma in the supply chain?
Answer:	Lack of information sharing or communication with stakeholders
	Organizational infrastructure
	Employee's resistance
	Poor facility planning and layout
	The lack of resources to invest/financial constraints
	Lack of top management commitment and support

Manager-2	X2
Q-1	What is your educational background & institution name?
Answer:	B.Sc. (honor's) , National University
Q-2	What is your working experiences?
Answer:	15 years
Q-3	What is the company's main area of activity?
Answer:	Woven & Knit
Q-4	Is your factory certified by accord/alliance?
Answer:	Yes
Q-5	Do you have any professional training on lean/lean six sigma?
Answer:	Yes
Q-6	Was the lean six sigma implementation done by your company?
Answer:	Yes
Q-7	What are the barriers do you think about the implementation of lean six sigma in the supply chain?
Answer:	Lack of information sharing or communication with stakeholders
	Organizational infrastructure
	Employee's resistance
	Poor facility planning and layout
	The lack of resources to invest/financial constraints
	Lack of top management commitment and support

Manager-3	X3
Q-1	What is your educational background & institution name?
Answer:	B.Sc. (honor's) , National University
Q-2	What is your working experiences?
Answer:	15 years
Q-3	What is the company's main area of activity?
Answer:	Knit
Q-4	Is your factory certified by accord/alliance?
Answer:	Yes
Q-5	Do you have any professional training on lean/lean six sigma?

Answer: Yes

Q-6 Was the lean six sigma implementation done by your company?

Answer: Yes

Q-7 What are the barriers do you think about the implementation of lean six sigma in the supply chain?

Answer: Lack of top management commitment and support

The lack of resources to invest/financial constraints

Lack of training and education

Employee's resistance

Poor facility planning and layout.

Manager-4	X4
Q-1	What is your educational background & institution name?
Answer:	B.Sc. (honor's) , National University
Q-2	What is your working experiences?
Answer:	15 years
Q-3	What is the company's main area of activity?
Answer:	Knit
Q-4	Is your factory certified by accord/alliance?
Answer:	Yes
Q-5	Do you have any professional training on lean/lean six sigma?
Answer:	Yes
Q-6	Was the lean six sigma implementation done by your company?
Answer:	Yes
Q-7	What are the barriers do you think about the implementation of lean six sigma in the supply chain?
Answer:	Lack of top management commitment and support
	The lack of resources to invest/financial constraints
	Lack of training and education
	Employee's resistance
	Poor facility planning and layout

Manager-5	X5
Q-1	What is your educational background & institution name?
Answer:	B.Sc. (honor’s) , National University
Q-2	What is your working experiences?
Answer:	15 years
Q-3	What is the company’s main area of activity?
Answer:	Woven & Knit
Q-4	Is your factory certified by accord/alliance?
Answer:	Yes
Q-5	Do you have any professional training on lean/lean six sigma?
Answer:	Yes
Q-6	Was the lean six sigma implementation done by your company?
Answer:	Yes
Q-7	What are the barriers do you think about the implementation of lean six sigma in the supply chain?
Answer:	Lack of information sharing or communication with stakeholders
	Organizational infrastructure
	Employee’s resistance
	Poor facility planning and layout
	The lack of resources to invest/financial constraints
	Lack of top management commitment and support

Table A1 Experts' feedback on barriers to lean six sigma implementation in the supply chain

Respondent	EB1 Lack of information sharing or communication with stakeholders	EB2 Lack of top management commitment and support	EB3 Lack of training and education	EB4 The lack of resources to invest/financial constraints	EB5 Poor facility planning and layout	EB6 Organizational cultural difference	EB7 Organizational infrastructure	EB8 Employee's resistance	EB9 Lack of knowledge about lean six sigma	EB10 Lack of supervision from line managers	EB11 Cross-functional conflict	EB12 Poor sales forecasting	EB13 Slow response to market	EB14 The absence of a sound action or planning system	EB15 Technological barriers
Manager-1	●	●	●	●	●	●	●	●	●	●					
Manager-2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Manager-3		●	●	●					●						
Manager-4		●	●			●			●						
Manager-5		●		●					●	●					
Manager-6		●	●	●											
Manager-7		●	●	●						●					
Manager-8	●	●	●	●	●	●	●	●	●	●		●			
Manager-9	●	●	●		●				●						●
Manager-10	●	●		●	●		●	●	●	●					
Manager-11	●	●		●			●		●						

Table A1 continued

Manager-12		●		●			●		●						
Manager-13		●	●						●					●	
Manager-14		●	●						●						
Manager-15	●	●		●	●		●	●							
Manager-16		●		●					●	●					
Manager-17		●	●	●	●			●							
Manager-18	●	●				●	●		●	●					
Manager-19	●	●							●	●					
Manager-20		●							●	●					
Manager-21		●		●	●		●	●	●	●					
Manager-22		●			●		●	●	●	●					
Manager-23		●			●		●	●	●						
Manager-24		●					●	●	●						
Manager-25		●			●		●	●		●					
Manager-26		●			●			●		●					
Manager-27	●	●		●	●		●	●							
Manager-28	●	●		●			●								
Manager-29		●	●	●		●	●			●					
Manager-30		●	●	●			●								
Manager-31		●	●	●			●								
Manager-32		●		●			●								
Manager-33		●		●			●								
Manager-34		●				●	●	●							
Manager-35		●	●	●			●		●	●					
	11	35	15	22	13	7	22	14	21	16	1	2	1	2	1

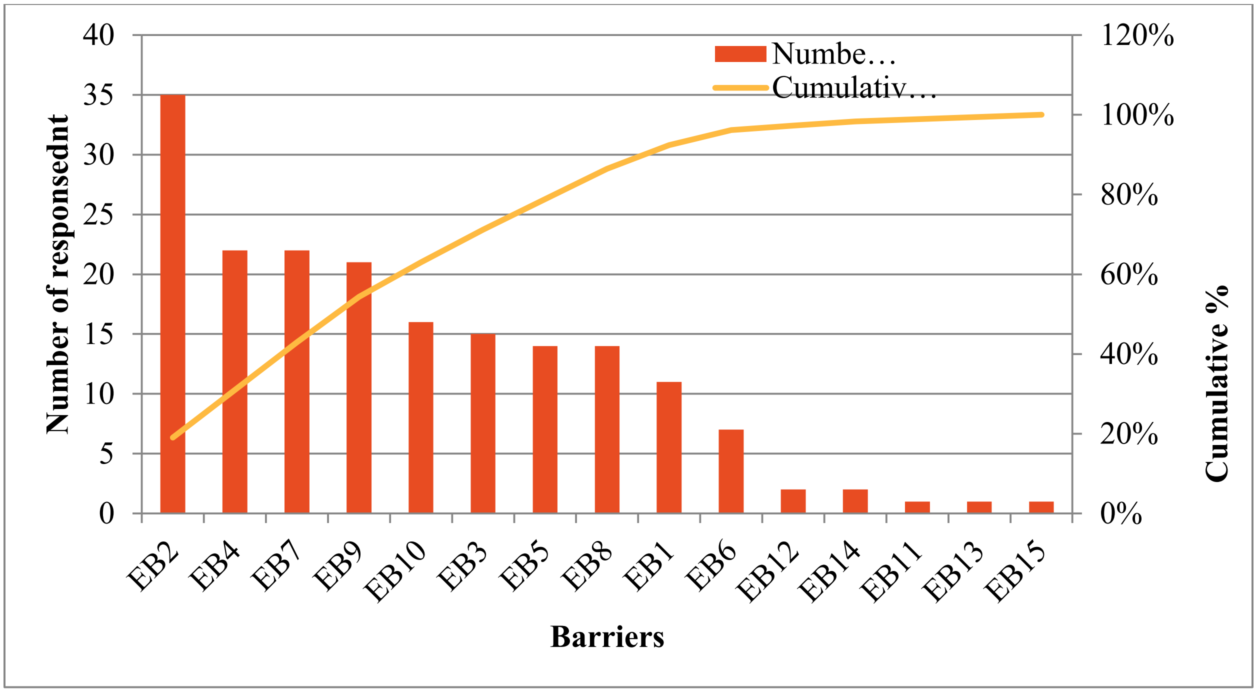

Figure. A1 Experts' feedback based selected barriers of lean six sigma implementation

Table A2 Experts' feedback based selected barriers of lean six sigma implementation

Cause	Number of Respondent	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%

DI matrix's is made based on manager feed back

Impact	High Impact-Low Difficulty	High Impact-High Difficulty
	EB1,EB3,EB4	EB2,EB4
	EB5,EB6,EB7,EB8,EB9,EB10	EB11,EB12,EB13,EB14,EB15
	Low Impact-Low Difficulty	Low Impact-High Difficulty
	Difficulty	

Figure. A2 Experts' feedback based selected barriers of lean six sigma implementation in the supply chain

List of the factories:

- Babylon Garments Ltd.
- Aboni Fashion Ltd.
- AKH Garments Ltd
- AKR Fashion Ltd.
- Fakruddin Textile Ltd.
- Babylon Casual Wear Ltd.
- Redisha Garments Ltd
- Dird Garments Ltd.
- Masco Garments Ltd.
- Oxford Shirt Ltd.
- IDS Fashion Ltd.
- Amman Garments Ltd.
- Al-Muslim Garments Ltd.
- Marks Design Ltd.
- Aboni Textile Ltd
- A-Plus Industries Ltd.
- The Finery Garments Ltd.
- AJI Apparels Industry Ltd.
- Esquare Garments Ltd.
- Abedin Garments Ltd