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Modelling and analysis of barriers affecting the implementation of lean green agile manufacturing system (LGAMS)

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Abstract

Purpose – Many types of research have already investigated the lean, green or agile manufacturing systems in a discrete manner or as combinations of two of them. In today's competitive scenario, if industry wants to perpetuate its name in the market, then it has to supervene proper thinking and smart approach. Therefore, the combination of lean, green and agile manufacturing systems can provide better and beneficial results. The purpose of this paper is to discern the barriers to the combined lean green agile manufacturing system (LGAMS), understand their interdependence and develop a framework to enhance LGAMS by using total interpretive structural modeling (TISM) and MICMAC (Matriced' Impacts Croise's Multiplication Appliquée a UN Classement) Analysis.

Design/methodology/approach – This paper uses TISM methodology and MICMAC analysis to deduce the interrelationships between the barriers and rank them accordingly. A total of 13 barriers have been identified through extensive literature review and discussion with experts.

Findings – An integrated LGAMS has been presented that balances the lean, green and agile paradigms and can help supply chains become more efficient, streamlined and sustainable. Barriers are identified while referring to all three strategies to showcase the clear relevance. TISM models the barriers in different levels showcasing direct and important transitive relations. Further, MICMAC analysis distributes the barriers in four clusters in accordance with their driving and dependence power.

Research limitations/implications – The inferences have been drawn from a model developed on the basis of inputs from a small fraction of the industry and academia and may show variations when considering the whole industry.

Practical implications – The outcome of this research can contribute to bringing the change to the manufacturing systems used in most developing nations. Also, top managers considering adoption of LGAMS can be cautious of the most influential barriers.

Originality/value – A TISM-based model of the barriers to an integrated LGAMS has been proposed with evaluation of the influence of the barriers.

Keywords Barriers, Total interpretive structural modelling (TISM)

Paper type Research paper

1. Introduction

The prior concerns for the industry are going to be a quality product, technological advancement conceding the erratic customer demands, non-fouling products and downsizing non-value added time. Despite the fact that espousing a new manufacturing approach is never an easy task, but if facing minor losses can bestow tremendous performance, then it is advised to adopt such methods. To accomplish the required actions, three approaches are used, i.e. lean approach, green approach and agile approach which are explained below.

The lean approach aims to diagnostically eat the problems and annihilated the radicle cause of undesirable waste which does not provide any value to the product as well as services (Jaiswal and Kumar, 2016). Lean cogitation is the basis for executing the modern

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techniques in service, manufacturing, industry and alteration to the lean state, behoove changes in the measurement system, accounting, and control (Darabi *et al.*, 2012). Čiarnienė and Vienažindienė (2013) have reviewed the research by George (2002) and Chen *et al.* (2010) and found that manufacturing companies are dealing with the pressure created by volatile demands of customer and market competition. The expectations of the clients can only be fulfilled through maintaining product quality, lowering casting time and abbreviating product price. Due to these reasons, industries are pressurized to adopt new technology to be competitive in the market, and that is where lean approach comes in.

In green approach, inputs provided for the process generation has squatty thump on the environment and is extremely productive with zero waste and spoliation. Examples of green practices are pollution reduction (minimal use of energy, solid waste and input material) and reuse and recycling (Ghazilla *et al.*, 2015). The successful implementation of this approach requires acceptance of unified three-step structure: planning for keeping it in the nucleus part, execution of green approach and acquainting and bolstering green approach and its profit to the stakeholders (Bhattacharya *et al.*, 2011; Mittal and Sangwan, 2014).

The agile approach is the way to be competitive in the market for surviving and booming in it (Gunasekaran, 1999), by responding firstly to the altering market, by keeping the priority of customer satisfaction and manufacturing the products as the client needs (Cho *et al.*, 1996). This approach is a new articulation, and it reflects the dexterity of a goods producer as well as the products and services to succeed in an ever-changing market environment and technological advancement (DeVor *et al.*, 1997; Sindhwani and Malhotra, 2013).

These methods have been investigated for the adoption and performance in the past literature either separately, or in a combination of any two, however, the combined lean, green and agile manufacturing system is the holistic view in line with triple bottom line, i.e. environmental, social and economic (Mittal *et al.*, 2017). The past literature reveals that these manufacturing systems have yielded immense benefits for the industry individually, so, it is expected that the performance of the manufacturing system can go manifold if LGAMS is adoption in manufacturing systems. However, the adoption of LGAMS in a synchronized manner is not easily done; it would face some challenges in the form of barriers, which are identified and investigated in the present research.

The objectives of this paper are as follows:

- to determine and inter-relate the barriers of LGAMS;
- to establish the mutual relationship, relative importance, and interdependence of each barrier with the help of TISM technique; and
- to examine the driving and dependence power of the barriers affecting LGAMS by using MICMAC analysis.

Further, the paper has been organized as follows: Section 2 provides the research background, Section 3 elucidates the barriers to LGAMS and Section 4 provides the methodology. Finally, results and discussion are presented in Section 5 followed by conclusion in Section 6.

2. Research background

2.1 Lean manufacturing (LM)

The term "Lean", in a manufacturing environment, describes a philosophy that incorporates a collection of tools and techniques into the business processes to optimize time, human resources, assets and productivity while improving the quality level of products and services to their customers (Becker, 1998). In other words, LM is an integrated system, which comprises of management practices that are applied to eliminate the waste and reduce the variability of suppliers, customers and processes (Anvari *et al.*, 2011; Shah *et al.*, 2008; Mostafa *et al.*, 2013). A non-exhaustive list of tools to implement LM: The Toyota Way

(Liker and Morgan, 2006), single minute exchange die (Dillon and Shingo, 1985), Value Stream Mapping (Jones and Womack, 2002), Just in Time, Kanban (Sugimori *et al.*, 1977), Poka-Yoke (Shingo, 1986), Total Productive Maintenance (Nakajima, 1988), etc. Further, in order to understand the relationship between lean principles and their effect on the performance of systems many researchers and practitioners have laid down enablers and barriers to the implementation of the LM system.

2.2 *Agile manufacturing (AM)*

AM has naturally evolved from the concept of LM. In LM, cost reduction is of utmost importance (Gunasekaran, 1999) while AM represents the capacity of a manufacturer of goods and services to thrive in the face of continuous change (DeVor *et al.*, 1997). So, the main driving force behind AM or only "agility" is change (Yusuf *et al.*, 1999). These changes can occur in different businesses and markets and in any other facet of a business enterprise (DeVor *et al.*, 1997). Technologies such as Standard for The Exchange of Products (STEP), hierarchical shop floor control system, virtual manufacturing, concurrent engineering and information and communication infrastructure, etc., play a prominent role in accomplishing AM (Cho *et al.*, 1996; Gunasekaran, 1999). AM should reduce manufacturing overheads, increase market share, satisfy the customer needs, smoothen rapid introduction of new products, eliminate non-value added processes and improve manufacturing competitiveness (Gunasekaran, 1999; Gunasekaran, 1998). However, adoption to AM is not an easy quest with barriers existing throughout its lifecycle, from evolution and execution to its maintenance and up gradation phases (Hasan *et al.*, 2007).

2.3 *Le-agile manufacturing system (LAMS)*

The manufacturing system is lean if it is achieved with minimal waste due to unwanted and the ineffective operations while the system is agile if it efficiently changes its operating states in retort to the ever-changing demands placed upon it (Al Samman, 2014). However, agility may or may not presume leanness, but both together are suited for the entire supply chain (Agarwal *et al.*, 2006). This resulted in the coining of a new production philosophy; Le-Agile (Naylor *et al.*, 1999). The implementation of LAMS consists of a short-term and a long-term phase. In the short term, the assessment and consecutive planning of the current state with respect to LAMS are undertaken while in long term, the plan is carried out and fully implemented (Elmoselhy, 2012).

2.4 *Green manufacturing (GM)*

GM encompasses all factors associated with environmental concerns in manufacturing by continuously integrating eco-friendly industrial processes and products. A heightened environmental awareness has led to consumers favoring eco-friendly products (Chuang and Yang, 2014). GM is also known by a plethora of different names or terms: clean manufacturing, environmentally conscious manufacturing, environmentally benign manufacturing, environmentally responsible manufacturing, sustainable manufacturing, or sustainable production (Sangwan and Mittal, 2015). Firms face multiple enablers which are influencing and/or forcing the system to adopt GM. These include competition among firms, governing laws, availability of efficient technology and incentives in the form of subsidies and tax exemptions provided by the government. These driving factors play an active role in the adoption and diffusion of GM in the industry (Mittal *et al.*, 2016). However, the implementation of GM in the industry is not an easy task because of many issues – limited financial and human resources, awareness about the environmental aspect of manufacturing, governmental policies, immediate impact on GDP, etc. (Mittal *et al.*, 2017).

2.5 Lean – green manufacturing system (LGMS)

LM minimizes waste material and power usage, as well as storage space and carrying expenses (Simpson and Power, 2005), while GM enhances the environmental performance in company's operations. Also, methods that support lean paradigm are related to the environmental performance factors (Duarte *et al.,* 2011). Integrating lean and green paradigms develops a composite system. The compatibility between lean and green paradigms represents a new way of thinking. Cost efficiency and environmental responsibility are not mutually exclusive; they are mutually enforcing (Duarte *et al.*, 2011; Mittal *et al.*, 2018). The lean system can more easily adapt the practices of a green system than companies that have not previously pursued leanness (Bergmiller and McCright, 2009).

2.6 Lean – green – agile manufacturing system (LGAMS)

Adoption of LM in a supply chain enhances profits through cost reduction, while AM maximizes profit by producing exactly what the customer wants and in GM sustainable and environmental policies must be addressed. The balance between lean, agile and green management paradigms are actual issues that can help supply chains to become more efficient, streamlined and sustainable (Carvalho and Cruz-Machado, 2011). This has given rise to a more advanced and integrated system, i.e. LGAMS as shown in Figure 1.

The adoption of the same would enhance the performance and effectiveness of the manufacturing system. The enablement of such new system is required to change the way the manufacturing is done. So, identification and analysis of LGAMS barriers are attempted in the present study.

3. Barriers to LGAMS

Thirteen barriers are identified through a review of literature and discussion with experts in the industry and academia. The development of these barriers is done while referring to lean, green and agile strategies to showcase the clear relevance of barriers. The descriptions of 13 barriers are mentioned below.

3.1 Lack of management commitment (B1)

Top managers, sometimes are not able to discern the probable benefits of LM. So, they show indistinct support for lean implementation (Jaiswal and Kumar, 2016; Nordin *et al.*, 2010; Achanga *et al.*, 2006). Support and dedication from the top management required are very much for the success of any planned program (Luthra *et al.*, 2011; Hamel and Prahalad, 1989; Zhu and Sarkis, 2007). Top management has the notable potential to effect, support the real genesis and Green initiative implementation across the organization (Sarkis, 2012). It plays a vital role in proffering constant shore up for GM approach in the strategic and action ideas for auspiciously implementing them (Ravi and Shankar, 2005). Similarly, support and

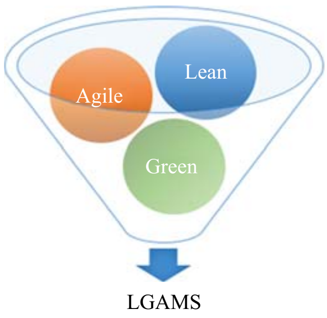

Figure 1.
Lean green agile manufacturing system

commitment from top management is essential for AM in order to build internal alliance and cooperation as attaining agility requires re-engineering business processes and adopting new organizational policies (Gunasekaran, 1999; Hasan *et al.*, 2007; Pan and Nagi, 2013; Mishra, 2014; Sindhwani and Malhotra, 2016a).

3.2 Fear and resistance to change (B2)

It can be difficult to implement LM if the organization is not well prepared to deal with the required changes (Čiarnienė and Vienažindienė, 2013; Sindhwani and Malhotra, 2016b). People of organizations, resist any changes in daily routine work and also trepidation comes amongst them because of unpredictable output (Hoffman and Henn, 2008). As AM is driven by dynamic changes in the organization environment, the organizations must be ready to undertake internal changes comprising of structural (e.g. equipment and system) and infrastructural (e.g. business practices) changes (Yusuf *et al.*, 1999; Ngai and Cheng, 1997; Hasan *et al.*, 2007).

3.3 Financial constraints (B3)

Implementation of lean means deconstructs the previous setup of plant and system, means high implementing cost (Čiarnienė and Vienažindienė, 2013). GM implementation needs a high investment, which is risky for every business leader. Also as AM is clientele's exaction based manufacturing, it needs a high budget for its implementation (Shankarmani *et al.*, 2012).

3.4 Lack of training and education (B4)

The organization must peruse the strength and capabilities of employees and should also teach them the ethics of lean (Jaiswal and Kumar, 2016; Camagu, 2010). In applying GM approach, it is necessary for both managers as well as employees, to have proper knowledge and training, then only green attitude can be maintained (Balasubramanian, 2012). It is observed that the output in AM is more sensitive to changes in human factors (skill, knowledge, attitudes and mental effort) rather than physical factors. In other words, implementation of AM is steered by human and behavioral factors (Gunasekaran, 1999). Due to high investment per employee, continuous workforce training and education must be delivered (Forsythe and Ashby, 1995; Forsythe, 1995; Pinochet *et al.*, 1996; Brown and Bessant, 2003; Hopp and Oyen, 2004; Irani *et al.*, 1997; Crocitto and Youssef, 2003; Hasan *et al.*, 2007).

3.5 Lack of government support (B5)

LM takes a long time to truly transform from the old technique to new technique. Any quick political changes can be a disaster for any reforming attempts (Aly, 2014). Organizations deal with the risk of uncertain future legislation as the plans they are implementing today may get affected in the future, if the government changes (Mittal and Sangwan, 2014; Seidel *et al.*, 2009; del Río González, 2005). Agility is inevitably influenced by external factors to the network and supply chain like government policies, trade regulations, inflation and overall health of the economy (Gunasekaran, 1998; Gunasekaran, 1999).

3.6 Volatile customer demand (B6)

Many organizations face the problem that their lean strategy is forestalled by growing unpredictable demands from the customers (Eswaramoorthi *et al.*, 2011). As many customers are unaware of green product benefits, so there can be variation from the customer side which is a problem for GM implementation (Luthra *et al.*, 2011; Mittal, 2013). Modern customers demand new innovative products and services without consideration of price. This is not only limited to varieties and quality but extends to new varieties to suit different tastes (Carvalho *et al.*, 2011; Sindhwani and Malhotra, 2016a).

3.7 Technological constraints (B7)

Each system works according to its features, motives and if changes occur, it can create implementation problem (Darabi *et al.*, 2012; Sindhwani and Malhotra, 2018). Change of technology means changes in organizational features, forms of authority, market operational strategy (Luthra *et al.*, 2011). Technology plays an important role in making an organization agile (Cho *et al.*, 1996). Technologies ranging from computer-aided design/ computer-aided manufacturing, robotics and www to electronic commerce require integration, support and skilled personnel to manage (Hasan *et al.*, 2007). Adoption and support of the above is a major financial step for any organization. Also, in AM customer feedback systems help integrate customer with the supply chain, which is possible only with appropriate tools, processes and technology (Uden, 2007; Moradlou and Asadi, 2015; Ngai and Cheng, 1997; Yusuf *et al.*, 1999; Storey *et al.*, 2005; Yusuf *et al.*, 2004).

3.8 Market competition (B8)

As many companies work in the manufacturing of customized products, so, implementation of LM for them becomes tough with the aspect of market competition (Mirzaei, 2011). Market uncertainty always acts as a barrier for new techniques. As GM requires innovations according to the green product, it is risky to implement innovated technology (Luthra *et al.*, 2011; Hosseini, 2007; Yu, 2007). Nowadays, the marketplace has turned into a battlefield with competitive priorities ranging from responsiveness, new product introduction, delivery, flexibility, quality to concern for the environment and international vying (Gehani, 1995; Sindhwani and Malhotra, 2015; Hasan *et al.*, 2007).

3.9 Improper communication (B9)

Sometimes slang is overused and it creates a lack of understanding for the staff (Čiarnienė and Vienažindienė, 2013; Radnor *et al.*, 2006). The communication structure used to implement GM approach is improper, which results in the inefficient base for GM implementation (Ghazilla *et al.*, 2015). In AM, due to the low bargaining power and the size of the companies, the relationship with the suppliers tend to be not as strong. Therefore, the lack of communication with the suppliers may result in company's isolation (Ismail *et al.*, 2007).

3.10 Lack of planning and strategies (B10)

In LM, it is necessary to plan properly, i.e., if a work is said to be done on a particular day, it should not be shifted on the next day, otherwise, it may create cataclysm atmosphere for the company. Methods should be clearly defined to search the particular knowledge required for LM operations. Each and every activity should be done according to the guidelines provided in the context of LM (Darabi *et al.*, 2012). Organizations lack in applying a proper strategy for product design and in setting proper green performance standards (Mutingi, 2013). Companies sometimes don't fully understand the drivers/enablers relevant to GM, so they lack in proper planning to adopt GM (Bhattacharya *et al.*, 2011). Before implementing GM, it is advisable to have a good background, work experience and risk profile of owner-managers, as the methods they will use to implement green approach will provide the base for the success of GM outcomes (Walker *et al.*, 2010; Redmond *et al.*, 2008; Walker *et al.*, 2008). For AM to be taken seriously, engineers need to work on the building blocks to achieve replicable and repeatable results from the initial principles. In order to avoid this, rational schedule comprising of defect-free processes must be developed and deployed (Mafakheri *et al.*, 2008; Sindhwani and Malhotra, 2013; Anand and Kodali, 2008; Sarkis, 2001; Storey *et al.*, 2005; Hasan *et al.*, 2007).

3.11 Inadequate data collection (B11)

Without an assessment of the effectiveness of changes implemented for LM, it can create a problem, i.e., whether the direction of progressing is right or not (Čiarnienė and Vienažindienė, 2013; Sindhwani and Malhotra, 2017b). There is a lack of efficacious GM progress measurement (Ghazilla *et al.*, 2015). Efficient measures for adaptability are to be required for agility. These measures will help in differentiating agility from other practices. This requires capabilities including an approach to developing, acquire, evaluate and upgrade upon these measures (Sarkis, 2001; Graves *et al.*, 1996; Sharp *et al.*, 1999; Hasan *et al.*, 2007).

3.12 Poor layout and infrastructure (B12)

As frequent design changes will be required for the LM implementation, it raises the cost, hence companies resist implementing LM (Eswaramoorthi *et al.*, 2011). There is a need of suitable additional infrastructure, where companies are lacking (Ghazilla *et al.*, 2015). Poor route planning, line imbalance, distant suppliers, poor layout and disorganized workplace can lead to transportation waste, forcing people to unnecessary motion (Sindhwani and Malhotra, 2015; Herron and Hicks, 2008; Dahlgaard and Mi Dahlgaard-Park, 2006).

3.13 Lack of mutual trust (B13)

In LM, the output is efficiently achieved only when mutual trust between management and employees is there. That is the view of lean thinking (Jaiswal and Kumar, 2016; Staudacher and Tantardini, 2008). This is a big barrier in front of an eco-friendly approach (Khiewnavawongsa and Schmidt, 2013). AM presents a threat to the managers due to the entitlement of product development teams and the unwanted increase in the flow of information. AM may fail to overcome the inertia of traditional practices. For this reason, elimination of any human points of failure is essential (Forsythe, 1995; Gunasekaran, 1999).

Table I presents various barriers identified through the survey of literature and discussions with experts from industry and academia along with their description as used in the present research.

Barrier No.	Barrier name	Self-description
B1	Lack of management commitment	The unwillingness of management for a particular step or lack of commitment towards a goal
B2	Fear and resistance to change	Resilience among employees or workers to adapt to new technology or work structure
B3	Financial constraints	Lack of funds or loss of business to/on adopting a new manufacturing system
B4	Lack of training and education	Irregular and Inappropriate training and guidance to employees/workers
B5	Lack of government support	Unsuitable government policies/laws and regulations
B6	Volatile customer demand	Irregular customer demand and preferences
B7	Technological constraints	Unavailability of the required technology or inability to harness it
B8	Market competition	Tough market and competitive atmosphere
B9	Improper communication	Lack of proper communication channels
B10	Lack of planning of strategies	Lack of intricate planning put into the strategies to adopt the new system
B11	Inadequate data collection	Inadequate data collection and performance management
B12	Poor layout and infrastructure	Poor industry layout and available infrastructure hinder progress
B13	Lack of mutual trust	Trust is the basis of a healthy work environment

Table I. List of LGAMS barriers along with their description (self-compiled)

4. Methodology

Interpretive Structural Modeling (ISM) is an established and widely used methodology for identifying relationships among specific items, which define a problem or an issue (Warfield, 1974; Sage, 1977). The model formed portrays the structure of a complex issue or problem (Attri *et al.*, 2013). Expert decisions are collected and used to decide how the variables or factors are interrelated (George and Pramod, 2014). The methodology is interpretive as the judgment of the group decides whether and how the variables are related. It is structural too, as on the basis of relationship; an overall structure is extracted from the complex set of variables.

Total interpretive structural modeling (TISM) is an advanced version of Warfield's ISM technique and is used to model and structure the factors for a better understanding of their relationship (Sushil, 2005). This technique involves the interpretation of every relation, i.e. not only direct relations but also considers transitive relations. This is not only useful in making the structural model fully interpretive but also helps in creating a knowledge base of all the interpretations of all relations (Sandbhor and Botre, 2014).

Here, TISM starts with an identification of barriers relevant to LGAMS and then extends with a group problem-solving technique. Then a contextually relevant relation among barriers is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix is developed. In the next step, the SSIM is converted into a reachability matrix. After that, transitivity is checked and final reachability matrix is formed. Then, the partitioning of the elements and an extraction of the structural model called TISM is derived (Attri *et al.*, 2013). Also, a MICMAC Analysis is performed to understand the driving and dependence powers of the barriers. Figure 2 gives an overview of the steps involved in TISM.

The following steps lead to the development of the model (Sushil, 2012; Dubey and Ali, 2014; Jain and Raj, 2015; Jayalakshmi and Pramod, 2015; Sindhwani and Malhotra, 2017a, Yeravdekar and Behl, 2017).

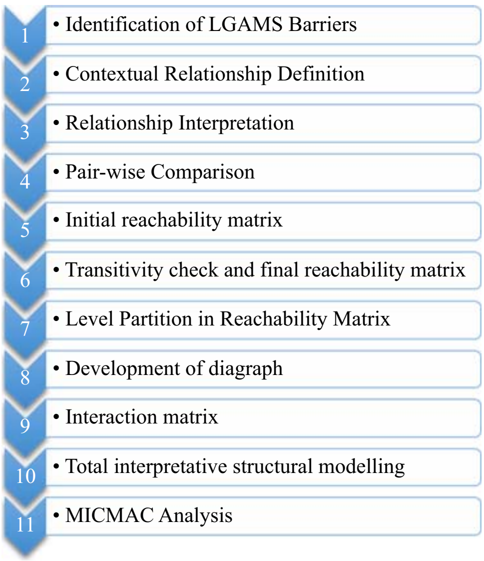

Figure 2.
Steps in TISM

4.1 Step 1: identification of LGAMS barriers
In this step, the barrier whose relationship is to be modeled needs to be identified. For this, the barriers to LGAMS are identified from literature and discussion with industry and experts as shown in Table I.

4.2 Step 2: contextual relationship development
To develop the LGAMS model, there is a need to find a type of contextual relationship between the barriers which is discussed above. The contextual relationship could be "A should influence or oppose to B" or "B should influence or oppose to A" in the implementation process of LGAMS. To obtain contextual relationship the barriers was discussed in a group of experts from industry and academia both.

4.3 Step 3: relationship interpretation
This is the main step of TISM which is mainly differ from ISM; in which we are finding how the interrelationship between barriers really works. In this step, explanation of how the barriers influence or oppose each other is considered.

4.4 Step 4: pair-wise comparison
A pair-wise comparison of elements is used to develop structured self-interaction matrix (SSIM). An interpretive query, in step 3, for each paired comparison is answered using concepts of TISM. The first element should be compared to all the elements in the respective row. For each comparison, the entry should be Yes (Y) or No (N). The reason for Y or N is provided in Appendix. After comparing all the barriers, a paired relationship in the form of interpretive logic – knowledge base is obtained and is shown in Table II.

4.5 Step 5: initial reachability matrix
In this step, cell represented with "Y" is replaced with "1" and cell represented with "N" is replaced with "0". The reachability matrix thus derived is known as initial reachability matrix which is depicted in Table III.

4.6 Step 6: transitivity check and final reachability matrix
Transitivity is a relation between three elements such that whenever an element a is related to an element b, and b is in turn related to an element c, then a is also related to c. The above

Barrier	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	–	N	N	N	N	N	Y	N	N	N	N	N	N
B2	Y	–	N	N	N	N	Y	N	N	N	N	N	N
B3	N	N	–	Y	N	N	Y	N	N	N	N	N	Y
B4	N	N	N	–	N	N	Y	N	Y	Y	N	N	N
B5	N	N	Y	Y	–	Y	Y	N	N	N	N	Y	N
B6	N	N	N	N	N	–	N	Y	N	Y	N	N	N
B7	Y	N	N	N	N	N	–	N	N	N	N	N	N
B8	N	N	N	N	N	N	N	–	Y	Y	N	N	N
B9	Y	Y	N	N	N	N	N	N	–	N	N	N	N
B10	N	Y	N	N	N	N	N	N	N	–	N	N	N
B11	Y	Y	N	N	N	N	N	N	Y	Y	–	N	Y
B12	Y	Y	N	N	N	N	N	N	Y	N	Y	–	Y
B13	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	–

Table II. Structural self-interactive matrix (SSIM)

Table III.
Initial reachability matrix

Barrier	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	–	0	0	0	0	0	1	0	0	0	0	0	0
B2	1	–	0	0	0	0	1	0	0	0	0	0	0
B3	0	0	–	1	0	0	1	0	0	0	0	0	1
B4	0	0	0	–	0	0	1	0	1	1	0	0	0
B5	0	0	1	1	–	1	1	0	0	0	0	1	0
B6	0	0	0	0	0	–	0	1	0	1	0	0	0
B7	1	0	0	0	0	0	–	0	0	0	0	0	0
B8	0	0	0	0	0	0	0	–	1	1	0	0	0
B9	1	1	0	0	0	0	0	0	–	0	0	0	0
B10	0	1	0	0	0	0	0	0	0	–	0	0	0
B11	1	1	0	0	0	0	0	0	1	1	–	0	1
B12	1	1	0	0	0	0	0	0	1	0	1	–	1
B13	1	1	0	0	0	0	0	0	1	1	1	0	–

matrix is checked for transitivity. Now, final reachability matrix is obtained by incorporating the transitivity relation. Final reachability matrix is shown in Table IV wherein transitivity is marked as 1*.

4.7 *Step 7: level partition in reachability matrix*

Level partitioning is carried out by identifying the reachability sets and antecedent sets for all the elements. Further, the intersection of the two sets is found out. The elements for which the reachability set and intersection set are the same occupy the top level in the hierarchy. Top level elements will not influence the remaining elements hence; they can be removed from further calculations. The summary of iterations is represented in Table V.

4.8 *Step 8: development of diagraph*

The relationship of the directed links is drawn for the barriers in the form of a graph as per the reachability matrix. In this transitive relationship is eliminated step by step after examining the interpretation from the knowledge base. Only important transitive links are considered as shown in Figure 3.

Table IV.
Final reachability matrix

Barrier	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	–	0	0	0	0	0	1	0	0	0	0	0	0
B2	1	–	0	0	0	0	1	0	0	0	0	0	0
B3	1*	1*	–	1	0	0	1	0	1*	1*	1*	0	1
B4	1*	1*	0	–	0	0	1	0	1	1	0	0	0
B5	1*	1*	1	1	–	1	1	1*	1*	1*	1*	1	1*
B6	0	1*	0	0	0	–	0	1	1*	1	0	0	0
B7	1	0	0	0	0	0	–	0	0	0	0	0	0
B8	1*	1*	0	0	0	0	0	–	1	1	0	0	0
B9	1	1	0	0	0	0	1*	0	–	0	0	0	0
B10	1*	1	0	0	0	0	1*	0	0	–	0	0	0
B11	1	1	0	0	0	0	1*	0	1	1	–	0	1
B12	1	1	0	0	0	0	1*	0	1	1*	1	–	1
B13	1	1	0	0	0	0	1*	0	1	1	1	0	–

Note: *denotes the values which are changed from “0” to “1” during transitivity check

Barrier	Reachability set (RS)	Antecedent set (AS)	Intersection	Level
B1	B1, B7	B1, B2, B3, B4, B5, B7, B8, B9, B10, B11, B12, B13	B1, B7	I
B2	B2	B2, B3, B4, B5, B6, B8, B9, B10, B11, B12, B13	B2	II
B3	B3	B3, B5	B3	V
B4	B4	B3, B4, B5	B4	IV
B5	B5	B5	B5	VI
B6	B6	B5, B6	B6	V
B7	B1, B7	B1, B2, B3, B4, B5, B7, B9, B10, B11, B12, B13	B1, B7	I
B8	B8	B5, B6, B8	B8	IV
B9	B9	B3, B4, B5, B6, B8, B9, B11, B12, B13	B9	III
B10	B10	B3, B4, B5, B6, B8, B10, B11, B12, B13	B10	III
B11	B11, B13	B3, B5, B11, B12, B13	B11, B13	IV
B12	B12	B5, B12	B12	V
B13	B11, B13	B3, B5, B11, B12, B13	B11, B13	IV

Table V. Levels of Barriers (Iteration I–VI)

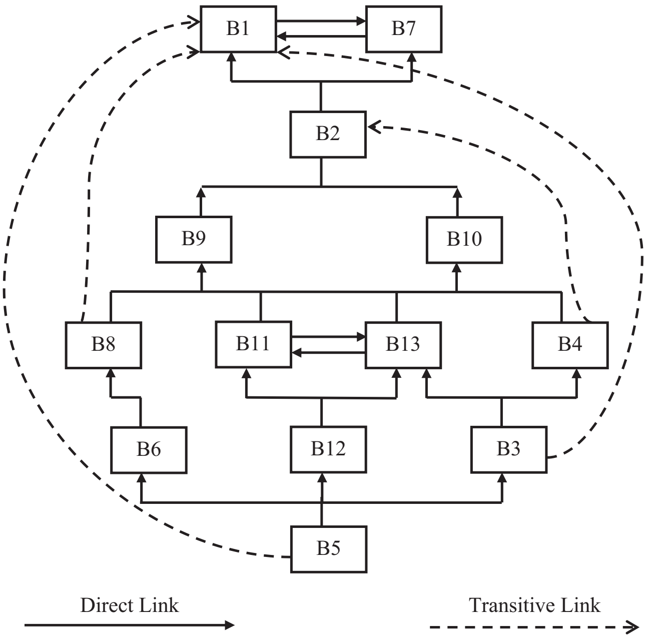

Figure 3. Diagraph showing different levels

4.9 Step 9: interaction matrix

The diagraph is translated into a binary interaction matrix form by depicting all the interactions by 1 in cells. Remaining cells entry is 0. The cell with "1" entry in interaction matrix is interpreted with the help of knowledge base as shown in Table VI. Here, 1 represents direct link and *1(Italic)* represents the significant transitive link.

4.10 Step 10: total interpretative structural modeling

The information contained in the interaction matrix and diagraph is used to obtain TISM. Nodes in the diagraph are replaced with the interpretation of elements and TISM model is shown in Figure 4.

Table VI.
Interaction matrix

Barrier	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	–	0	0	0	0	0	1	0	0	0	0	0	0
B2	1	–	0	0	0	0	1	0	0	0	0	0	0
B3	*1*	0	–	1	0	0	0	0	0	0	0	0	1
B4	0	*1*	0	–	0	0	0	0	1	1	0	0	0
B5	*1*	0	1	0	–	1	0	0	0	0	0	1	0
B6	0	0	0	0	0	–	0	1	0	0	0	0	0
B7	1	0	0	0	0	0	–	0	0	0	0	0	0
B8	*1*	0	0	0	0	0	0	–	1	1	0	0	0
B9	0	1	0	0	0	0	0	0	–	0	0	0	0
B10	0	1	0	0	0	0	0	0	0	–	0	0	0
B11	0	0	0	0	0	0	0	0	1	1	–	0	1
B12	0	0	0	0	0	0	0	0	0	0	1	–	1
B13	0	0	0	0	0	0	0	0	1	1	1	0	–

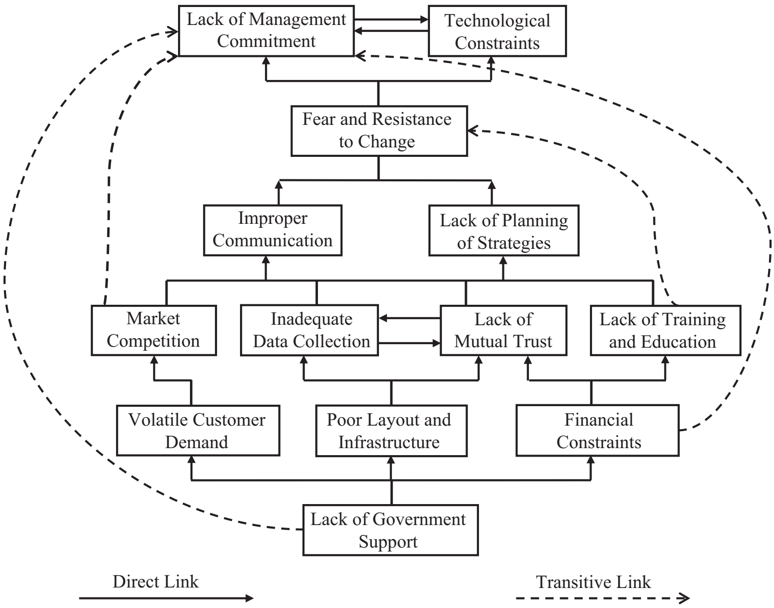

Figure 4.
TISM model for barriers of LGAMS

The model shown identifies the barriers ranging from depending on driving nature from top to bottom. The barriers in the topmost position of the model have high dependence and are influenced by the barriers below them. The arrowhead points in only upward direction resembling the transfer from driving to dependence nature. The transitive links among barriers are shown with dotted lines.

The interpretation of the important transitive relations is as follows:

(1) Lack of government support (B5) – lack of management commitment (B1) – insufficiency of legislation and policies may affect adherence of the top managers towards the system.

(2) Market competition (B8) – lack of management commitment (B1) – Ever-changing market environment and instability may drive top managers towards non-acceptance of the system.

(3) Financial constraints (B3) – lack of management commitment (B1) – adaption of any new system requires a huge investment. This may be a hindrance to the management's goals.

(4) Lack of training and education (B4) – fear and resistance to change (B2) – employees may resist change in the system due to the deprivation of higher education and competent skill training.

4.11 Step 11: MICMAC analysis

Matrice d'Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) was developed by Duperrin and Godet (1973). Popularly known as cross-impact matrix multiplication applied to Classification, MICMAC analysis contains the following three steps: identify relevant elements, build the causal relationship between elements and identify key elements.

The objective of MICMAC analysis is to analyze the driver power and the dependence power of the elements. Subsequently, the driver power-dependence diagram is constructed, using final reachability matrix (Table IV), as shown in Figure 5.

In order to construct the above grid, the horizontal cell entries for each barrier have been summed which represent the "Driving Power" of that barrier. Similarly, the summation of vertical entries of that barrier represents its "Dependence Power". These two calculations give a unique combination that has been plotted in the form of a grid to infer results in accordance with MICMAC Analysis.

Cluster 1: autonomous barriers – These barriers have a weak driving power and weak dependence. In this cluster, we have three barriers, i.e. lack of training and education (B4), volatile customer demand (B6) and market competition (B8). These barriers do not influence the system to a great extent due to low driving power.

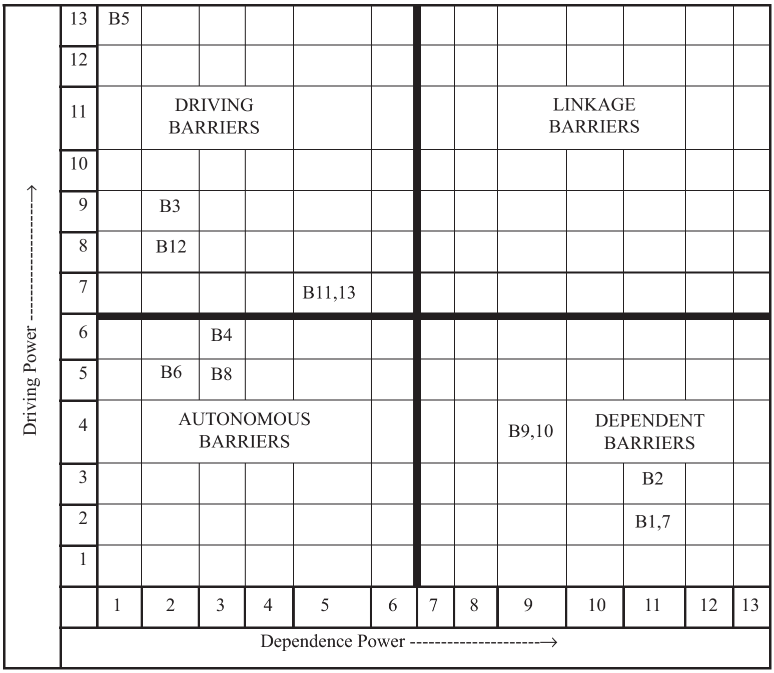

Figure 5.
MICMAC analysis

Cluster 2: dependent barriers – These barriers have a weak driving power but strong dependence. In this cluster, we have five barriers, i.e. lack of management commitment (B1), fear and resistance to change (B2), technological constraints (B7), improper communication (B9) and lack of planning of strategies (B10). Due to their dependency, these barriers can be found at the top of the TISM Model.

Cluster 3: linkage barriers – these barriers have a strong driving power as well as strong dependence. No barrier comes under this cluster for our study. This signifies that none of the barriers is unstable as it does not reflect back any change on any other barrier.

Cluster 4: driving barriers – these barriers have a strong driving power but weak dependence. In this cluster, we have five barriers, i.e. financial constraints (B3), Lack of government support (B5), inadequate data collection (B11), poor layout and infrastructure (B12) and lack of mutual trust (B13). This result is synonymous with the model derived from TISM application. Barriers B3, B5, B11, B12 and B13 highly affect other barriers due to their influence on LGAMS.

5. Results and discussion

After an extensive literature review regarding the three systems, i.e. lean manufacturing system, agile manufacturing system and green manufacturing system, a hybrid system considering all the attributes of the above was developed which was called lean green agile manufacturing system. The barriers from the three systems were selected in order to infer their combined effect on the proposed LGAMS. A mathematical model approach was implemented to bring about the hierarchy among the identified barriers. The barriers were then subjected to industry and academia opinions, and TISM was implemented. Both direct links and transitive links among the barriers defining their influence on each other were taken into consideration.

Further, an interrelationship was developed among the barriers by partitioning them in different levels. Level partition is done by considering reachability, antecedent and intersection sets as described in Section 4. There are six partition levels as represented in Figure 3. Level I is occupied by barriers B1 and B7. Level II houses only barrier B2. Barriers B9 and B10 fall in level III. Level IV has barriers B4, B8, B11, and B13. Level V has barriers B3, B6, and B12. Only barrier B5 falls in Level VI. Interrelationship among the barriers can be seen in Figure 4. The respective levels signify the position of the barriers taken in the TISM Model. The barriers that get partitioned earliest took the topmost position in the proposed model. Also, the transitive interaction among barriers was shown in the model due to their indirect influence/effect on each other.

In the proposed model, Barrier B5, i.e. lack of government support is shown driving the model due to its high influence on LGAMS. It also indirectly affects management support towards goal commitment. Financial constraints or risk of business indirectly affects the determination of the workforce towards system change. Barriers B1 and B7 have high dependence power due to which they depend on any other barrier to bringing about any significant resistance to the acceptance of the system. Further, tough market competition and risk of business also indirectly influence the commitment of top management.

6. Conclusion

This research paper identifies the 13 key barriers which affect the modeling of LGAMS. The present model identifies the influence of barriers, mutual relationship, relative importance and interdependence of barriers with the help of TISM and MICMAC analysis. ISM is not able to identify the mutual relation between barriers so, in this paper, TISM model is used to identify the mutual relationship. Finally, integrated model of LGAMS has been developed by using TISM and MICMAC analysis. This mathematical model can be used as an aid to developing a suitable strategy for the designing and implementation of

LGAMS in any organization. This finding will allow management to efficiently utilize their resources to focus attention on the most significant barriers.

A further expansion of barriers with the help of collecting the data from industry and academia experts, researchers, etc., gives more help in the understanding of LGAMS. Furthermore, statistical analysis can be performed for a better understanding of LGAMS.

The proposed model and barriers can help any organization or industry that is willing to implement LGAMS in it. The hierarchy of barriers can enable to recognize the effect of the most driving barrier in their context and the subsequent effect it can have on other barriers. A framework can therefore be apprehended to enable a successful implementation of LGAMS as an industry framework.

Based on the results obtained from the study, the following observations are made:

(1) Government policies and legislation are the main drivers of LGAMS as their continuous support will enable the implementation of this system.

(2) Top Management is highly dependent on various aspects. Its commitment and support towards LGAMS need to be backed up by several social and economic factors.

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Appendix. Interpretation of relationship

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
B1 – *Lack of management commitment*				
1	B1–B2	Lack of management commitment influences or enhances the fear and resistance to change	N	
2	B2–B1	Fear and resistance to change influences or enhances the lack of management commitment	Y	Unsupportive work culture may hamper the support of management
3	B1–B3	Lack of management commitment influences or enhances the financial constraints	N	
4	B3–B1	Financial Constraints influences or enhances the Lack of Management Commitment	N	
5	B1–B4	Lack of management commitment influences or enhances the lack of training and education	N	
6	B4–B1	Lack of training and education influences or enhances the lack of management commitment	N	
7	B1–B5	Lack of management commitment influences or enhances the lack of government support	N	
8	B5–B1	Lack of government support influences or enhances the lack of management commitment	N	
9	B1–B6	Lack of management commitment influences or enhances the volatile customer demand	N	
10	B6–B1	Volatile customer demand influences or enhances the lack of management commitment	N	
11	B1–B7	Lack of Management Commitment influences or enhances the Technological Constraints	Y	Management may not readily accept new technology
12	B7–B1	Technological constraints influences or enhances the lack of management commitment	Y	Suitable technology may not be available to commit to prospective goals
13	B1–B8	Lack of management commitment influences or enhances the market competition	N	
14	B8–B1	Market competition influences or enhances the lack of management commitment	N	
15	B1–B9	Lack of management commitment influences or enhances the improper communication	N	

(*continued*)

Table AI. Interpretation of relationship

Table AI.

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
16	B9–B1	Improper communication influences or enhances the lack of management commitment	Y	Lack of communication channels effects reporting and feedback
17	B1–B10	Lack of management commitment influences or enhances the lack of planning of strategies	N	
18	B10–B1	Lack of planning of strategies influences or enhances the lack of management commitment	N	
19	B1–B11	Lack of management commitment influences or enhances the inadequate data collection	N	
20	B11–B1	Inadequate data collection influences or enhances the lack of management commitment	Y	Lack of feedback reports on performance may lead to a wrong analysis of progress
21	B1–B12	Lack of management commitment influences or enhances the poor layout and infrastructure	N	
22	B12–B1	Poor layout and infrastructure influences or enhances the lack of management commitment	Y	Industry layout may hinder future progress
23	B1–B13	Lack of management commitment influences or enhances the lack of mutual trust	N	
24	B13–B1	Lack of mutual trust influences or enhances the lack of management commitment	Y	Trust is essential to control line order
B2 – *Fear and resistance to change*				
25	B2–B3	Fear and resistance to change influences or enhances the financial constraints	N	
26	B3–B2	Financial constraints influences or enhances the fear and resistance to change	N	
27	B2–B4	Fear and resistance to change influences or enhances the lack of training and education	N	
28	B4–B2	Lack of training and education influences or enhances the fear and resistance to change	N	
29	B2–B5	Fear and resistance to change influences or enhances the lack of government support	N	
30	B5–B2	Lack of government support influences or enhances the fear and resistance to change	N	

(*continued*)

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
31	B2–B6	Fear and resistance to change influences or enhances the volatile customer demand	N	
32	B6–B2	Volatile customer demand influences or enhances the fear and resistance to change	N	
33	B2–B7	Fear and resistance to change influences or enhances the technological constraints	Y	Workers may not adapt to new ways of doing things
34	B7–B2	Technological constraints influences or enhances the fear and resistance to change	N	
35	B2–B8	Fear and resistance to change influences or enhances the market competition	N	
36	B8–B2	Market competition influences or enhances the fear and resistance to change	N	
37	B2–B9	Fear and resistance to change influences or enhances the improper communication	N	
38	B9–B2	Improper communication influences or enhances the fear and resistance to change	Y	Irregular reporting may cause aversion of workers
39	B2–B10	Fear and resistance to change influences or enhances the lack of planning of strategies	N	
40	B10–B2	Lack of planning of strategies influences or enhances the fear and resistance to change	Y	Improper planned strategies will lead to workers inability to adapt to it
41	B2–B11	Fear and resistance to change influences or enhances the inadequate data collection	N	
42	B11-B2	Inadequate data collection influences or enhances the fear and resistance to change	Y	Lack of feedback reports may cause problems in decision making
43	B2–B12	Fear and resistance to change influences or enhances the poor layout and infrastructure	N	
44	B12–B2	Poor layout and infrastructure influences or enhances the fear and resistance to change	Y	Unsuitable infrastructure will discourage employees
45	B2–B13	Fear and resistance to change influences or enhances the lack of mutual trust	N	
46	B13–B2	Lack of mutual trust influences or enhances the fear and resistance to change	Y	Trust is the basis to create a good work environment

(*continued*)

Table AI.

Table AI.

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
B3 – *financial constraints*				
47	B3–B4	Financial constraints influences or enhances the lack of training and education	Y	Lack of funds will affect training programs
48	B4–B3	Lack of training and education influences or enhances the financial constraints	N	
49	B3–B5	Financial constraints influences or enhances the lack of government support	N	
50	B5–B3	Lack of government support influences or enhances the financial constraints	Y	Unsuitable government declarations may cause harm to business
51	B3–B6	Financial constraints influences or enhances the volatile customer demand	N	
52	B6–B3	Volatile customer demand influences or enhances the financial constraints	N	
53	B3–B7	Financial constraints influences or enhances the technological constraints	Y	Technologies may be quite expensive to obtain
54	B7–B3	Technological constraints influences or enhances the financial constraints	N	
55	B3–B8	Financial constraints influences or enhances the market competition	N	
56	B8–B3	Market competition influences or enhances the financial constraints	N	
57	B3–B9	Financial constraints influences or enhances the improper communication	N	
58	B9–B3	Improper communication influences or enhances the financial constraints	N	
59	B3–B10	Financial constraints influences or enhances the lack of planning of Strategies	N	
60	B10–B3	Lack of planning of strategies influences or enhances the financial constraints	N	
61	B3–B11	Financial constraints influences or enhances the inadequate data collection	N	
62	B11–B3	Inadequate data collection influences or enhances the financial constraints	N	

(*continued*)

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
63	B3–B12	Financial constraints influences or enhances the poor layout and infrastructure	N	
64	B12–B3	Poor layout and infrastructure influences or enhances the financial constraints	N	
65	B3–B13	Financial constraints influences or enhances the lack of mutual trust	Y	Inability to develop with the market may cause lack of trust in the industry
66	B13–B3	Lack of mutual trust influences or enhances the financial constraints	N	
B4 – *lack of training and education*				
67	B4–B5	Lack of training and education influences or enhances the lack of government support	N	
68	B5–B4	Lack of government support influences or enhances the lack of training and education	Y	Government support can help in proper education programs
69	B4–B6	Lack of training and education influences or enhances the volatile customer demand	N	
70	B6–B4	Volatile customer demand influences or enhances the lack of training and education	N	
71	B4–B7	Lack of training and education influences or enhances the technological constraints	Y	Specialization in handling different technologies can be beneficial
72	B7–B4	Technological constraints influences or enhances the lack of training and education	N	
73	B4–B8	Lack of training and education influences or enhances the market competition	N	
74	B8–B4	Market competition influences or enhances the lack of training and education	N	
75	B4–B9	Lack of training and education influences or enhances the improper communication	Y	Lack of suitable training will lead to less understanding
76	B9–B4	Improper communication influences or enhances the lack of training and education	N	
77	B4–B10	Lack of training and education influences or enhances the lack of planning of strategies	Y	Improper training causes hindrance to planning

(*continued*)

Table AI.

Table AI.

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
78	B10–B4	Lack of planning of strategies influences or enhances the lack of training and education	N	
79	B4–B11	Lack of training and education influences or enhances the inadequate data collection	N	
80	B11–B4	Inadequate data collection influences or enhances the lack of training and education	N	
81	B4–B12	Lack of training and education influences or enhances the poor layout and infrastructure	N	
82	B12–B4	Poor layout and infrastructure influences or enhances the lack of training and education	N	
83	B4–B13	Lack of training and education influences or enhances the lack of mutual trust	N	
84	B13–B4	Lack of mutual trust influences or enhances the lack of training and education	N	
B5 – *lack of government support*				
85	B5–B6	Lack of government support influences or enhances the volatile customer demand	Y	Government policies will affect customer demands
86	B6–B5	Volatile customer demand influences or enhances the lack of government support	N	
87	B5–B7	Lack of government support influences or enhances the technological constraints	Y	Government policies may not allow the use of certain technologies
88	B7–B5	Technological constraints influences or enhances the lack of government support	N	
89	B5–B8	Lack of government support influences or enhances the market competition	N	
90	B8–B5	Market competition influences or enhances the lack of government support	N	
91	B5–B9	Lack of government support influences or enhances the improper communication	N	
92	B9–B5	Improper communication influences or enhances the lack of government support	N	

(*continued*)

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
93	B5–B10	Lack of government support influences or enhances the lack of planning of strategies	N	
94	B10–B5	Lack of planning of strategies influences or enhances the lack of government support	N	
95	B5–B11	Lack of government support influences or enhances the inadequate data collection	N	
96	B11–B5	Inadequate data collection influences or enhances the lack of government support	N	
97	B5–B12	Lack of government support influences or enhances the poor layout and infrastructure	Y	Government policies may not support the expansion of industries
98	B12–B5	Poor layout and infrastructure influences or enhances the lack of government support	N	
99	B5–B13	Lack of government support influences or enhances the lack of mutual trust	N	
100	B13–B5	Lack of mutual trust influences or enhances the lack of government support	N	
B6 – *volatile customer demand*				
101	B6–B7	Volatile customer demand influences or enhances the technological constraints	N	
102	B7–B6	Technological constraints influences or enhances the volatile customer demand	N	
103	B6–B8	Volatile Customer Demand influences or enhances the Market Competition.	Y	Irregular customer demands effects the competition
104	B8–B6	Market competition influences or enhances the volatile customer demand	N	
105	B6–B9	Volatile customer demand influences or enhances the improper communication	N	
106	B9–B6	Improper communication influences or enhances the volatile customer demand	N	
107	B6–B10	Volatile customer demand influences or enhances the lack of planning of strategies	Y	Due to the variability of demand, accurate planning may not be possible

(*continued*)

Table AI.

Table AI.

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
108	B10–B6	Lack of planning of strategies influences or enhances the volatile customer demand	N	
109	B6–B11	Volatile customer demand influences or enhances the inadequate data collection	N	
110	B11–B6	Inadequate data collection influences or enhances the volatile customer demand	N	
111	B6–B12	Volatile customer demand influences or enhances the poor layout and infrastructure	N	
112	B12–B6	Poor layout and infrastructure influences or enhances the volatile customer demand	N	
113	B6–B13	Volatile customer demand influences or enhances the lack of mutual trust	N	
114	B13–B6	Lack of mutual trust influences or enhances the volatile customer demand	N	
B7 – *technological constraints*				
115	B7–B8	Technological constraints influences or enhances the market competition	N	
116	B8–B7	Market competition influences or enhances the technological constraints	N	
117	B7–B9	Technological constraints influences or enhances the improper communication	N	
118	B9–B7	Improper communication influences or enhances the technological constraints	N	
119	B7–B10	Technological constraints influences or enhances the lack of planning of strategies	N	
120	B10–B7	Lack of planning of strategies influences or enhances the technological constraints	N	
121	B7–B11	Technological constraints influences or enhances the inadequate data collection	N	
122	B11–B7	Inadequate data collection influences or enhances the technological constraints	N	

(*continued*)

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
123	B7–B12	Technological constraints influences or enhances the poor layout and infrastructure	N	
124	B12–B7	Poor layout and infrastructure influences or enhances the technological constraints	N	
125	B7–B13	Technological constraints influences or enhances the lack of mutual trust	N	
126	B13-B7	Lack of mutual trust influences or enhances the technological constraints	N	
B8 – *market competition*				
127	B8–B9	Market competition influences or enhances the improper communication	Y	Market may develop not in accordance with the industry's expectations
128	B9–B8	Improper communication influences or enhances the market competition	N	
129	B8–B10	Market competition influences or enhances the lack of planning of strategies	Y	Tough competition may lead to improper planning
130	B10–B8	Lack of planning of strategies influences or enhances the market competition	N	
131	B8–B11	Market competition influences or enhances the inadequate data collection	N	
132	B11–B8	Inadequate data collection influences or enhances the market competition	N	
134	B8–B12	Market competition influences or enhances the poor layout and infrastructure	N	
135	B12–B8	Poor layout and infrastructure influences or enhances the market competition	N	
136	B8–B13	Market competition influences or enhances the lack of mutual trust	N	
138	B13–B8	Lack of mutual trust influences or enhances the market competition	N	
B9 – *improper communication*				
139	B9–B10	Improper communication influences or enhances the lack of planning of strategies	N	

(*continued*)

Table AI.

Table AI.

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
140	B10–B9	Lack of planning of strategies influences or enhances the improper communication	N	
141	B9–B11	Improper communication influences or enhances the inadequate data collection	N	
142	B11–B9	Inadequate data collection influences or enhances the improper communication	Y	Improper feedback will lead to miscommunication
143	B9–B12	Improper communication influences or enhances the poor layout and infrastructure	N	
144	B12–B9	Poor Layout and Infrastructure influences or enhances the improper communication	Y	The poor layout will lead to a lack of communication
145	B9–B13	Improper communication influences or enhances the lack of mutual trust	N	
146	B13–B9	Lack of mutual trust influences or enhances the improper communication	Y	Untrust among workers causes lack of sharing of views
B10 – *lack of planning of strategies*				
147	B10–B11	Lack of planning of strategies influences or enhances the inadequate data collection	N	
148	B11–B10	Inadequate data collection influences or enhances the lack of planning of strategies	Y	Performance measurement is required for planning
149	B10–B12	Lack of planning of strategies influences or enhances the poor layout and infrastructure	N	
150	B12–B10	Poor layout and infrastructure influences or enhances the lack of planning of strategies	N	
151	B10–B13	Lack of planning of strategies influences or enhances the lack of mutual trust	N	
152	B13–B10	Lack of mutual trust influences or enhances the lack of planning of Strategies	Y	Workers may not support new work policies
B11 – *inadequate data collection*				
153	B11–B12	Inadequate data collection influences or enhances the poor layout and infrastructure	N	

(*continued*)

S. No.	Barrier	Paired comparison of barriers	Y/N	In what way a barrier will influence or enhance the other barrier Give reason in brief
154	B12–B11	Poor layout and infrastructure influences or enhances the inadequate data collection	Y	Poor infrastructure will affect data collection
155	B11–B13	Inadequate data collection influences or enhances the lack of mutual trust	Y	Feedback may lead to a lack of trust
156	B13–B11	Lack of mutual trust influences or enhances the inadequate data collection	Y	Lack of trust influences data collection
B12 – *poor layout and infrastructure*				
157	B12–B13	Poor layout and infrastructure influences or enhances the lack of mutual trust	Y	The poor layout will lead to a lack of trust
158	B13–B12	Lack of mutual trust influences or enhances the poor layout and infrastructure	N	

Table AI.

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