The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1726-0531.htm

Structural modeling of lean supply chain enablers: a hybrid AHP and ISM-MICMAC based approach

Hemant Sharma
Department of Mechanical Engineering, Prestige Institute of Engineering Management and Research, Indore, India
Nagendra Sohani
Department of Mechanical Engineering, Institute of Engineering and Technology DAVV, Indore, India, and
Ashish Yadav
Department of Mechanical Engineering, Anand College of Engineering and Management, Kapurthala, India

Received 16 August 2021
Revised 13 September 2021
Accepted 24 September 2021

Abstract

Purpose – Today the role of industry 4.0 plays a very important role in enhancing any supply chain network, as the industry 4.0 supply chain uses Big Data and advanced analytics to inform the complete visibility. Latest data are available to bring clarity and support real-time decision-making in the entire supply chain that's why adopting optimization techniques such as lean manufacturing and lean supply chain concept for enhancing the supply chain network of the organizations is a good idea and would benefit them in increasing their cost efficiency and productivity. The purpose of this work is to develop a technique, which may be useful for future researchers and managers to identify and classification of the significant lean supply chain enablers.

Design/methodology/approach – In this paper, the authors considered hybrid analytical hierarchy process to find the ranking of the identified lean supply chain enablers by calculating their weightage. Interpretive structural modeling (ISM) is applied to develop the structural interrelationship among various lean supply chain management enablers. Considering the results obtained from ISM the Matrices d'Impacts Croises Multiplication Appliqué a un Classement (MICMAC) analysis is done to identify the driving and dependence power of Lean Supply Chain Management Enablers (LSCMEs).

Findings – Further, the best results applying these methodologies could be used to analyze their inter-relationships for successful Lean supply chain management implementation in an organization. The authors developed an integrated model after the identification of 20 key LSCMEs, which is very helpful to identify and classify the important enablers by ISM methodology and explore the direct and indirect effects of each enabler by MICMAC analysis on the LSCM implementation. This will help organizations optimize their supply chain by selective control of lean enablers.

Practical implications – For lean manufacturing practitioners, the result of the study can be beneficial where the manufacturer is required to increase efficiency and reduce cost and wastage of resources in the lean manufacturing process, as well as in enhancing the supply chain.

Originality/value – This paper is the first research paper that considered firstly deep literature review of identified lean supply chain enablers and second developed structured modeling of various lean enablers of supply chain with the help of various methodologies.

Keywords ISM, AHP, Lean supply chain management, MICMAC, Lean supply chain enablers

Paper type Research paper

Journal of Engineering, Design and Technology

1726-0531
DOI 10.1108/JEDT-08-2021-0419

1. Introduction

The role of analytics in industry 4.0 has become very vital today as nearly all supply chain planners and managers rely on analytics to inform and optimize production, as well as for enhancement of the whole supply chain network. The industry 4.0 supply chain uses Big Data and advanced analytics techniques, which not only results in the lean focused efficient supply chain but also a responsive supply chain because of which a manufacturing companies can focus in overall supply chain improvements (Shurrab and Hussain, 2018).

Lean practices and implementation has become very popular globally as it aims to eliminate the wastes both internal and external to any organization to improve their performance. This is the result of increasing competition in the global business because of which many organizations are looking for ways to gain competitive advantage in market. Vonderembse *et al.* (2006) observe that now a day the market competition has shifted from company orientation to supply chain orientation; therefore supply chain improvement and optimization has become a necessity for their survival. Therefore a proper supply chain strategy is needed that the organizations find a way to win over the competition. Organizations should primarily consider the nature of demand before selecting a supply chain strategy (Fisher, 1997). One among the various types of supply chain strategy is lean supply chain strategy which is most appropriate for stable demand (Towill, 2000). A lean supply chain strategy always aimed at eliminating waste therefore just-in-time philosophy could be implemented which is strongly favored by many authors (Christopher and Towill, 2000; Huang, 2002; Zhao, 2011; Borgstrom and Hertz, 2011; Shadur and Bamber, 1994). Many researchers are progressively working to demonstrate the results while implementing the lean concept in the supply chain (Cudney and Elrod, 2011; Oliver, 1993; Taylor, 2006; Womack and Jones, 1994). The lean implementation is the very basis of any supply chain network (Agus and Hajinoor, 2012). There are several case studies done previously on how implementations of lean in the supply chain have resulted in important improvements (Eriksson, 2010; Perez *et al.*, 2010; Taylor, 1999; Wee and Wu, 2009). Lean is an evolving concept and is fast gaining its popularity as one of the important supply chain management strategy (Hines *et al.*, 2004). Thus, it is important to have a detailed understanding of lean supply chain strategy. Lean is continuously striving for creating an efficient operation and also by bringing together the best practices and concepts of productivity and problem-solving techniques (Kumar *et al.*, 2018).

Lean has also evolved as one of the most effective and prominent improvement technique adopted by many manufacturing and service sectors across the world over the past few decades for enhancing the production line, as well as their supply chain (Maleyeff, 2012). It has been recognized that the integrated approach of lean helps in eliminating the non-value added activities, as well as in reducing the defect rates (Assarlind and Aaboen, 2013). Today the industry professionals are experiencing an intensive pressure to capitalize the opportunities, which come along in the entire development process which will be helpful for building up, as well as maintaining the organizations' productive future consistently (Psomas and Antony, 2015). Combining knowledge sharing with innovative activities in supply chain can enhance the competitive advantage of organizations (Rajabion, 2019). To improve their outcomes as their results and competitiveness, organizations in a wide variety of economic sectors have started adopting lean management. Lean principles must be adopted throughout the whole supply chain, from suppliers to customers, not only inside the companies to get the optimum results. For that one has to increase the integration with key suppliers and customers within the supply chain network and spread the lean principles and practices in each connecting chain of the network (Martínez-Jurado and Moyano-Fuentes, 2013).

That the supply chain strategy can be well-implemented, the development of the exact strategy and the practices appropriate to the strategy should be implemented (Qrunfleh and Tarafdar, 2013). Therefore, when the company is starting developing its strategy, the very key success variable or the enablers to the successful implementation of supply chain strategy has to be identified. Also for the focused development, there exists a strong need for identification and hierarchical structuring of the enablers that contribute toward the effective implementation of improved LSCM. To model the enablers, today there are several methods developed and applied by researchers in various disciplines, but the selection of the methodology relies on the type of problem, its usefulness, and the form of outcome needed by the practitioners and researchers. The best-known methods among many are the analytical hierarchy process (AHP), analytic network process (ANP) and interpretive structural modeling (ISM) (Drohomeretski *et al.*, 2014). These methods are used mostly for modeling and multi-criteria decision-making. Comparison of the above three methods and proposing their feasibility of usage as per the environment requirement and need is very helpful for the researchers (Gorane and Kant, 2015). ISM methodology is used to help and manage the relationship between enablers by providing a hierarchy of the enablers (Warfield, 1974; Gupta, 2013; Sharma and Bhat, 2014). Today ISM is preferred frequently and largely for the study and preferred over other techniques because it portrays the hierarchical structure and also the levels of partition, which is very helpful for the practitioners and researchers to visualize the implementation structure in a better way. However, other techniques such as AHP are preferred for the case of ranking or prioritizing. In the present study, AHP and ISM methodology are used and integrated with MICMAC analysis; as this methodology helps to identify the driving and the dependence power of the enablers (Fore and Mbohwa, 2015).

This study originates from the very aim to explore the interactions among LSCEs and how strongly they influence the implementation of lean in the entire supply chain system. In the literature review, many lean enablers very identified and very few of them portrays their effect on the successful implementation of lean (Hilton and Sohal, 2012; Jeyaraman and Teo, 2010; Naslund, 2013). Hence, there exist a strong need of a study that not only explores the appropriate set of enablers and but also finds the interactions among them. So this study is an attempt to accomplish the above purpose. In this research, the LSCEs are defined based on the research of the previous research (Srinivasan *et al.*, 2005; Monczka *et al.*, 2009; Jayaram *et al.*, 1999; Naylor *et al.*, 1999; Persson and Olhager, 2002; Reese, 2007). There are 35 lean enablers identified after the rigorous analysis of collected articles from the literature review. The strategy to be well implemented, it has to be appropriate with the practices of the company. Therefore in-depth interview and brainstorming sessions were conducted with the group of experts such as the Director and the Operations Managers of selected industries, educationists and consultants to gain any information about if the 35 variables identified from the literature relevant with the need of the company. After finishing this step, then 7 out of 35 variables were removed because the experts stated that those are either irrelevant or repetitive.

However, while assessing the number of interactions, as well as inter-relationship within multiple enablers, the mapping between the enablers becomes extremely complicated. So, to achieve the best hierarchical structure, a hybrid AHP and ISM-MICMAC framework is proposed. It will reduce the complexity and help finding the impact of the selected enablers toward successful LSCM implementation. The complete sectioning of the paper is done in six different parts including the introduction as the first section. Section 2 presents the literature review about lean and the enablers discussed by various authors. Section 3 elaborates the problem description; Section 4 explains the unique methodology adopted in this study along with describing and implementing the process of execution of hybrid AHP and ISM-MICMAC method followed by their application through modeling lean enablers. Section 5 includes results and finally Section 6 consists of conclusions.

2. Problem description

In this section, authors mentioned two subsection motivation and problem structure that helps new researcher to understand real-world scenario.

2.1 Motivation

As discussed in the introduction section that there are many issues related to supply chain, as well as the optimization tools. Also as discussed in the literature review section many authors have elaborated the work done in enhancing the supply chain and many optimization techniques developed and adopted by the organizations for increasing their productivity. The implementation of lean supply chain strategy will result in a cost-efficient supply chain and that will benefit many stakeholders. The real world facing problems such as defects, wastage, transportation and inventory issues, over production and over-processing motivates the author to think about improvement in this direction. The problem was further analyzed in detail and with expert suggestion and it is observed that there are few problem faced by the real world due to lack of structural modeling in lean supply chain. Based on the recent research work in the area of lean supply chain motivates the authors to work in this direction.

Here, authors identifying the enablers of lean supply chain that are responsible for the success of any organization. In this paper, the hybrid AHP methodology is applied to find the weightage of all the lean enablers for their ranking. In the next process, the hybrid ISM-MICMAC methodology is applied to develop the structural interrelationship among various Lean supply chain management enablers (LSCMEs) and enhance lean supply chain productivity.

2.2 Problem structure

The extensive literature review and the brainstorming sessions led to the conclusion and also help in the problem identification that the organizations are unable to progress and make decisions in the area of lean supply chain as how to implement the best strategies or how to focus strategically in implementation of different LSCEs. The managers are helpless improving the organizations supply chain as without the proper understanding of the correlation, as well as the interrelationship among different LSCEs, it is impossible to implement the best strategy for the maximum outputs in terms of efficiency and responsiveness of any supply chain. For years researchers are in the progress to understand different tools, which are helpful in improving organizations supply chain and increase its effectiveness.

The lean plays a very vital role in improving the supply chain in terms of its efficiency as it helps in identifying and eliminations of different types of wastes involved in lowering the effectiveness of the supply chain. So, the identification of enablers as per the knowledge by extensive literature review of well-known papers of researcher and also form the deep knowledge of industry and operations experts from many organizations was the utmost important action to be needed. Then only one could build any interrelationship between different LSCEs with the help of different tools identified by different researchers in past and their research done in elaborating its effective implementation as the case studies of various organizations. Once the proper modeling is done by organizing all the enablers as per their correlation and interrelationship identified with the help of implementation of different tools and building different levels, then one can easily understood how there enablers are effective and which enablers is having driving powers and which are having dependence powers. Then thereafter it would be very easy to build best strategies, which focuses on the improvement of those enablers which are utmost important and whose effectiveness could have a greater impact on whole supply chain.

3. Literature review

The literature review defines "a systematic, explicit, and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents" (Fink, 1998). This section provides a review of literature about the various work done in the area of supply chain management. To explore the research related to lean supply chain and identify various lean supply chain enablers discovered by the authors in part for the successful lean supply chain management implementation. A literature review is conducted to address the above-mentioned research objective. A lean supply chain must allow a flow of information, goods, services and technology from suppliers to customers along with waste elimination (Wee and Wu, 2009).

The primary focus of lean supply chain principles is to identify waste in the supply chain process. Waste is an activity that does not create any value to the customer or product. In supply chain management, wastes are created by improper information flow, material flow and money flow in the system (Jasti and Kodali, 2015). Information and inventory have close relationship in the system and are dependent on each other (Baum, 2004). One of the main objectives of lean principles is to control inventory in the system. It is understood that the need of avoiding information waste in the lean supply chain is to bring down inventory levels of the organization. Information is considered to a major cause of wastes in the lean supply chain management system.

Anand and Kodali (2008) developed a conceptual framework for lean supply chain implementation based on the literature review. A lean supply chain should act as per the customers' needs and demands thus encouraging all stakeholders of the supply chain to produce under a pull system rather than push system (Jasti and Kodali, 2015). Thus it is effective and efficient to flow the information from the end customer to all tiers of the lean supply chain (Vitasek *et al.*, 2005). Vinodh and Joy (2011) discussed a study using fuzzy association rule approach to evaluate the leanness of an Indian modular switches manufacturing organization. Blos *et al.* (2015) presented a framework based on eight supply chain management operational constructs, whose purpose is to keep the supply chain more resilient for both internal and external risks, namely, customer service, inventory management, flexibility, time to market, finance, ordering cycle time, quality and market. Dong *et al.* (2001) and Green *et al.* (2014) discussed the application of JIT, suppliers and customers relationship in the lean supply chain management. Hallgren and Olhager (2009) viewed two main strategies in the supply chain. The strategies which include "lean and agility" are termed as "generic" supply chain strategies. "Lean" works best under the conditions of high-volume, low-variety and predictable environments whereas "agility" is highly needed in a less predictable environment where the demand for variety is high (Christopher, 2005; Watson, 1978; Shirzad Talatappeh and Lakzi, 2020).

The understanding of the company's current context is important for the implementation of lean supply chain (Achanga *et al.*, 2006) and organizations should adopt the practices and processes that are effective and efficient in their context (Anvari *et al.*, 2011). Theagarajan and Manohar (2015) suggested that research related to the lean supply chain practices implementation usually neglect the supply chain contexts. Zarei *et al.* (2011) presented an integrated framework based on fuzzy quality function deployment and AHP to enhance leanness by analyzing enablers of lean supply chain linked with lean attributes. Jasti and Kodali (2015) identified eight practices as pillars of lean SCM implementation: information technology management, supplier management, elimination of waste, JIT production, customer relationship management, logistics management, top management commitment and continuous improvement. Soni and Kodali (2012) analyzed leagile SCM factors and performed empirical analysis to identify leagile factors suitable for Indian manufacturing industry. Haq and Boddu (2015) presented an integrated fuzzy quality function deployment and technique for order performance by similarity to ideal solution approach for the enhancement of leanness in supply chain. Supplier management, production automation and knowledge and information management are the top ranked enablers in the implementation of lean supply chain. Dave and Sohani (2019) gave the findings in their research that the industries should adopt the concept of lean manufacturing in totality, not through the island approach for overall productivity improvements.

Soni and Kodali (2012) analyzed the interrelationships between the pillars and constructs of the framework of LSCM in Indian manufacturing industries. Six pillars of lean supply chain namely strategic management, marketing management, manufacturing management, logistics management, supplier management and collaboration management (Soni and Kodali, 2012). Tortorella *et al.* (2017) empirically investigating the effect of a set of contextual variables (i.e. plant size, supply chain level, level of onshore suppliers and age of the lean manufacturing initiative) on the implementation of lean supply chain practices. Tortorella *et al.* (2018) investigate the relationships among the implementation of LSC practices and examined 27 lean supply chain practices from different sectors located in Southern Brazil.

In this study, a total of 35 lean supply chain enablers were identified which can be seen in Appendix 1. Brainstorming sessions were conducted to finalized lean supply chain enablers. The objective of the research study was discussed with the experts in the first meeting. All the identified lean supply chain enablers were discussed and similar attributes lean supply chain enablers were grouped in to five groups namely strategic, managerial, operational, technological and socio-cultural in the second meeting. In the next meeting, the experts finalized the relevant lean supply chain enablers, discard the same meaning lean supply chain enablers and merged the same meaning lean supply chain enablers. The list of such irrelevant and same meaning enables can be seen in Appendix 2. Twenty-eight lean supply chain enablers were finalized for further research which is mentioned in Table 3.

According to our best knowledge, there has not been any published study that proposed hybrid AHP and ISM-MICMAC framework to weight the enablers of lean supply chain, analyze the structural interrelationship among enablers of lean supply chain and classify these enablers of lean supply chain based on dependence power and driving power. In this context, this paper presents the following contributions to the research field:

- In this paper, authors developed an integrated model after the identification of 20 key LSCMEs, which is very helpful to identify and classify the important enablers and explore the direct and indirect effects of each enabler on the LSCM implementation.
- The main aim of this work is to consider new MCDM approaches such as hybrid AHP and ISM-MICMAC method is applied for assigning weights, as well as analyzes the structural interrelationship among enablers of lean supply chain.
- The results of structural interrelationship among various LSCMEs will help organizations to set the proper strategy which will help reduce waste and improve the cost-effectiveness of the supply chain.

The remaining part of the paper are structured is as follows. In Sections 2 and 3 authors has already provided a motivation and problem structure. Section 4 indicates the research methodology and solution approach. Section 5 indicates data and its computational results. Section 6 of this paper are presented conclusions and future work directions that are very helpful for the researcher.

4. Methodology

The methodology applied is described in this section which is implemented by collecting essential information of lean supply chain. The methodology to get a solution can be briefly described in seven steps. In this research, interviews with experts of industry, consultants, as well as educationists was conducted with brainstorming sessions along with the synthesis of literature review, the key variables were identified and thereafter hybrid AHP and ISM-MICMAC methodology have been used to achieve research objectives. The methodologies and the results, respectively, are discussed in sequence. The research methodology adopted for the study is represented in Figure 1.

Step I: Performing an exhaustive literature review to explore the LSCEs from the articles related to "lean supply chain" collected from well know SCOPUS and Web of Science database as per review protocol.

In the beginning, literature review was conducted in which articles related to "lean supply chain" are collected from well know SCOPUS and Web of Science database as per review protocol shown in Table 1.

Step II: Brainstorming sessions with group of experts consisting of academicians, practitioners and consultants to collect opinion of experts for finalizing the relevant LSCEs by discarding or merging similar meaning enablers and finally grouping the similar attribute enablers.

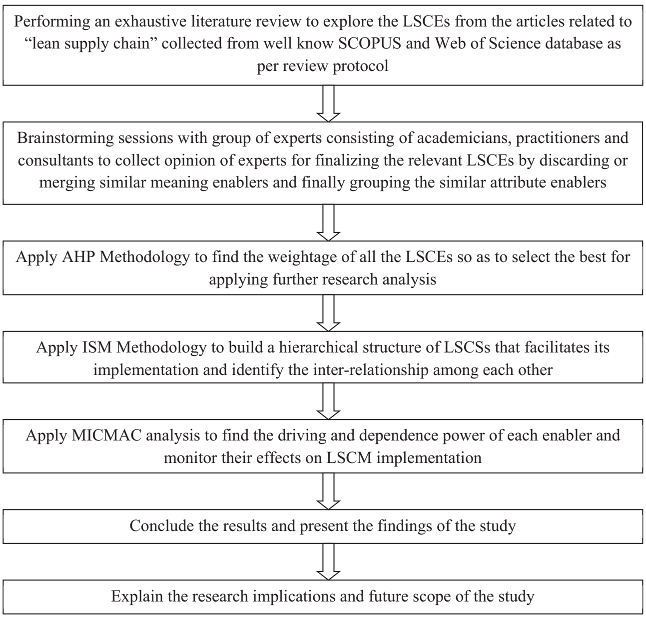

Figure 1.
Research methodology steps

Table 1.
Review protocol

Item	Explanation
Keywords	Lean supply chain, enabler and critical success factor
Search field	Title; Abstract; Keywords
Boolean operator	AND between keywords; OR between Database search field
Search string	"lean supply chain" and "enabler," "lean supply chain" and "critical success factor"
Database	Web of Science, Scopus
Time window	10–08-2020
Publication type	Articles
Exclusion criteria	Articles that do not address the main topic
Language	English

Table 2.
List of experts

Experts Group	Field	Designation	Experience (years)
Expert Group 1	Industry	General Manager	25
Expert Group 2	Industry	Vice President	20
Expert Group 3	Consultant	Consultant	18
Expert Group 4	Academician	Professor	27
Expert Group 5	Academician	Professor	25

After the rigorous analysis of collected articles, lean supply chain enablers are identified. A group of experts is formed to collect their opinion which consists of academicians, practitioners and consultants. The academicians were selected from some best IIT, IIM and NIT colleges. The practitioners were from some automobile sectors such as Mahindra, Eicher, Force motors and some renowned manufacturing sectors. The consultants were General Manager Operation's and Operations Managers from Logistics, IOCL, etc. The group of expert panel is shown in Table 2.

4.1 Solution approaches

In this section, author mentioned three sub-sections AHP, ISM and MICMAC methods solution steps, as well as computational results. The computational results is obtained using excel solver with Intel Core i5, 3.20 GHz processor and 4GB of RAM.

Step III: Apply AHP Methodology to find the weightage of all the LSCEs so as to select the best for applying further research analysis. This is described in detail under the solution approaches.

4.1.1 Analytic hierarchy process. Saaty (1986) defines "The foundation of the AHP is a set of axioms that carefully delimits the scope of the problem environment." The very base of it depends on the well-defined mathematical structure of consistent matrices and their associated Eigen vector's ability to generate true or approximate weights, (Merkin, 1979; Saaty, 1980, 1994). The AHP methodology compares various criteria's or alternatives with respect to a criterion, in a natural and in a pair wise mode. For doing this, the AHP uses a fundamental scale of absolute numbers that have already been proven in practice and also validated by physical and decision problem experiments.

This fundamental scale has been shown to be a scale that captures individual preferences with respect to quantitative or qualitative attributes just as well or better than other scales (Saaty, 1980, 1994). Then it converts the individual preferences into ratio scale weights that can be combined into a linear additive weight for each alternative. The resultant can be finally used to compare and rank the alternatives and, hence, support the decision-maker in making a choice

Code	LSCEs	Description	Literature support
LSCE1	Top management commitment	The top management should provide essential infrastructure and training to the employees to implement operation strategy of the organization	Marodin and Saurin (2013); Netland (2015), Jasti and Kodali (2015)
LSCE2	Total quality management	TQM focuses on market requirements and satisfying customer needs. TQM requires the involvement of every employee and it is the responsibility of organization to foster the friendly work culture	Tortorella *et al.* (2017);Tortorella *et al.* (2018)
LSCE3	Performance measurement	By identifying performance metrics and applying performance evaluation methods, performance of lean supply chain organization can be studied which helps in improving the efficiency of the organization	Arif-Uz-Zaman and Nazmul Ahsan (2014); Marodin and Saurin (2013); Netland (2015)
LSCE4	Long term planning	Long term planning addresses decisions that helps to determine overall strategic directions for the implementation of lean supply chain	Marodin and Saurin (2013); Netland (2015)
LSCE5	Quality improvement	Quality improvement at every stage leads to successful implementation of lean supply chain	Haq and Boddu (2015)
LSCE6	Supplier management	The suppliers play an important role in the implementation of lean supply chain management in the organization	Jasti and Kodali (2015)
LSCE7	Logistic management	Logistics management is one of the pillars of supply chain management to implement successful lean practices in the lean supply chain management for any organization	Jasti and Kodali (2015); Expert opinion
LSCE8	Inventory management	Inventory management means the right stock, at the right levels, in the right place, at the right time and at the right cost	Haq and Boddu (2015); Expert opinion
LSCE9	Customer relationship management	It is beneficial to interact with the potential customer to enhance the performance of lean supply chain	Jasti and Kodali (2015); Expert opinion
LSCE10	Knowledge and information management	Knowledge and information management helps to promote all kinds of innovation to improve the productivity of organization	Haq and Boddu (2015); Expert opinion
LSCE11	Value chain management	Value chain management is key to optimizing business activities, operations and maximizing profit	Tortorella *et al.* (2017), Tortorella *et al.* (2018)
LSCE12	Marketing management	Marketing management strategy has an impact on the customer satisfaction in a lean supply chain environment	Soni and Kodali (2012)

(*continued*)

Table 3.
LSCEs with description and literature support

Code	LSCEs	Description	Literature support
LSCE13	Continuous improvement (Kaizen)	Continuous improvement initiates the activities that are improving the success rate and reducing the failure rate in the organizations	Piercy and rich (2009), Pan and Pokharel (2007); Nachtmann and Pohl (2009); Marodin and Saurin (2013); Netland (2015), Jasti and Kodali (2015)
LSCE14	JIT production	JIT production also known as Toyota production system (TPS) aims to reduce the time within the production system, as well as response time from suppliers to customers.	Jasti and Kodali (2015), Haq and Boddu (2015)
LSCE15	Eliminate wastes	Waste activities is to reduce setup time and defects in the manufacturing operations. Waste can be group into seven wastes: over production, inventory, motion, over-processing, defects, transportation and waiting	Jasti and Kodali (2015)
LSCE16	Kanban system or pull system	Kanban plays a crucial role in pull scheduling, it is an information system connecting production and delivery in which upstream supplier does not produce until the downstream customer signals a need	Storey *et al.* (2006), Kumar *et al.*, 2008; Parker and Dellay (2008), Tortorella *et al.* (2017); Tortorella *et al.* (2018)
LSCE17	Housekeeping (5S)	Housekeeping (5S) involves the principle of waste elimination in the workplace organization. 5S in the Japanese words namely seiri, seiton, seiso, seiketsu and shitsuke	Najmi *et al.*, 2012; Mustaffa and Potter (2009), Perry and Kocakülâh (2010), Samaranayake *et al.* (2010)
LSCE18	Total productive maintenance	Total productive maintenance is the team based maintenance process designed to maximize machine availability and performance of product quality	Papadopoulos (2011), Kumar *et al.*, 2008
LSCE19	Reduction in lead time	Reduction in lead time is enabler to improve efficiency of organization	Papadopoulos (2011), Mustaffa (2009)
LSCE20	Information Technology	The perspectives of information technology is essential to control and access information flow across the supply chain activities	Jasti and Kodali (2015)
LSCE21	Standardization of work	Work standardization refers to operational procedures on the shop floor that ensure customer satisfaction	Tortorella *et al.* (2017), Tortorella *et al.* (2018);
LSCE22	Production Automation	Production automation results in reduced downtimes, enhance the productivity, improved quality, safety and energy savings in the lean supply chain	Haq and Boddu (2015); Expert opinion
LSCE23	Efficient replenishment	Replenishment is based upon consumer demand and point of sale information	Tortorella *et al.* (2017), Tortorella *et al.* (2018)

Table 3.

(*continued*)

Code	LSCEs	Description	Literature support
LSCE24	Coordination and collaboration among SC	Coordination and collaborative relationship among the stakeholders of the lean supply chain is essential for achieving its full benefits	Tortorella *et al.* (2017), Tortorella *et al.* (2018);
LSCE25	Human resource training and education	Training and education related to specific work is important to build necessary skills in the employee and make them competent to do work	Marodin and Saurin (2013); Netland (2015), Haq and Boddu (2015)
LSCE26	Employee participation and empowerment	Employee participation and empowerment involves ability to participate in the decision making in the implementation of lean supply chain	Marodin and Saurin (2013); Netland (2015)
LSCE27	Change management (cultural change)	The creation of a supportive organizational culture is an important platform for the implementation of lean supply chain management	Tortorella *et al.* (2018): Expert opinion
LSCE28	Reward and recognition	Reward and recognition are imperative to enhance the performance of lean supply chain	Marodin and Saurin (2013) Netland (2015)

Table 3.

among alternatives. In this study, all the criteria have been rated from 1 to 9 versus all other criteria, accordingly (Crowe *et al.*, 1998; Saaty, 2000; Hafeez *et al.*, 2002). Based on the ratings obtained through the brainstorming sessions with the experts, matrices are formed and the priorities are synthesized using the methodology of AHP. The AHP decomposes a complex problem into a hierarchy, in which each level has particular characteristics. These elements, in turn, are further deconstructed into sub-elements, thereby developing a hierarchical representation of the problem until at the lowest level.

AHP process consists of the following seven steps.

Step-1: Defining an unstructured problem and determining its goal.

Step-2: Structuring the hierarchy from the top (objectives from a decision-makers viewpoint) through intermediate levels (criteria on which subsequent levels depend) to the lowest level, which contains a list of alternatives.

Step-3: Use a pair-wise comparison approach. Saaty (2001) explored and developed the fundamental scale for pair-wise comparisons. The pair-wise comparison matrix A, in which the element a_{ij} of the matrix is the relative importance of the i-th factor with respect to the j-th factor, could be calculated as:

$$A = [a_{ij}] = \begin{bmatrix} 1 & a12 & \cdots & a1n \\ 1/a12 & 1 & \cdots & a2n \\ \vdots & \vdots & \vdots & \vdots \\ 1/a1n & 1/a2n & \cdots & 1 \end{bmatrix}$$

There are n (n-1)/2 judgments require developing the set of matrices in Step 3. Reciprocals are then automatically assigned to each pair-wise comparison, where n is the matrix size.

Step-4: Hierarchical synthesis is then used to weight the eigenvectors according to weights of criteria. The sum is for all the weighted eigenvectors corresponding to those in the next lower hierarchy level.

Step-5: Having made all pair-wise comparisons, consistency is identified by using the Eigenvalue λ_{max}, to calculate the consistency index. Saaty (1990) proposed that the largest Eigenvalue, λ_{max}, will be:

$$\lambda \ max = \sum_{j=1}^{n} aij \quad \frac{Wj}{Wi}$$

where λ_{max} is the principal or largest Eigenvalue of positive real values in a judgment matrix; Wj is the weight of j-th factor Wi is the weight of i-th factor.

Step-6: The consistency test in which each pair-wise comparison contains numerous decision elements for the consistency index (CI), which measures the entire consistency judgment for each comparison matrix and the hierarchy structure. Saaty (1990) used the CI and consistency ratio (CR) to assess the consistency of the comparison matrix. The CI and CR are defined as:

$$CI = \frac{\lambda max - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

The judgment consistency can be checked by taking the CR of CI with the appropriate value.

The CR should not exceed a value 0.10 for its acceptance. For the CR value > 0.10, the judgment matrix is inconsistent and to acquire a consistent matrix, judgments should be reviewed and improved. Hierarchy construction is the first step in the problem-solving process. The goal of an AHP decision is to find the rankings of all the enablers as per their weightage.

4.1.1.1 Analytic hierarchy process application and calculations. Twenty-eight enablers which are identified are grouped in five different categories, namely, strategic, managerial, operational, technological and socio-cultural, which are the main criteria's and pair wise comparison matrix is formed by applying AHP the results of which are as shown in Table 4. The weights are found which indicates strategic criterion is having maximum weight as per the results and the socio-cultural criterion is having the least weight.

Then the pair wise comparison of sub-criteria's is formed by applying AHP. The result of the sub-criteria of strategic group shows that the code LSCE1 is having the maximum weight and the code LSCE5 is having the minimum weight. After that the globalized weight is calculated and the final priorities of LSCEs are found out as shown in Table 5.

Categories	Strategic	Managerial	Operational	Technological	Socio-cultural	Weight
Strategic	1.00	3.00	3.00	5.00	5.00	0.44
Managerial	0.33	1.00	3.00	5.00	7.00	0.29
Operational	0.33	0.33	1.00	3.00	7.00	0.16
Technological	0.20	0.20	0.33	1.00	3.00	0.07
Socio-cultural	0.20	0.14	0.14	0.33	1.00	0.04

Table 4.
Pair wise comparison matrix of the main criteria

Main LSCEs	Weight	Sub criteria	Weight	Globalized weight	Ranking
Strategic LSCEs	0.44	LSCE1	0.58	0.2552	1
		LSCE2	0.2	0.088	3
		LSCE3	0.12	0.0528	6
		LSCE4	0.066	0.02904	10
		LSCE5	0.035	0.0154	16
Managerial LSCEs	0.29	LSCE6	0.42	0.1218	2
		LSCE7	0.22	0.0638	5
		LSCE8	0.15	0.0435	7
		LSCE9	0.09	0.0261	12
		LSCE10	0.06	0.0174	14
		LSCE11	0.04	0.0116	17
		LSCE12	0.02	0.0058	23
Operational LSCEs	0.16	LSCE13	0.45	0.072	4
		LSCE14	0.26	0.0416	8
		LSCE15	0.17	0.0272	11
		LSCE16	0.06	0.0096	19
		LSCE17	0.04	0.0064	21
		LSCE18	0.02	0.0032	25
Technological LSCEs	0.07	LSCE19	0.5	0.035	9
		LSCE20	0.24	0.0168	15
		LSCE21	0.13	0.0091	20
		LSCE22	0.09	0.0063	22
		LSCE23	0.04	0.0028	26
Socio-cultural LSCEs	0.04	LSCE24	0.49	0.0196	13
		LSCE25	0.28	0.0112	18
		LSCE26	0.12	0.0048	24
		LSCE27	0.07	0.0028	27
		LSCE28	0.04	0.0016	28

Table 5.
Final priorities of LSCEs

Top 20 enablers are selected for further study as lowest 8 enablers are having very low globalized weight so they are of very less importance. As per the recommendations of experts they are having very less significance and may be discarded for ISM-MICMAC analysis.

Step IV: Apply ISM Methodology to build a hierarchical structure of LSCSs that facilitates its implementation and identify the inter-relationship among each other.

4.1.2 Interpretative structural modeling. ISM was first proposed by Warfield (1974) to analyze the complex socioeconomic systems. ISM helps an individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation. The very basic idea is to use expert's practical experience and knowledge to crumble a complicated system into several sub-systems (elements) and construct a multilevel structural model. Many researchers recommended using ISM methodology to impose order and direction on the complexity of relationships among variables of any system. ISM is an established and most appropriate technique, which is applied to analyze the interactions and contextual interrelationships of the elements that define a system (Janes, 1988). Warfield proposed the ISM technique in the year 1974 to analyze the interrelationships among various elements related to a defined problem (Mandal and Deshmukh, 1994; Haleem *et al.*, 2012). ISM is very useful technique to deal with systems that have more complexity and also with elements that are not properly linked (Sage, 1977). In such systems, ISM analyzes the undefined elements using pair wise relationship and creates a hierarchical system based on the elements to build an established defined model. The only limitation of ISM is that the respondent's inputs with respect to a particular defined system may be biased considering their expertise which may affect the whole interrelationship among the elements. The steps involved in ISM methodology are (Watson, 1978):

- Identify the variables that constitute the system to be defined. In the present case, the variables are the enablers of lean supply chain management.
- Identification of enablers is done through extensive literature review.
- After recognizing the enablers, a contextual relationship is arrived between them. This is done by creating a structural self-interaction matrix (SSIM) with reference to pairwise comparison among the identified enablers.
- A reachability matrix is constructed with respect to SSIM, where the symbols (V, A, X, O) are replaced using binary digits (0 and 1) and its transitivity is being checked. The implication of transitivity rule is as explained that if enabler X affects enabler Y and enabler Y affects enabler Z, then enabler X necessarily affects enabler Z.
- Level partitioning is done in line with obtained reachability matrix, to determine various levels in the model.
- Based on the final reachability matrix, a digraph is constructed through nodes and arrow lines and its transitivity links are deleted.
- The resultant digraph is later transformed into ISM model by substituting enabler nodes with statements.

4.1.2.1 Structural self-interaction matrix development. The contextual relationship is determined by examining and exploring the relationship between the two enablers (i and j) and their direction too. For symbolize directions, four symbols have been used and recommended; each symbol denotes a unique relationship based on the direction.

Table 6. Structural self-interaction matrix

LSCEs	25	24	21	20	19	16	15	14	13	11	10	9	8	7	6	5	4	3	2
1	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
2	V	V	V	V	V	V	V	V	X	V	V	V	V	V	X	V	V	V	
3	V	V	V	V	V	V	V	V	A	V	V	V	X	X	A	V	V		
4	V	V	V	V	X	V	X	X	A	V	V	V	A	A	A	V			
5	V	A	V	X	A	V	A	A	A	X	A	A	A	A	A				
6	V	V	V	V	V	V	V	V	X	V	V	V	V	V					
7	V	V	V	V	V	V	V	V	A	V	V	V	X						
8	V	V	V	V	V	V	V	V	A	V	V	V							
9	V	X	V	V	A	V	A	A	A	V	X								
10	V	X	V	V	A	V	A	A	A	V									
11	V	A	V	X	A	V	A	A	A										
13	V	V	V	V	V	V	V	V											
14	V	V	V	V	X	V	X												
15	V	V	V	V	X	V													
16	X	A	X	A	A														
19	V	V	V	V															
20	V	A	V																
21	X	A																	
24	V																		
25																			

These four symbols are:

(1) V: enabler i will lead to enabler j.

(2) A: enabler i will be achieved by enabler j.

(3) X: enabler i and enabler j will facilitate to achieve each other.

(4) O: enabler i and enabler j are not related.

Based on the contextual relationship between enablers, SSIM has been configured in Table 6.

4.1.2.2 Initial reachability matrix. The developed SSIM is transformed to a binary matrix after transforming V, A, X and O by 1 and 0 according to the given case. The resultant matrix is the initial reachability matrix as shown in Table 7. The replacement of 1 and 0 is based on below-mentioned rules (Watson, 1978):

- If (i, j) entry in the SSIM is V, then (i, j) entry in the reachability matrix changes to 1 and the (j, i) entry changes to 0.
- If (i, j) entry in the SSIM is A, then (i, j) entry in the reachability matrix changes to 0 and the (j, i) entry changes to 1.
- If (i, j) entry in the SSIM is X, then (i, j) entry in the reachability matrix changes to 1 and the (j, i) entry also changes to 1.
- If (i, j) entry in the SSIM is O, then (i, j) entry in the reachability matrix changes to 0 and (j, i) entry also changes to 0.

4.1.2.3 Final reachability matrix. Based on the initial reachability model, the final reachability matrix is developed after checking for transitivity. Using this relationship, transitivity is validated for the initial reachability matrix. After imposing transitivity, final reachability matrix is developed as depicted in Table 8.

LSCEs	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	19	20	21	24	25
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
3	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
4	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
5	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
6	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
8	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
9	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	1
10	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	0	1	1
11	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
13	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
15	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
19	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
24	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1

Table 7. Initial reachability matrix

Table 8.
Final reachability matrix

LSCEs	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	19	20	21	24	25
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	1	1	1	1	1	1*	1	1	1	1	1	1	1
3	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
4	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
5	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
6	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
8	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1
9	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	1
10	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1*	1	1
11	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
13	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
15	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
19	0	0	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1
20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
24	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1

Note: *Transitivity

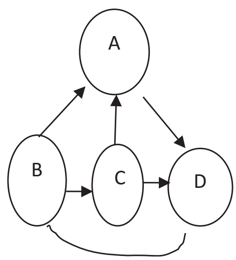

Figure 2.
Transitivity diagram

Transitivity is significant parts of ISM where relationships are made on assumptions. Here transitivity relationships are indicated by 1*. The transitivity concept is shown in Figure 2.

4.1.2.4 Level partitions. To determine the hierarchy amongst barriers, level partitions are being performed. The reachability and antecedent set for every enabler is to be identified after analyzing the final reachability matrix. The enablers that have identical reachability and antecedent sets are specified top position in ISM hierarchy. The enablers at top-level of the hierarchy does not permit in achieving any other enabler located at top of its own level. On recognizing the top-level enablers, they are deleted from next consecutive iterations and the same method is done successively leading to the attainment of a lower level. The hierarchy levels help in developing the final ISM model. Level partitioning of reachability matrix consisting of all iterations and enabler levels is shown in Table 9.

4.1.2.5 Development of interpretative structural modeling model. The final structural model is derived based on the final reachability matrix and is designated as a digraph. The digraph shows the relationship among enablers and is represented by arrows as shown in Figure 3.

LSCEs code	Reachability set	Antecedent set	Common set	Level	Driving power	Dependence power
1	1	1	1	VII	20	1
2	2,6,13	1,2,6,13	2,6,13	VI	19	4
3	3,7,8	1,2,3,6,7,8,13	3,7,8	V	16	7
4	4,14,15,19	1,2,3,4,6,7,8,13,14,15,19	4,14,15,19	IV	13	11
5	5,11,20	1,2,3,4,5,6,7,8,9,10,11,13,14,15,19, 20,24	5,11,20	II	6	17
6	2,6,13	1,2,6,13	2,6,13	VI	19	4
7	3,7,8	1,2,3,6,7,8,13	3,7,8	V	16	7
8	3,7,8	1,2,3,6,7,8,13	3,7,8	V	16	7
9	9,10,24	1,2,3,4,6,7,8,9,10,13,14,15,19,24	9,10,24	III	9	14
10	9,10,24	1,2,3,4,6,7,8,9,10,13,14,15,19,24	9,10,24	III	9	14
11	5,11,20	1,2,3,4,5,6,7,8,9,10,11,13,14,15,19, 20,24	5,11,20	II	6	17
13	2,6,13	1,2,6,13	2,6,13	VI	19	4
14	4,14,15,19	1,2,3,4,6,7,8,13,14,15,19	4,14,15,19	IV	13	11
15	4,14,15,19	1,2,3,4,6,7,8,13,14,15,19	4,14,15,19	IV	13	11
16	16,21,25	1,2,3,4,5,6,7,8,9,10,11,13,14,15, 16,19,20,21,24,25	16,21,25	I	3	20
19	4,14,15,19	1,2,3,4,6,7,8,13,14,15,19	4,14,15,19	IV	13	11
20	5,11,20	1,2,3,4,5,6,7,8,9,10,11,13,14,15,19, 20,24	5,11,20	II	6	17
21	16,21,25	1,2,3,4,5,6,7,8,9,10,11,13,14,15,16, 19,20,21,24,25	16,21,25	I	3	20
24	9,10,24	1,2,3,4,6,7,8,9,10,13,14,15,19,24	9,10,24	III	9	14
25	16,21,25	1,2,3,4,5,6,7,8,9,10,11,13,14,15, 16,19,20,21,24,25	16,21,25	I	3	20

Table 9. Partition and levels of the LSCEs

The final digraph model is derived based on final reachability matrix which is then transformed into ISM model as depicted in Figure 4.

Step V: Apply MICMAC analysis to find the driving and dependence power of each enabler and monitor their effects on LSCM implementation.

4.1.3 Micmac analysis. Matriced' Impacts croises-multipication applique' and classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The MICMAC principle is based on the multiplication properties of matrices (Sharma *et al.*, 1995). MICMAC analyses the enablers based on their driving and dependence powers which are dependent on a binary relationship (Duperrin and Godet, 1973). This is done so as to identify the key enablers that drive the system in various categories. In the present study, various enablers have been classified into four categories based on their driving power and dependence power, as follows:

1. *Autonomous enablers*: These enablers are having weak driving power and weak dependence. They are relatively disconnected from the system, with which they have few links, which may be very strong. These enablers are represented in Quadrant I.
2. *Dependent enablers*: This category includes those enablers which are having weak drive power but strong dependence power and they are placed in Quadrant II.
3. *Linkage enablers*: These enablers are having strong driving power, as well as strong dependence and are placed in Quadrant III. They are also unstable because of which any action on them will have an effect on others and also a feedback effect on themselves.
4. *Driving or independent enablers*: These enablers are having strong driving power but weak dependence power. These are represented in Quadrant IV.

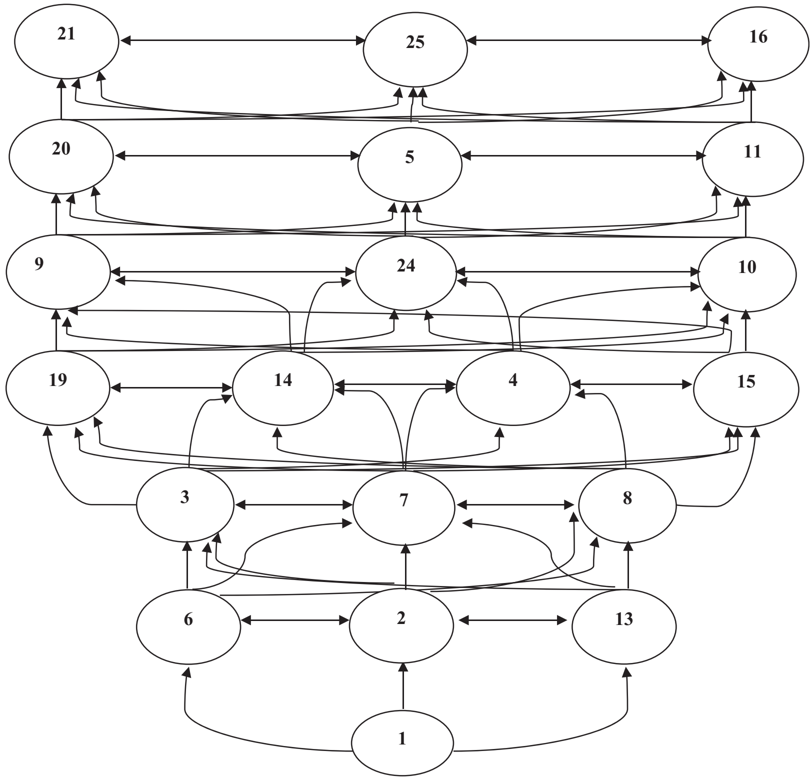

Figure 3.
Diagraph of ISM model

Figure 5 shows the MICMAC analysis where driving power on Y-axis and dependence power on the X-axis.

Enables having low dependence and low driving power are called autonomous enables and are marked as Cluster I. No enables are autonomous, which indicates that no enabler is disconnected from the system. Managers need to pay attention and focus on all identified enablers. Enables having high dependence and low driving power are called dependent enablers and are marked as Cluster II. Enablers of Level 5 i.e. LCSEs-9, 10, 24 termed as customer relationship management, coordination and collaboration among supply chain, knowledge and information management, Level 6 i.e. LCSEs-5, 11, 20 termed as the information technology, quality improvement and value chain analysis and Level 7 i.e. LCSEs-16, 21, 25 termed as the standardization of work, human resource training and education and kanban system are classified as very high dependent enablers. Enablers of Level 4 i.e. LCSEs-4, 14, 15, 19 termed as reduction in lead time, JIT, long-term planning and eliminating waste are classified as linkage enablers marked as Cluster III. These are the intermediate enablers, which highly affect and as well are affected by other enablers. Enablers of Level 3 i.e. LCSEs-3, 7, 8 termed as performance management, logistic management and inventory management, Level 2 i.e. LCSEs-2, 6, 13 termed as supplier management, total quality management and continuous improvement and Level 1 i.e. LCSEs-1 termed as the top management commitment are called as driving or independent

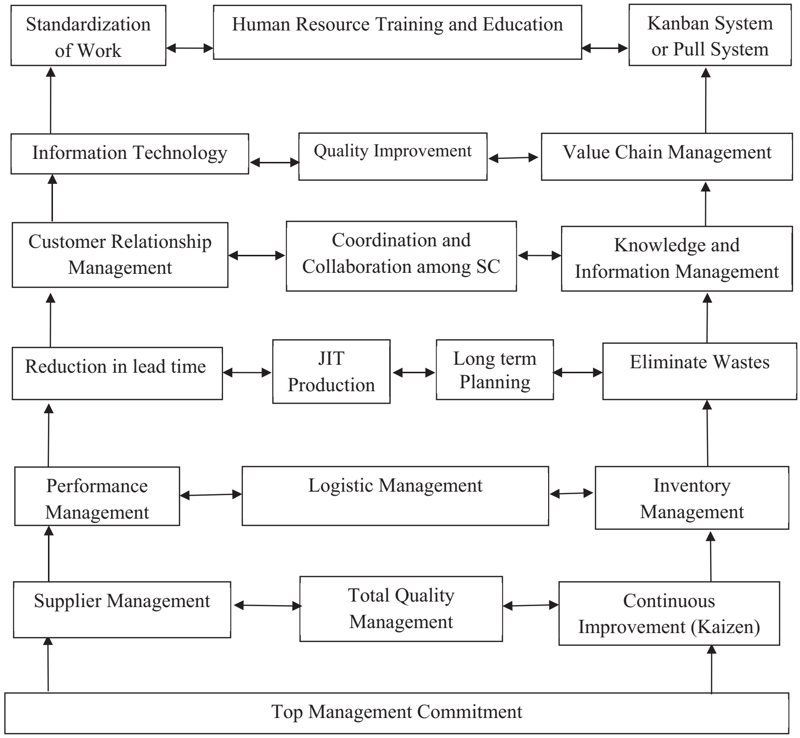

Figure 4.
ISM model of LSCEs

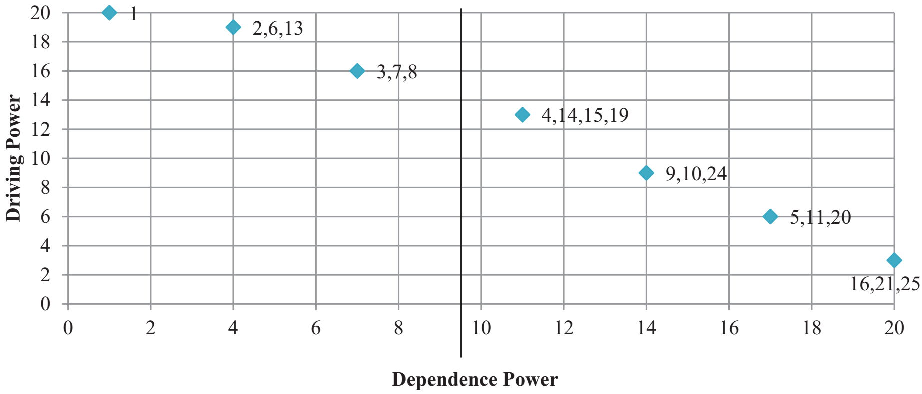

Figure 5.
MICMAC analysis

enablers and are marked as Cluster IV. These enablers occupy bottom place of the hierarchy as they have low dependence and high driving power. The summary is shown in Table 10.

Step VI: Conclude the results and present the findings of the study. This is described in detail under Section 5 of the study.

Table 10.
Summary table

Cluster	Name of cluster	Level in ISM model	Code of enabler	Name of enabler	Priority weight of enabler	Cumulative level weight	Cumulative cluster weight
Cluster I	Autonomous enablers			No enabler exist in this cluster			
Cluster II	Dependent enablers (bottom enablers)	Level 5	LSCE 9	Customer relationship management	0.0261	0.0631	0.1368
			LSCE 10	Knowledge and information management	0.0174		
			LSCE 24	Coordination and collaboration among SC	0.0196		
		Level 6	LSCE 5	Quality improvement	0.0154	0.0438	
			LSCE 11	Value chain management	0.0116		
			LSCE 20	Information Technology	0.0168		
		Level 7	LSCE 16	Kanban system or pull system	0.0096	0.0299	
			LSCE 21	Standardization of work	0.0091		
			LSCE 25	Human resource training and education	0.0112		
Cluster III	Linkage enablers (intermediate enablers)	Level 4	LSCE 4	Long term planning	0.02904	0.13284	0.13284
			LSCE 14	JIT production	0.0416		
			LSCE 15	Eliminate wastes	0.0272		
			LSCE 19	Reduction in lead time	0.035		
Cluster IV	Driving/ independent enablers (top level enablers)	Level 1	LSCE 1	Top management commitment	0.2552	0.2552	0.6971
		Level 2	LSCE 2	Total quality management	0.088	0.2818	
			LSCE 6	Supplier management	0.1218		
			LSCE 13	Continuous improvement (Kaizen)	0.072		
		Level 3	LSCE 3	Performance measurement	0.0528	0.1601	
			LSCE 7	Logistic management	0.0638		
			LSCE 8	Inventory management	0.0435		

5. Results and discussions

The objectives of this research are to study, examine and find the globalized weight of identified enablers for their ranking by applying AHP methodology. Other objectives are to establish relationship between them by applying ISM and to find out the driving and the dependence power of these LSCEs by applying MICMAC for successful implementation of LSCM. The study identified 35 LSCEs by reviewing a number of research articles and discussion with experts. The present study shows the utilization of an innovative approach to the LSCM implementation in different organization. From brainstorming sessions and analysis the number of LSCEs are reduced from 35 to 28 for further analysis. The ISM and MICMAC approach have been applied to analyze the contextual relationship and developed an integrated model between top 20 LSCEs. Through the ISM, an interrelationship model among LSCEs has been developed. This model has been developed on the basis of literature review and input from experts. The results of the ISM model are used as an input to the MICMAC analysis to identify the driving and dependence power.

Concluding for the AHP results, the final priority table shows that we can group all the lean enablers in three categories or levels as per their ranking. At the top level, we can group those enablers who are having maximum contribution in priority weightage which is found to be 53.7% and these include top management commitment, supplier management, total quality management and continuous improvement which are the most important lean enablers. The management should focus on these enablers at top priority. In the next level, there are various enablers such as logistic management, performance management, inventory management, JIT production, reduction in lead time, long-term planning and eliminate wastes. The priority of these enablers is 29.3%. These enablers are termed as the intermediate enablers to be taken care by management while the improvement of its supply chain. The enablers occupying the third level are customer relationship management, coordination and collaboration among SC, knowledge and information management, information technology, quality improvement, value chain management, human resource training and education, kanban system or pull system and standardization of work. The priority of these enablers is 13.7%. These enablers are termed as the bottom-level enablers and least care should be taken by management as a rule of selective control over resources. The least priority enablers are housekeeping, production automation, marketing management, employee participation and empowerment, HR training and education, efficient replenishment, change management, reward and recognition occupying 3.4% weightage among all the enabler. These enablers could be eliminated while conduction future research likes developing interrelationships among them.

It has been observed from Figure 4 that the top management commitment is at the first level of ISM model and leads to supplier management, total quality management and continuous improvement which constitutes a second level. Level 3 constitutes the mutual relationship between performance management, logistic management and inventory management. These three levels act as the strong base of the whole hierarchy and will provide sufficient financial and investment support to the organization. Level 3 will lead to the development of Level 4 i.e. reduction in lead time, JIT, long-term planning and eliminating waste and these all are mutually supporting each other. This is the key intermediate level which is very important to understand, as this level is highly affected by the decision policies of first three levels and will highly affect its succeeding levels in the hierarchy. At Level 5, customer relationship management, coordination and collaboration among supply chain, knowledge and information management are the important enablers, which further supports the above two levels of the hierarchy. Level 6 consisting of the information technology, quality improvement and value chain analysis supporting together.

Then finally the LSCEs of Level 7 lead to the standardization of work, human resource training and education and kanban system. If all the seven levels are implemented in the organization, then these key finding offers a meaningful base to deepen the understanding for implementation and also an indication to develop an effective LSCM implementation in a stepwise manner.

The second objective of this study was to analyze the driving and the dependence power of the LSCEs that influence the LSCM implementation through MICMAC analysis. The MICMAC analysis included partitioning of LSCEs among four clusters (Figure 5), where each cluster represents the behavior pattern of LSCEs falling under that cluster. The Cluster I portray the autonomous LSCEs which exhibit weak driving and dependence power. The enablers occupying place in this cluster must be removed immediately as these enablers slow down the entire system. The Cluster II comprises of dependent LSCEs that bear weak driving but strong dependence power. The Cluster III provides linkage or intermediate enablers, exhibiting very strong driving, as well as strong dependence power. These enablers are highly unstable and any modifications in these enablers strongly affect other enablers and have a consolidated effect on overall organizational performance. The cluster IV includes the independent LSCEs that possess high driving power but low dependence power. The description of four clusters is mentioned beneath.

5.1 Cluster I – autonomous LSCEs

The enablers under this cluster are termed as autonomous or excluded enablers. These enablers are having weak driving, as well as weak dependence power and are so posted in the bottom-left zone of the graph. These enablers exhibit the attributes out of line within the entire system. The enablers existing among this cluster are usually disconnected from the system as they do not possess much influence with the implementation process. No enabler selected for present study falls under this cluster hence it signifies that the shortlisted enablers are accurate and best suited for the organization environment and should be taken care by top management on a priority basis.

5.2 Cluster II – dependent LSCEs

The enablers subsisting under this cluster are termed as dependent or resultant enablers. These enablers comprise of weak driving and strong dependence power and are so posted in the bottom right zone of the graph. Nine LSCEs exist under this cluster, which signifies that these enablers are highly dependent on the input variables. Customer relationship management, coordination and collaboration among supply chain, knowledge and information management, information technology, quality improvement, value chain analysis, standardization of work, human resource training and education and kanban system lies on the top of the hierarchy; possessing the property of being highly dependent but portrays weak driving characteristics.

5.3 Cluster III – Linkage LSCEs

The enablers existing under this cluster depicts the concurrent behavior of highly influent and highly dependent. These enablers exhibit the strong driving and strong dependence power and are placed in the top-right zone of the graph being unstable. Small modification in these enablers affects other enablers very quickly while the feedback effect on themselves also alters their output to the system. In the present study, four LSCEs exist in this cluster, which are reduction in lead time, JIT, long-term planning and eliminating waste. These enablers are influenced by lower-level enablers and are unstable in nature and have a greater impact on upper-level enablers and significantly affect the LSCM.

5.4 Cluster IV – Driving or independent LSCEs

The enablers subsisting in this cluster are a strong driver and very weakly dependent on other enablers. These enablers exhibit the characteristics of strong driving and weak dependence power and exist in the top-left zone of the graph, while they act as initiators in the implementing process. These enablers help to achieve successfully other enablers and behave as input for the implementation process. In the present study seven enablers comes under this cluster. The LSCEs; top management commitment, supplier management, total quality management, continuous improvement, performance management, logistic management and inventory management are considered as the driving or independent enablers. They support, facilitate and drive other enablers in the system as they act as a foundation. The management must take care in handling these enablers as they are the root cause for developing the top hierarchy.

The top management should also address the driving and dependent enablers more cautiously, so that the decision-makers of any organization can apply a phased implementation approach beneath the limitations of existing resources to provide the assurance for the effective LSCM implementation. The Priority percentages of different clusters including the cluster of rejected enablers is shown below in Figure 6.

Step VII: Explain the research implications and future scope of the study. This is described in detail under Section 6 of the study.

6. Conclusion and future scope

In the present scenario, almost all the organizations are facing high competition globally instead of making nationwide rivalries and comparisons. As observed the quality has now become the most critical issue in the era of globalization. Therefore, the organizations are forced and bounded for exploring various areas in supply chain enhancement for delivering products at minimum costs for having a cutting edge advantage over their competitors. So, for achieving and maintaining quality at marginal cost; implementation of LSCM has now emerged as one of the most optimization tool. To achieve the above objective, it becomes very important to specify various LSCEs and observe them very minutely. Various LSCEs were reported in the literature reviews which are very important for the implementation of LSCM in any organization. The present study has identified 28 key LSCEs by literature review of peer-reviewed journals and the brainstorming sessions with the group of experts consisting of academicians, practitioners and consultants. As the contribution of individual LSCE would not lead to achieving LSCM implementation; therefore it become very important to identify the inter-relationships among LSCEs. The ISM methodology develops the relationship among each selected enabler through a structural hierarchy and the output

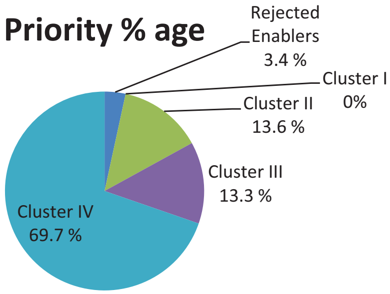

Figure 6. Priority percentage of different clusters

of ISM is used as an input for MICMAC analysis so as to elaborate the driving and dependence power of LSCEs.

6.1 Theoretical implications

The present study uses a hybrid AHP and ISM-MICMAC approach to propose a hierarchical model of LSCEs that may be helpful for practitioners of any organization to classify and key out the significant LSCEs and to interpret the results and the effects of each LSCE on LSCM implementation. This study proposed the hybrid framework to weight the enablers of lean supply chain, analyze the structural interrelationship among enablers of lean supply chain and classify these enablers of lean supply chain based on dependence power and driving power. The findings of the study provide a significant road map for practitioners to implement in their organizations and helps academicians to carry out further research to figure out different issues which can contribute to the betterment of LSCEs for amended LSCM implementation. The interrelationship developed by ISM model will help managers using these LSCEs at maximum potential and implementing LSCM efficiently.

The MICMAC analysis result helps the managers' well understanding to the driving and dependence power of LSCEs. The enhanced focus on managers should be on LSCEs possessing strong driving power as they highly affect in achieving those LSCEs with strong dependence power. The driving power enablers behave as strong inputs while the enablers with higher dependence are strong outputs of the system. Once the LSCEs with high driving power are keyed out, it becomes the primary responsibility of the management to develop action plans to revolutionize their effects during the journey of LSCM implementation.

6.2 Practical implications

The study establishes the basis for integrating organization's strategic objective with the identification of LSCEs for LSCM implementation. The hybrid model of AHP and ISM-MICMAC approach is developed, which may be useful for managers to use this model for identification and classification of the significant LSCEs for their needs. This model also elaborates the direct and indirect inter-relationships and their effect on the LSCM implementation. This study has strong managerial implication for both organizations and researchers. The practitioner of organizations needs to concentrate more on important identified LSCEs more cautiously during LSCM implementation in their organizations. On the other hand, researchers in education institutes may be encouraged to categorize various issues and contributing in future findings. ISM model identifies the hierarchy of actions to be considered by practitioners for the maximization of the effects of LSCEs to successfully implement the LSCM. The MICMAC analysis helps identification of the category of the LSCEs, which needs more attention by practitioners according to their dependence power and driving power. Practitioners should concentrate on those LSCEs which have higher driving power because of these LSCEs should be emphasized for successful implementation. These higher driving LSCEs are the root cause for other LSCEs which have higher depending. Once these higher driving power LSCEs are identified, the top management could formulate a strategy for enhancing their effects during LSCM implementation. Accordingly, LSCM managers may also strategically plan its long-term growth strategy to meet LSCM action plan.

6.3 Limitations and future scope

The developed ISM model in this research is based upon the various experts' opinion of supply chain in automobile sector, as well as the educationist of reputed educational institutes. The final results and findings may vary for different sectors under consideration.

In future, more number of critical enablers affecting LSCM could be identified by findings of different researchers and the interrelationships of various enablers can also be validated with the help of various decision-making tools and approaches. Finally, the developed model obtained can also be statistically validated using different methodologies such as structural equation modeling (SEM) or systems dynamics modeling; and also by conducting the study with reference to various industrial sectors taking as the case studies. There are scope of applying fuzzy AHP, fuzzy ISM and fuzzy MICMAC analysis and then comparing their results with the final results of present study.

In the future as we are in era of interdisciplinary research, so there is an opportunity to explore supply chain optimization with technology. Applying various methodologies for developing the framework with analysis on NVivo Software would be a very good idea for quick and speedy calculations and outputs. Working on developing model for performance optimization or supply chain optimization by SEM method which will also help in reliability and validation of the proposed model. The data automatically will be audited and if some data is not collected, then proper collection method will be designed. Data of operation from enterprise resource planning and other sources is proposed to be used. Hadoop based program could be generated so as to find the right data at right time in right format. This data could be analyzed by programming on R or Python. The machine learning program based on MongoDB and Python by integrating R software for final outcomes is proposed to be developed in future on the basis of which we can further develop web-based search engine for customized optimization of supply chain. Finally, we can also go for patent of the developed concept and product, thereafter for its commercialization in the global market.

References

Achanga, P., Shehab, E., Roy, R. and Nelder, G. (2006), "Critical success factors for lean implementation within SMEs", *Journal of Manufacturing Technology Management*, Vol. 17 No. 4, pp. 460-471.

Agus, A. and Hajinoor, M.S. (2012), "Lean production supply chain management as driver towards enhancing product quality and business performance: case study of manufacturing companies in Malaysia", *International Journal of Quality and Reliability Management*, Vol. 29 No. 1, pp. 92-121.

Anand, G. and Kodali, R. (2008), "A conceptual framework for lean supply chain and its implementation", *International Journal of Value Chain Management*, Vol. 2 No. 3, pp. 313-357.

Anvari, A., Zulkifli, N., Yusuff, R.M., Hojjati, S.M.H. and Ismail, Y. (2011), "A proposed dynamic model for a lean roadmap", *African Journal of Business Management*, Vol. 5 No. 16, pp. 6727-6737.

Arif-Uz-Zaman, K. and Nazmul Ahsan, A.M.M. (2014), "Lean supply chain performance measurement", *International Journal of Productivity and Performance Management*, Vol. 63 No. 5, pp. 588-612.

Assarlind, M. and Aaboen, L. (2013), "Forces affecting one lean six sigma adoption process", *International Journal of Lean Six Sigma*, Vol. 5 No. 3, pp. 324-340.

Baum, D. (2004), "Creating the lean enterprise", *Profit, November*, p. 44, available at: www.oracle.com/oramag/profit/04-nov/p44lean.html (accessed 14 May 2014).

Blos, M., Hoeflich, S. and Miyagi, P. (2015), "A general supply chain continuity management framework", *Procedia Computer Science*, Vol. 55, pp. 1160-1164.

Borgstrom, B. and Hertz, S. (2011), "Supply chain strategies: changes in customer order-based production", *Journal of Business Logistics*, Vol. 32 No. 4, pp. 361-373.

Christopher, M. (2005), *Logistics and Supply Chain Management: Creating Value-Added Networks*, Prentice Hall, Harlow.

Christopher, M. and Towill, D.R. (2000), "Supply chain migration from lean and functional to agile and customised", *Supply Chain Management: An International Journal*, Vol. 5 No. 4, pp. 206-213.

Crowe, T.J., Noble, J.S. and Machimada, J.S. (1998), "Multi-attribute analysis of ISO 9000 electronics firms", *Journal of Small Business Management*, Vol. 33 No. 4, pp. 53-65.

Cudney, E. and Elrod, C. (2011), "A comparative analysis of integrating lean concepts into supply chain management in manufacturing and service industries", *International Journal of Lean Six Sigma*, Vol. 2 No. 1, pp. 5-22.

Dave, Y. and Sohani, N. (2019), "Improving productivity through lean practices in Central India-based manufacturing industries", *International Journal of Lean Six Sigma*, Vol. 10 No. 2, pp. 601-621.

Dong, Y., Carter, C. and Dresner, M. (2001), "JIT purchasing and performance: an exploratory analysis of buyer and supplier perspectives", *Journal of Operations Management*, Vol. 19 No. 4, pp. 471-483.

Drohomeretski, E., Gouvea da Costa, S.E., Pinheiro de Lima, E. and Garbuio, P.A.D.R. (2014), "Lean, six sigma and lean six sigma: an analysis based on operations strategy", *International Journal of Production Research*, Vol. 52 No. 3, pp. 804-824.

Duperrin, J.C. and Godet, M. (1973), "'Methode De hierrchisation des elements D'un systeme' [methodology for prioritizing elements from a system]", Rapport Economique Du CEA, R-45-41, Paris.

Eriksson, P.E. (2010), "Improving construction supply chain collaboration and performance: a lean construction pilot project", *Supply Chain Management: An International Journal*, Vol. 15 No. 5, pp. 394-403.

Fink, A. (1998), *Conducting Research Literature Reviews: From Paper to the Internet*, Sage, Thousand Oaks, CA.

Fisher, M.L. (1997), "What is the right supply chain for your product?", *Harvard Business Review*, Vol. 75 No. 2, pp. 105-116.

Fore, S. and Mbohwa, C. (2015), "Greening manufacturing practices in a continuous process industry: case study of a cement manufacturing company", *Journal of Engineering, Design and Technology*, Vol. 13 No. 1, pp. 94-122.

Gorane, S.J. and Kant, R. (2015), "Modelling the SCM implementation barriers: an integrated ISM-fuzzy MICMAC approach", *Journal of Modelling in Management*, Vol. 10 No. 2, pp. 158-178.

Green, K., Inman, R., Birou, L. and Whitten, D. (2014), "Total JIT (T-JIT) and its impact on supply chain competency and organizational performance", *International Journal of Production Economics*, Vol. 147, pp. 125-135.

Gupta, V., Acharya, P. and Patwardhan, M. (2013), "A strategic and operational approach to assess the lean performance in radial tyre manufacturing in India: a case based study", *International Journal of Productivity and Performance Management*, Vol. 62 No. 6, pp. 634-651.

Hafeez, K., Zhang, Y. and Malak, N. (2002), "Determining key capabilities of a firm using analytical hierarchy process", *International Journal of Production Economics*, Vol. 76 No. 1, pp. 39-51.

Haleem, A., Sushil, Qadri, M.A. and Kumar, S. (2012), "Analysis of critical success factors of world-class manufacturing practices: an application of interpretative structural modelling and interpretative ranking process", *Production Planning and Control*, Vol. 23 Nos 10/11, pp. 722-734.

Hallgren, M. and Olhager, J. (2009), "Lean and agile supply chain: external and internal drivers and performance outcomes", *International Journal of Operations and Production Management*, Vol. 29 No. 10, pp. 976-999.

Haq, A.N. and Boddu, V. (2015), "An integrated fuzzy QFD and TOPSIS approach to enhance leanness in supply chain", *International Journal of Business Performance and Supply Chain Modelling*, Vol. 7 No. 2, pp. 171-188.

Hilton, R.J. and Sohal, A. (2012), "A conceptual model for the successful deployment of lean six sigma", *International Journal of Quality and Reliability Management*, Vol. 29 No. 1, pp. 54-70.

Hines, P., Holweg, M. and Rich, N. (2004), "Learning to evolve: a review of contemporary lean thinking", *International Journal of Operations and Production Management*, Vol. 24 No. 10, pp. 994-1011.

Huang, S.H., Uppal, M. and Shi, J. (2002), "A product driven approach to manufacturing supply chain selection", *Supply Chain Management: An International Journal*, Vol. 7 No. 4, pp. 189-199.

Janes, F.R. (1988), "Interpretive structural modelling: a methodology for structuring complex issues", *Transactions of the Institute of Measurement and Control*, Vol. 10 No. 3, pp. 145-154.

Jasti, N. and Kodali, R. (2015), "A critical review of lean supply chain management frameworks: proposed framework", *Production Planning and Control*, Vol. 26 No. 13, pp. 1051-1068.

Jayaram, V., Vickery, S.K. and Droge, C. (1999), "An empirical study of time-based competition in the North American automotive supplier industry", *International Journal of Operations and Production Management*, Vol. 19 No. 10, pp. 1010-1034.

Jeyaraman, K. and Teo, L.K. (2010), "A conceptual framework for critical success factors of lean six sigma: implementation on the performance of electronic manufacturing service industry", *International Journal of Lean Six Sigma*, Vol. 1 No. 3, pp. 191-215.

Kumar, S., Dhingra, A. and Singh, B. (2018), "Lean-Kaizen implementation: a roadmap for identifying continuous improvement opportunities in Indian small and medium sized enterprise", *Journal of Engineering, Design and Technology*, Vol. 16 No. 1, pp. 143-160.

Kumar, A., Ozdamar, L. and Ning Zhang, C. (2008), "Supply chain redesign in the healthcare industry of Singapore", *Supply Chain Management: An International Journal*, Vol. 13 No. 2, pp. 95-103.

Maleyeff, J. (2012), "The continuing evolution of lean six sigma", *The TQM Journal*, Vol. 24 No. 6, pp. 542-555.

Mandal, A. and Deshmukh, S.G. (1994), "Vendor selection using interpretive structural modelling (ISM)", *International Journal of Operations and Production Management*, Vol. 14 No. 6, pp. 52-59.

Marodin, G.A. and Saurin, T.A. (2013), "Implementing lean production systems: research areas and opportunities for future studies", *International Journal of Production Research*, Vol. 51 No. 22, pp. 6663-6680.

Martínez-Jurado, P. and Moyano-Fuentes, J. (2013), "Lean management and sustainability: a literature review", *Journal of Cleaner Production*, In Press, pp. 1-17.

Merkin, B.G. (1979), *Group Choice*, John Wiley and Sons, New York, NY.

Monczka, R., Handfield, R., Giunipero, L. and Patterson, J. (2009), *Purchasing and Supply Chain Management*, 4th ed, Cengage Learning, Mason.

Mustaffa, N. and Potter, A. (2009), "Healthcare supply chain management in Malaysia: a case study", *Supply Chain Management: An International Journal*, Vol. 14 No. 3, pp. 234-243.

Nachtmann, H. and Pohl, E. (2009), "The state of healthcare logistics, cost and quality improvement opportunities", *Center for Innovation in Healthcare Logistics*, University of AR.

Najmi, M., Etebari, M. and Emami, E. (2012), "A framework to review performance prism", *International Journal of Operations and Production Management*, Vol. 32 No. 10, pp. 1124-1146.

Naslund, D. (2013), "Lean and six sigma- critical success factors revisited", *International Journal of Quality and Service Sciences*, Vol. 5 No. 1, pp. 86-100.

Naylor, J.B., Naim, M.M. and Berry, D. (1999), "Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain", *International Journal of Production Economics*, Vol. 62 Nos 1/2, pp. 107-118.

Netland, T. and Ferdows, K. (2014), "What to expect from a corporate lean program", *MIT Sloan Management Review*, Vol. 55 No. 3, pp. 83-89.

Netland, T., Schloetzer, J. and Ferdows, K. (2015), "Implementing lean: the effect of takt time", *Proceedings of Euroma Conference, Vol. 2015, Neuchatel, June 28-30*.

Oliver, N. (1993), "JIT: Issues and items for research agenda", *International Journal of Physical Distribution and Logistics Management*, Vol. 20 No. 7, pp. 3-11.

Pan, Z. and Pokharel, S. (2007), "Logistics in hospitals: a case study of some Singapore hospitals", *Leadership in Health Services*, Vol. 20 No. 3, pp. 195-207.

Papadopoulos, T. (2011), "Continuous improvement and dynamic actor associations: a study of lean thinking implementation in the UK national health service", *Leadership in Health Services*, Vol. 24 No. 3, pp. 207-227.

Parker, J. and DelLay, D. (2008), "The future of the healthcare supply chain: suppliers wield considerable power, but healthcare organizations can benefit from virtual centralization of the supply chain", *Healthcare Financial Management*, Vol. 62 No. 4, pp. 66-69.

Perez, C., Castro, R., Simons, D. and Gimenez, G. (2010), "Development of lean supply chains: a case study of the Catalan pork sector", *Supply Chain Management: An International Journal*, Vol. 15 No. 1, pp. 55-68.

Perry, A. and Kocakülâh, H. (2010), "Healthcare supply chain leadership and strategy: How it can help cost containment in the healthcare industry", *Cost Management,*, Vol. 24 No. p. 2, p.37.

Persson, F. and Olhager, J. (2002), "Performance simulation of supply chain designs", *International Journal of Production Economics*, Vol. 77 No. 3, pp. 231-245.

Piercy, N. and Rich, N. (2009), "Lean transformation in the pure service environment: the case of the call service centre", *International Journal of Operations and Production Management*, Vol. 29 No. 1, pp. 54-76.

Psomas, E.L. and Antony, J. (2015), "The effectiveness of the ISO 9001 quality management system in service companies", *International Journal of Production Research*, Vol. 53 No. 7, pp. 2089-2099.

Qi, Y., Zhao, X. and Sheu, C. (2011), "The impact of competitive strategy and supply chain strategy on business performance: the role of environmental uncertainty", *Decision Sciences*, Vol. 42 No. 2, pp. 371-389.

Qrunfleh, S. and Tarafdar, M. (2013), "Lean and agile supply chain strategies and supply chain responsiveness: the role of strategic supplier partnership and postponement", *Supply Chain Management: An International Journal*, Vol. 18 No. 6, pp. 571-582.

Rajabion, L., Mokhtari, A.S., Khordehbinan, M.W., Zare, M. and Hassani, A. (2019), "The role of knowledge sharing in supply chain success: Literature review, classification and current trends", *Journal of Engineering, Design and Technology*, Vol. 17 No. 6, pp. 1222-1249.

Reese, A.K. (2007), "Disaster-proofing the supply chain", *Supply and Demand Chain Executive*, Vol. 8 No. 3, pp. 42-46.

Saaty, T. (1994), "How to make a decision: the analytic hierarchy process", *Interfaces*, Vol. 24 No. 6, pp. 19-43.

Saaty, T.L. (1980), "What is the analytic hierarchy process?", In *Mathematical Models for Decision Support.* , *Springer, Berlin, Heidelberg*, pp. 109-121

Saaty, T.L. (1986), "Axiomatic foundation of the analytic hierarchy process", *Management Science*, Vol. 32 No. 7, pp. 841-855.

Saaty, T.L. (1990), "An Exposition on the AHP in reply to the paper remarks on the analytic hierarchy process", *Management Science*, Vol. 36 No. 3, pp. 259-268.

Saaty, T.L. (2001), "Fundamentals of the analytic hierarchy process", in: Schmoldt, D.L., Kangas, J., Mendoza, G.A. and Pesonen, M. (eds), *The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making. Managing Forest Ecosystems*, Springer, Dordrecht, Vol. 3.

Saaty, T.L. (2000), *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, Vol. 6, *RWS Publications*, Pittsburgh.

Sage, A.P. (1977), "*Interpretive Structural Modeling: Methodology for Large-Scale Systems*, McGraw-Hill, New York, NY, pp. 91-164.

Samaranayake, P., Punnakitikashem, P. and Laosirihongthong, T. (2010), "Logistics and supply chain management in healthcare service operations – a holistic approach to planning/execution", *In 8th ANZAM Operations, Supply Chain and Services Management Symposium, Sydney, 6–8 June-1–13.*

Shadur, M.A. and Bamber, G.J. (1994), "Toward lean management? International transferability of Japanese management strategies to Australia", *The International Executive*, Vol. 36 No. 3, pp. 343-364.

Sharma, S.K. and Bhat, A. (2014), "Modelling supply chain agility enablers using ISM", *Journal of Modelling in Management*, Vol. 9 No. 2, pp. 200-214.

Sharma, H.D., Gupta, A.D. and Sushil, S. (1995), "The objectives of waste management in India: a futures inquiry", *Technological Forecasting and Social Change*, Vol. 48 No. 3, pp. 285-309.

Shirzad Talatappeh, S. and Lakzi, A. (2020), "Developing a model for investigating the impact of cloud-based systems on green supply chain management", *Journal of Engineering, Design and Technology*, Vol. 18 No. 4, pp. 741-760.

Shurrab, J. and Hussain, M. (2018), "An empirical study of the impact of lean on the performance of the construction industry in UAE", *Journal of Engineering, Design and Technology*, Vol. 16 No. 5, pp. 694-710.

Soni, G. and Kodali, R. (2012), "Evaluating reliability and validity of lean, agile and leagile supply chain constructs in Indian manufacturing industry", *Production Planning and Control*, Vol. 23 Nos 10/11, pp. 864-884.

Srinivasan, M.M., Srinivasan, T. and Choi, E.W. (2005), "Build and manage a lean supply chain", *Industrial Management*, Vol. 47 No. 5, pp. 20-25.

Storey, J., Emberson, C., Godsell, J. and Harrison, A. (2006), "Supply chain management: theory, practice and future challenges", *International Journal of Operations and Production Management*, Vol. 26 No. 7, pp. 754-774.

Taylor, D. (1999), "Parallel incremental transformation strategy: an approach to the development of lean supply chains", *International Journal of Logistics Research and Applications*, Vol. 2 No. 3, pp. 305-323.

Taylor, D.H. (2006), "Strategic considerations in the development of lean agri-food supply chains: a case study of the UK pork sector", *Supply Chain Management: An International Journal*, Vol. 11 No. 3, pp. 271-280.

Theagarajan, S. and Manohar, H. (2015), "Lean management practices to improve supply chain performance of leather footwear industry", *International Conference on Industrial Engineering and Operations Management, Dubai, March 3-5*.

Tortorella, G., Miorando, R. and Tlapa, D. (2017), "Implementation of lean supply chain: an empirical research on the effect of context", *The TQM Journal*, Vol. 29 No. 4, pp. 610-623.

Tortorella, G., Giglio, R., Fettermmann, D.C. and Tlapa, D. (2018), "Lean supply chain practices: an exploratory study on their relationship", *The International Journal of Logistics Management*, Vol. 29 No. 3, pp. 1049-1076.

Towill, D.R. (2000), "A route map for substantially improving supply chain dynamics", *International Journal of Manufacturing Technology and Management*,, Vol. 1 1, pp. 94-112.

Vinodh, S. and Joy, D. (2011), "Structural equation modelling of lean manufacturing practices", *International Journal of Production Research*, Vol. 50 No. 6, pp. 1598-1607.

Vitasek, K., Manrodt, K.B. and Abbott, J. (2005), "What makes a lean supply chain?", *Supply Chain Management Review*, Vol. 9 No. 7, pp. 39-45.

Vonderembse, M.A., Uppal, M., Huang, S.H. and Dismukes, J.P. (2006), "Designing supply chains: towards theory development", *International Journal of Production Economics*, Vol. 100 No. 2, pp. 223-238.

Warfield, J.N. (1974), "Developing interconnection matrices in structural modeling", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-4 No. 1, pp. 81-87.

Watson, R.H. (1978), "Interpretive structural modeling-A useful tool for technology assessment?", *Technological Forecasting and Social Change*, Vol. 11 No. 2, pp. 165-185.

Wee, H. and Wu, S. (2009), "Lean supply chain and its effect on product cost and quality: a case study on ford motor company", *Supply Chain Management: An International Journal*, Vol. 14 No. 5, pp. 335-341.

Womack, J.P. and Jones, D.T. (1994), "From lean production to the lean enterprise", *Harvard Business Review*, Vol. 72 No. 2, pp. 93-103.

Zarei, M., Fakhrzad, M.B. and Paghaleh, M.J. (2011), "Food supply chain leanness using a developed QFD model", *Journal of Food Engineering*, Vol. 102 No. 1, pp. 25-33.

Further reading

Ayough, A., Rafiei, R. and Shabbak, A. (2021), "Making distribution operations lean: the management system approach in a case", *Journal of Engineering, Design and Technology*.

Jasti, N. and Kodali, R. (2014), "Lean production: literature review and trends", *International Journal of Production Research*, Vol. 53 No. 3, pp. 1-19.

Marodin, G., Frank, A., Tortorella, G. and Saurin, T. (2016), "Contextual factors and lean production implementation in the Brazilian automotive supply chain", *Supply Chain Management: An International Journal*, Vol. 21 No. 4, pp. 417-432.

Mason-Jones, R., Nailor, B. and Towill, D.R. (2000), "Lean, agile or leagile? Matching your supply chain to the marketplace", *International Journal of Production Research*, Vol. 38 No. 17, pp. 4061-4070.

Qi, Y., Zhao, X. and Sheu, C. (2011), "The impact of competitive strategy and supply chain strategy on business performance: the role of environmental uncertainty", *Decision Sciences*, Vol. 42 No. 2, pp. 371-389.

Appendix 1

S. No.	LSCEs
1	Supplier management
2	Top management commitment
3	Continuous improvement
4	JIT production
5	Logistic management
6	Total quality management
7	Reduction in lead time
8	Eliminate wastes
9	Information Technology
10	Performance measurement
11	Kanban system or pull system
12	Standardization of work
13	Inventory management
14	Customer relationship management
15	Production Automation
16	Knowledge management
17	Coordination among SC
18	Value chain management
19	Efficient replenishment
20	Long term planning
21	Quality improvement
22	Human resource training
23	Employee participation
24	Marketing management
25	Change management (cultural change)
26	Housekeeping (5S)
27	Total productive maintenance
28	Reward
29	Information management
30	Education to employees
31	Collaboration among supply chain
32	Kaizen philosophy
33	Recognition
34	Inventory control
35	Empowerment of employee

Table A1. List of enablers identified

Appendix 2

S. No.	LSCEs
1	Knowledge management
2	Information management
3	Human resource training
4	Education to employees
5	Employee participation
6	Empowerment of employees
7	Coordination among supply chain
8	Collaboration among supply chain
9	Recognition
10	Reward
11	Inventory management
12	Inventory control
13	Continuous improvement
14	Kaizen philosophy

Table A2.
List of enablers either eliminated or merged

Corresponding author
Ashish Yadav can be contacted at: ashishsgsits11@gmail.com