Management and Industrial Engineering

Kaliyan Mathiyazhagan · K. E. K. Vimal · Harish Kumar · Anbanandam Ramesh · Vernika Agarwal *Editors*

Lean and Green Manufacturing

Towards Eco-Efficiency and Business Performance

Springer

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Preface

In recent years, many companies have established a fundamental goal to minimize the environmental impact while maintaining high quality and service for all business processes and products. This growing concern for environmental issues prompts organizations to incorporate "greening initiatives" into their supply chain operations. The preliminary step in this direction is to identify the environmental concerns and take appropriate measures to reduce them. Green manufacturing is part of a continuous improvement strategy to help manufacturers improve their productivity, profitability, and competitiveness.

Recently, a few organizations approaching toward green manufacturing have tried to use it as a marketing tool to attain an edge over their competitors. Only a few organizations show real concerns over adopting green manufacturing practices due to their associated economic investments. The primary aim of "greening manufacturing" is to coordinate the production activities within the supply chain to reduce waste and maximize the use of clean technology to meet the organization's needs at the "least cost" to the environment. Thus, manufacturing organizations needs to streamline their operations by eliminating wastes and non-value-added activities. Lean principles involve a systematic approach to identifying and eliminating waste and non-value-added activities through continuous improvement, which is also the key to enhance environmental performance. The manufacturers are starting to realize that the mission to become greener takes them right back to the lean manufacturing approach.

The key to achieving these challenges is by changing the company's decision-making processes to incorporate environmental aspects, be in the form of "green" or "lean SC operations," which will affect the operations' overall environmental cost. Reducing the raw materials and inventory helps not only the environment but also your bottom line. Additionally, developing more sustainable practices will help you comply with local, federal, and global environmental initiatives and might even earn you some excellent incentives from your state or local government. And last but not least, there is the benefit of working toward a greener future by reducing pollutants and other forms of waste that harm our planet. The purpose of these supply chain initiatives is to reduce both costs and wastes. Conventional decision-making approaches commonly overlook or inadequately represent the costs and benefits of departments outside the decision-maker's area. These developments led to few unanswered questions like how to integrate the tools and the complications in correlating the two paradigms that are still not answered. Further, the analytical and scientific methods to support practitioners were not explicitly discussed in the past.

This book is planned to provide a stage-by-stage integration of lean and green manufacturing paradigms to achieve environmental and economic benefits. The book's various chapters are expected to support the practicing managers during the implementation of integrated lean and green manufacturing paradigms. The book chapters will be organized into three parts: (1) conceptualizing integrated lean and green manufacturing paradigms; (2) tools and techniques for integrated lean and green paradigms, and (3) case studies demonstrating the implementation of integrating lean-green paradigms.

Chapter "Analyzing the Barriers for the Implementation of Lean and Green Closed-Loop Supply Chain in Indian SMEs" deals with analyzing the barriers in implementing the lean and green closed-loop supply chain in the Indian small and medium enterprises (SMEs). A total of thirty-five barriers were identified from the literature survey; out of that, fifteen potential barriers have been shortlisted using the best-worst method. After finalizing the top barriers, interpretive structural modeling has been adopted to analyze the barriers' relationship. The proposed framework provides a systematic approach for analyzing the barriers and creating roadmaps to implement a lean and green closed-loop supply chain in the SMEs.

Chapter "Assessing the Drivers and Challenges to Deploying Lean-Green Practices the in Indian Manufacturing Sector" discusses the drivers and challenges pertaining to current lean-green deployment practices in Indian manufacturing based on the recent literature and experts in the manufacturing space. The study involved a literature review and expert consultation in identifying the factors followed by data collection. Fuzzy TOPSIS was used to rank the drivers and challenges concerning the consumer, industry, and government perspectives. The top-ranked driver and the top-ranked challenge were identified. Insights into the present scenario of lean-green deployment in manufacturing are facilitated by the factors identified from the recent literature.

Chapter "Performance Evaluation of Lean-Green Healthcare Manufacturing Plants: A Fuzzy TOPSIS Approach" aims to understand how to enhance the healthcare sector to ensure that it provides for a better system for the patients. The evaluation is carried out on the lean-green strategy utilized by the manufacturing plants. The case of a healthcare manufacturing firm is considered, which has multiple plants. To evaluate which of the firm's plants has been able to implement the lean-green strategy in the manufacturing of medical equipment, F-TOPSIS is utilized.

Chapter "Impact of Policy Change on Sustainability Initiatives by Indian Firms" discusses a novel conceptual framework that can be used to classify a firm's operations strategic initiatives by blending its Corporate Social Responsibility (CSR) initiatives of a firm and its adoption of ethical standards to classify a firm's operations strategic initiatives. Further, by illustrating a CSR spend analysis for an Indian firm, the paper discusses how a firm can strategically position its sustainability to achieve a competitive advantage.

Chapter "Trade Prediction Outcomes During Pandemic and Its Impact in Lean Implementation" measures the variation in international trade using a prediction model for few major commodities. This predicted trade variation and its impact in the manufacturing sector are identified as the variation in input resources and worker movement restriction due to containment. These identified trade prediction outcomes and their impact on few lean implementation practices of manufacturing organizations were discussed. This research aims to give insights and thoughts to the traders that could result in effective and successful trading during crisis times. The prediction of commodities as an input resource has resulted in low, medium, and high impact on various lean implementation tools.

Chapter "Traceability Systems and Technologies for Sustainability in Food Supply Chains" discusses traceability in the food supply chain. This article underscores the role of traceability systems, an important driver of sustainability, in the food supply chain and explores the underlying technologies and a brief overview of the barriers to their adoption. Thus, this paper paves the way for future research in traceability technologies to enable SSCM practices.

Chapter "Application of Lean Tools in New Product Development: A Case Study from Precision Metrology Manufacturing" aims to understand the application of lean tools implementation in various phases of the New Product Development (NPD) process in a meteorology instrument manufacturing company. The significant improvements of crucial key performance indicators were analyzed and discussed in detail. Based on the analysis, the study proposes a practical lean framework for businesses to use. The chapter discusses the lessons learned and the implications for engineering production managers based on the case study. The findings of this study show the impact of implementing a lean tool to improve business performance.

Chapter "Assessing Application of Lean and Green Practices in Indian Hotel Industry Using Thematic Analysis" discusses lean-green management in the accommodation Industry. The opportunity and participation of organizations in adopting lean and green management strategies is increasing but it remains a challenge in the hospitality industry. The current chapter aims at exploring the lean and green practices prevailing in the Indian hotel industry. A structured questionnaire was developed to collect the information from hoteliers. Usable responses were analyzed by the thematic analysis, which revealed that Indian Hotel Industry is already applying lean and green practices. However, certain practices are still not given much importance, like energy conservation, stakeholder involvement, employee training, and innovative sustainable practices. However, these practices are currently in the neglected stage, but these can contribute to the organization's future growth.

Chapter "Analysing Green Aspects in Lean Manufacturing for Textile Industry Using Grey DEMATEL Approach" deals with understanding the motivational factors that can direct the achievement of green in lean manufacturing in the Indian textile industry, so the manufacturer has the least impact on the environment. The present chapter aims to understand the relationship between the motivational factors in achieving economic, social, and environmental aspects. The focus is to identify the motivational factors that can help achieve green in lean manufacturing. Grey DEcision-MAking Trial and Evaluation Laboratory (DEMATEL) methodology is employed to understand the contextual relationship between the motivation factors. The present study is being validated using the case of the Indian Textile sector.

Chapter "Lean and Green in Supply Chain Management: Push and Pull Mechanism" focuses on the idea of lean SCM, which refers to eliminating waste and reducing non-value-adding activities associated with spare time, labor, equipment, space, and inventory. The key is to identify non-value-adding items and eliminate these to reduce the cost. There are few items for which clients are not willing to pay. The green paradigm raises the efforts to minimize the negative effect of firms and industries on the environment. It includes climatic changes, pollution, and nonrenewable resources. The green approach requires working with dealers and clients to improve the efficiency and sustainability for a lean and green environment. This research aims to analyze and examine the relationship between lean and green supply chain strategies. This chapter seeks to explore the push and pull system's role and its impact on lean-green and sustainable supply chain management. The chapter further focuses on the methods to implement the same in the industry.

This book is aimed at both academics and practitioners alike. The potential audience included researchers, rofessionals of manufacturing industry, supply chain managers, and stakeholders [suppliers, distributors, retailers, third-party logistics (3PL) companies], policy-makers, and other technical and administrative personnel. The book focuses on dealing with the hierarchical decision-making process for the field of lean-green manufacturing. Specifically, the book provides an essential framework for policy-makers and executives for strategic and tactical decision-making. This book can be used as a guideline for supply chain management and the logistics sector. The book can be used as a textbook or supplementary task for the graduate program in Supply Chain Management, Operations Management, Logistics Management, Sustainable Management, and Business Administration. Lean-green manufacturing is an emerging and critical subject that has not been comprehensively addressed in the literature.

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Analyzing the Barriers for the Implementation of Lean and Green Closed-Loop Supply Chain in Indian SMEs

Sonu Rajak, K. Sivakumar, and V. Raja Sreedharan

Abstract The dynamics of the supply chain has been changing since the past two decades. The different view of the supply chain is proposed by the researchers to achieve sustainability in the system. With consideration of the environment and cleaner production concerns, lean and green closed-loop supply chain aspect is crucial to enhance the sustainability of an organization. In this context, this chapter analyzes the barriers for the implementation of lean and green closed-loop supply chain in the Indian small and medium enterprises (SMEs). A total of 35 barriers have been identified from the literature survey; out of which, 15 potential barriers have been shortlisted by using the best–worst method (BWM). After finalizing the top 15 barriers, interpretive structural modeling (ISM) has been adopted to analyze the relationship among the barriers. The proposed framework provides systematic approach for analyzing the barriers, and also creates roadmaps for the implementation of lean and green closed-loop supply chain in the SMEs.

Keywords Lean and green · Closed-loop supply chain · Barriers · Best worst method · Interpretive structural modeling

1 Introduction

In today's manufacturing world, globalization policies have created extra intensive competition among manufacturers. However, producers or manufacturers have grown to adopt revolutionary technologies and strategies together with efficient supply chain

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management to achieve a sustainable competitive benefit. Over the past few years, businesses are facing huge competition due to technological changes, innovation, and globalization (Sharma et al., 2011). In recent years, people have started considering environmental protection as the most important area of concern around the globe. Also, the customer is aware of environmental impacts due to pollution by manufacturing sectors. Maximizing the value of items by recycling, reusing, remanufacturing, and closed-loop supply chain (CLSC) have environmental benefits (Tibben-lembke & Rogers, 2002) as well as minimize the impacts on the environment.

In general, customers want to throw or separate product residues and packaging from their nearby once they utilized the product completely. It is necessary to take this material from the customers to renew its usage value or to neutralize the negative impact on the environment. In practice, closed-loop supply chain is often related to waste management, so it is necessary to point out their diversity. Waste management is defined as efficient waste collection and processing, and closed-loop supply chain treats products for which there is a certain usable value that can be recovered and reused. In this way, CLSC took the role of tool recreating and restoring the economic and ecological balance opposite to that of open-loop supply chain, where the entire technique is allowing for items movement from the point in their usual very last vacation spot to the point of starting place/recovery. As a consequence, closed-loop supply chain can pay attention because of the potentials of cost healing from the used and returned items. Closed-loop supply chain starts from the customer and then tries to manage end-of-life (EOL) products through different processes, including recycling, remanufacturing, repairing, and finally disposing of some used parts. Some renowned companies of the world like Dell, Canon, Xerox, and IBM have gained benefits through the implementation of CLSC (Ravi et al., 2005).

In this chapter, a new method, called the best–worst method (BWM), is used to solve multi-criteria decision-making (MCDM) problems. According to BWM, the best (e.g., most desirable, most important) and the worst (e.g., least desirable, least important) barriers are identified first by the decision-maker. Using solver in MS Excel, the global weights are calculated to rank the barrier. Based on the ranking of sub-barriers, the interpretive structural modeling (ISM) is applied to develop the model and to analyze the interrelationship among the top 15 sub-barriers, which are a hindrance to the implementation of lean and green closed-loop supply chain in the Indian small and medium enterprises (SMEs).

2 Literature Review

The literature reviewed mainly focused on creating awareness about the usage of closed-loop supply chain systems and on capitalizing on its advantages in the supply chain management system. Retrieval of materials for low-value (recycling) or high-value (remanufacturing) are related to closed-loop supply chains (CLSCs). The returned goods at the end of lifecycle or post-use are utilized to create this material through production (Rahim et al., 2011; Fatin Ainaa et al., 2011). Disposal streams are redirected to develop into manufacturing streams or new raw materials in "closed-loop" approaches (Ayres & Simonis, 1994). Strategies such as remanufacturing, refurbishment/reconditioning, reuse, repair, and recycling are included in closed loop (Ijomah et al., 1999; Korchi & Millet, 2011; Xerox, 2009). Rathore et al. (2011) pointed out that from an environmental perspective closed-loop approaches are better than open-loop approaches, because in closed loop they make use of natural resources where value and resources are already whereas in open loop the materials are dumped into the ground or burned up. Over the past few years, closed-loop supply chains (CLSC) has attracted the attention of industrial managers and researchers (Fleischmann et al., 2000; Nikolaou et al., 2013; Prahinski & Kocabasoglu, 2006). Researchers and practitioners are taking note of CLSC-related issues due to growing environmental worries, competitive benefits, promising financial capability, legislative motives, and social responsibility. As a result, the scope of CLSC has been widening (Sasikumar & Kannan, 2008). Kumar and Putnam (2008) explored closed-loop supply chain opportunities and techniques in different industries. Bing et al. (2014) proposed a framework for infrastructure development for the CLSC network for household plastic waste to make the community extra sustainable and electricity efficient. Prakash and Barua (2015) investigated barriers to CLSC within the Indian electronics enterprise. Kara and Onut (2010) designed a reverse delivery chain community for recycling paper in India.

The idea of supply chain management (SCM) may be defined from exclusive approaches. In a purpose to attain the objective of this chapter, the definition proposed by the Council of Supply Chain Control Professionals (CSCMP) is assumed. SCM encloses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management. In addition to that, it also includes coordination and collaboration with channel partners, which may be suppliers, intermediaries, third-party service providers, and customers. SCM integrates supply and demand management within and throughout organizations. Businesses have confirmed an interest in the adoption of sustainable practices in enterprise operations for the use of an integrated quality, environmental, and protection control machine. Recent studies by various authors examine the implementation of sustainability concepts that are intently associated with sustainable practices in the field of closed-loop supply chain. Effective closed-loop supply chain specializes in the backward flow of material from customers to suppliers to maximize value from the returned object and establish its proper disposal (Rogers & Tibben-Lembke, 1999; Stock, 1992). This includes product returns, recycling, item replacement, reuse of substances, waste disposal, refurbishing, repair, and remanufacturing (Stock, 1992).

Consequently, closed-loop supply chain studies have emphasized using environmentally conscious logistics strategies, the so-known as green logistics (Carter & Ellram, 1998; Van Hoek, 1999). Many firms apprehend the monetary or economic effect of closed-loop supply chain further to the environmental elements (Klausner & Hendrickson, 2000; Ritchie et al., 2000). Furthermore, a few studies indicate that companies can recapture price via an efficient and powerful returns manner (Autry et al., 2001). Additionally, Freires and Guedes (2008) display the existence of forward relation between belief among sellers of the deliver chain and effectiveness and performance of closed-loop supply chain systems. Firms are willing to just accept returns from clients due to the fact that quick and efficient managing of returned products can also be critical in sustaining relationships and creating repeat purchases. As a result, closed-loop supply chain lets companies differentiate themselves from competitors, builds customer loyalty in the market, and undoubtedly affects customer satisfaction.

Large organizations face better costs of returns due to greater lenient return regulations, and consequently, the issue of return is more severe in such companies. Many companies will receive nearly all things that are dispatched or sent back up the channel, regardless of reason or circumstance, if they perceive that it could advantage the consumer relationship (Stock, 1992). Moreover, Rogers and Tibben-Lembke (1999) carry out an intensive survey to figure out and describe present-day practices and trends of closed-loop supply chain. However, most of the firms covered in the research were huge agencies. Anyhow, if SMEs want to boom competitiveness in the new scenario, they need to consider new management trends, as efficient as reverse supply chain systems. Nevertheless, firms/managers should not forget that some adjustments cannot be carried out immediately. Because of this, the firms want to investigate their specific barrier, challenges, resources, and abilities before considering their solutions and decisions.

3 Barriers to Closed-Loop Supply Chain

Barriers are factors that hinder the process adoption because of any inadequacies of the organization. For the successful adoption of lean and green CLSC, organizations need to find out their barriers or factors which are restricting the adoption. Based on the discussion with industrial experts, academic experts, and from the existing literature sources, this study identified eight main barriers which are further classified into a subgroup of thirty-four sub-barriers. The identified barriers and sub-barriers are shown in Table 1.

3.1 Management Barriers

Management barriers contain a firm's strategy, planning, involvement, hiring and training personnel, the requirement of a performance measurement system, ready-to-learn best practices, and proper support structures.

Table 1 Barriers of lean and green closed-loop supply chain for SMEs

Main barriers	Sub barrier	Source
Management barriers	Lack of CLSC expert at management level (MB1)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	Lack of trained personnel (MB2)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	Low commitment (MB3)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	Lack of waste management practices (MB4)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
Infrastructure barriers	Lack of in-house facilities (storage, handling equipment, and vehicles) (INF1)	Rogers and Tibben-Lembke, (2002); Prahinski & Kocabasoglu, (2006); Dibenedetto, (2007); Jack et al., (2010)
	Lack of systems (hardware/software) to monitor returns (INF2)	Rogers and Tibben-Lembke, (2002); Prahinski & Kocabasoglu, (2006); Dibenedetto, (2007); Jack et al., (2010)
	Lack of coordination with third party logistics (3PL) providers(INF3)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
Policy barriers	Lack of government support (PO1)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	CLSC does not consider critical to performance (PO2)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	Lack of enforceable Laws and directives (PO3)	Yacob et al., (2012); Abdulrahman et al., (2014); Xia et al., (2015); Sirisawat and Kiatcharoenpol, (2019)
	Lack of policy and funds for training (PO4)	Ravi and Shankar (2005); Prahinski & Kocabasoglu, (2006)

(continued)

Table 1 (continued)

Main barriers	Sub barrier	Source
Environmental barriers	The high cost of the process of environmental adaptation (new machinery, certification) (ENV1)	Post and Altma (1994); Del Brìo and Junquera (2003); Hillary (2004); Zilahy (2004); Presley et al., (2007); González-Torre et al., (2010)
	Inappropriate environmental regulations on the part of the government (ENV2)	Hillary (2004); Zilahy (2004); Presley et al., (2007); González-Torre et al., (2010)
	Deficient industrial infrastructure (ENV3)	Post and Altma (1994); Del Brìo and Junquera (2003); Hillary (2004); Zilahy (2004); Presley et al., (2007); González-Torre et al., (2010)
	Lack of implementing green practice (ENV4)	Post and Altma (1994); Del Brìo and Junquera (2003); Hillary (2004); Zilahy (2004); Presley et al., (2007)
Social barriers	Lack of awareness of increasing global competition due to customer interest (S1)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
	Less experience about changing customer preference (S2)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
	Customer reluctance (S3)	Ravi and Shankar, (2005); Prahinski & Kocabasoglu, (2006)
	Online retailer thinking to sell returns in the secondary market and not optimizing it (S4)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
Economic barriers (E)	Lack of economic benefit (E1)	Starostka-Patyk et al., (2013)
	High running and operating costs (E2)	Starostka-Patyk et al., (2013); Wu and Cheng, (2006)
	Lack of economy of scale (E3)	Starostka-Patyk et al., (2013); Wu and Cheng, (2006)
	Lack of initial capital (E4)	Starostka-Patyk et al., (2013); Wu and Cheng, (2006)
	Inefficiency to meet high-profit margin (E5)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
	Lack of funds for return monitoring systems (E6)	Ravi and Shankar, (2005); Prahinski & Kocabasoglu, (2006)

(continued)

Table 1 (continued)

Main barriers	Sub barrier	Source
	Lack of funds for storage and maintenance (E7)	Prahinski & Kocabasoglu, (2006)
Technological barriers	Lack of information technology (IT) implementation (T1)	Foster and Simmons, (2000); Rahimifard et al., (2009)
	Underdevelopment of recycling technology (T2)	Foster and Simmons, (2000); Rahimifard et al., (2009)
	Lack of information knowledge and training (T3)	Foster and Simmons, (2000); Rahimifard et al., (2009)
	Lack of information and technological systems (T4)	Rogers and Tibben-Lembke, (2002); Ravi and Shankar (2005); Dibenedetto, (2007); González-Torre et al., (2010); Jack et al., (2010)
	Resistance to technology advancement adoption (T5)	Rogers and Tibben-Lembke, (2002); Dibenedetto, (2007); Jack et al., (2010)
Organizational barriers	Scant commitment of workers (lack of training and qualification) (O1)	Hillary (2004); Post and Altma (1994); Zilahy (2004); Ravi and Shankar (2005); González-Torre et al., (2010)
	Inappropriate organizational structure (O2)	Post and Altma (1994); Foster and Simmons, (2000); Presley et al., (2007); González-Torre et al., (2010)
	Lack of organizational encouragement (O3)	Post and Altma (1994); Foster and Simmons, (2000); Del Brìo and Junquera (2003); Hillary (2004); Zilahy (2004); Presley et al., (2007); González-Torre et al., (2010)

3.2 Infrastructure Barriers

Infrastructure plays a vital role in lean and green CLSC implementation. Researchers and practitioners felt that affordable recycling technologies with the support and coordination of all the members would enhance the success of lean and green CLSC implementation.

3.3 Policy Barriers

Policy barriers include both external and internal stakeholders' views on firms. Policy and schemes of different governments can affect lean and green closed-loop supply chain activities.

3.4 Environmental Barriers

Environmental management is important in enterprise performance. Furthermore, reuse, recovery, and effective waste management may enable the enterprise to improve its image, as customers are more sensitive to environmental issues and sustainability. For example, lean and green CLSC practices contribute to environmental improvement by reducing energy use and (CO_2) emissions per item.

3.5 Social Barriers

The co-operative behavior of society people is necessary for the sharing of information. Supply chains have a tremendous impact on societies, which can be seen with the example of raw materials and products shipped around the world for the next step of production to allow the use of cheaper labor or other resources.

3.6 Economic Barriers

The economic barrier as a financial aspect might be considered in two ways, one about the costs and another about the benefits. Lean and green closed-loop supply chain during the implementation stage is seen as quite an expensive challenge. While its processes are very specific, it is necessary to invest a lot of financial means into new infrastructure, training, technologies, information system, etc.

3.7 Technological Barriers

Enterprises are not doing advancements in machinery and equipment to improve product quality. These types of barriers are included in the technological barrier

3.8 Organizational Barriers

Inadequate organizational structure discourages firms from making changes in their production processes and ways of organizing work, which leads to a lower production rate, thus making the firm economically weak.

4 Methodology

4.1 Best and Worst Method

The best and worst method (BWM) is a multi-criteria decision-making (MCDM) technique developed by Dr. Jafar Rezaei (Delft College of generation) in 2015 to solve MCDM problems on the basis of pairwise comparison (Rezaei, 2015). BWM may be utilized in diverse decision-making areas, including enterprise and economics, health, IT, engineering, and agriculture. There are various MCDM methods such as the analytic hierarchy process (AHP), analytic network process (ANP), TOPSIS, and BWM available from the literature for ranking the criteria. Among the available MCDM methods, BWM has been applied in this chapter to identify the prominent barriers based on the ranking of barriers. In general, BMW uses pairwise comparison for the selection of the best and worst criteria with other criteria from the set of decision criteria (Ahmad et al., 2017). Also, BWM has been applied previously in the selection and segmentation of suppliers (Rezaei et al., 2016), in identifying the solutions to overcome the barriers for green innovation in SMEs (Gupta & Barua, 2018), assessment of risk (Torabi et al., 2016), ranking of sustainable manufacturing barriers (Malek & Desai, 2019), and assessment of technologies from the sustainability perspective (Ren et al., 2017). In this precept, wherever the aim is to rank and pick an alternative among a set of options, the BWM approach can be used. BWM can be used by one decision-maker or a set of decision-makers. The salient features of BWM, in comparison to maximum present MCDM techniques, are: (i) it requires less comparison data; (ii) it ends in more consistent comparison because of this that it produces a reliable result (Rezaei, 2015). The methodology consists of the following steps as follows.

Step1: Let $C = \{c_1, c_2, \ldots..c_n\}$ be the set of criteria, where "n" denotes the number of criteria. Based on discussions with the decision-maker in practice, the criteria "C" is finalized.

Step 2: In this step, the decision-maker identifies the best and worst criteria for comparison.

Step 3: Determine the preference of best criteria over the other criteria using the score of 1 to 9 given by the decision-makers, which result in the best criteria to other (BO) vectors as given as

$$P_b = (p_{b1},\ p_{b2, \ldots\ldots\ldots\ldots} p_{bn}) \tag{1}$$

where p_{bj} indicates the preference of best criteria "*b*" over "*j*".

Step 4: Determine the preference of all criteria over the worst criteria using the score of 1 to 9, which results in the worst criteria to others (WO) vector as given as

$$P_{w=}(p_{1w},\ p_{2w},\ldots\ldots.p_{n\,w})^T \quad (2)$$

where p_{jw} indicates the preference of "*j*" criteria over worst criteria "*w*".

Step 5: Find the optimal weight ($w_1{}^*$, $w_2{}^*$, $w_3{}^*$,…$w_n{}^*$) and the sets of weight that should satisfy the following relationship.

$$w_b/w_i = p_{b\,i}\text{and}w_i/w_w = p_{iw} \quad (3)$$

In this step, the maximum and minimum of absolute difference is found $|w_b/w_i - p_{b\,i}|$ and $|w_i/w_w - p_{iw}|$. The optimal weights need to fulfill the above conditions for all criteria.

$$\text{Model } min\zeta_{s.t}|w_b/w_i - p_{bi}| \le \zeta \text{ for all } i \text{ and } |w_i/w_w - p_{Iw}| \le \zeta \text{ for all } i \quad (4)$$

The mathematical model is solved using a solver in MS Excel. Before solving, the nomenclature of different criteria to be set and also the selection of best and worst criteria among the criteria to be done. Results are obtained along with graphs and charts through which the optimal weight is obtained.

Step 6: Repeat steps 1–5 for each barrier group.

4.2 Interpretive Structural Modeling

Interpretive structural modeling (ISM) was first proposed by J Warfield in 1973 to analyze the complex socioeconomic system. It is interpretive as the judgment of the group decides whether and how different elements are related (Govindan et al., 2013; Rajesh, 2017). The steps followed in ISM are as follows:

Step 1: The first step in ISM is to identify the barriers based on the literature review and from the expert's opinion. In this chapter, the study at present found the top fifteen barriers by applying the best and worst methods.

Step 2: In this step, the relationship between the barriers *i* and *j* are established.

Step 3: Four symbols are used to denote the direction of the relationship between the criterion *i* and *j*. the four symbols and the corresponding relations are as follows:

V – for the relation from element *i* to element *j* and not in both directions;

A – for the relation from element *j* to element **i** and not in both directions;

X – for both the directional relations from element *i* to element *j* and *j* to *i*;

O – if the relation between the elements did not appear.

Step 4: Construction of structural self-interaction matrix based on the inputs given by decision-makers by comparing the relationship among the criteria.

Step 5: Formulation of an initial reachability matrix and final reachability matrix considering the transitivity.

Step 6: Creation of level partition from the final reachability matrix.

Step 7: Formulation of an ISM model.

Step 8: Development of MICMAC analysis by drawing a two-dimensional graph for analyzing the driver and dependence power of the barriers.

5 Application of Proposed Methodology

A case study of the barriers for the successful implementation of lean and green closed-loop supply chain in Indian SME firms illustrated the application of the proposed method. The case organization is an automotive parts manufacturing firm and located in Jamshedpur, Jharkhand. The company has already successfully implemented lean concepts such as 5S, Just in Time (JIT), ISO 9000, ISO 14000, and environment management systems. Now, they want to implement the lean and green concepts in their closed-loop supply chain. In this context, this chapter analyzes the barriers to the implementation of lean and green closed-loop supply chain. The flow chart of the proposed methodology has been shown in Fig. 1.

The proposed methodology starts with the identification of barriers for lean and green closed-loop supply chain with the help of existing literature and the expert's opinion in their fields. To compute the significance of the sub-barrier with each barrier group, BWM was utilized. For instance, the management barriers are related to the four sub-barriers; therefore, the weights of each sub-barrier are computed using BWM. In the next step, the best and the worst sub barrier for the first barrier groups are identified. In the subsequent steps, the experts give an opinion on the barriers for BO (best to other) and OW (other to worst) by utilizing the score of 1–9 for the initial table. The optimal value of the sub barrier is determined by using MS Excel solver. Similarly, the optimal values for other sub-barriers are computed concerning each barrier group, and the results are shown in Table 2.

The global weights of each sub barrier are computed by using the following equation, which is shown in Table 2.

$$\text{Weight}_{\text{main criteria}} * \text{Weight}_{\text{sub-criteria}} = \text{Weight}_{\text{global}} \quad (5)$$

The ranking is established based on global weights for all thirty-eight sub-barriers. The sub-barriers which are ranked from one to fifteen are selected for the ISM study.

The essential barriers barrier for the implementation of lean and green closed-loop supply chain in Indian SMEs identified using BWM are selected for the ISM study. In ISM, these fifteen sub-barriers are analyzed to establish the relationship among the other sub-barriers. The top fifteen sub-barriers determined from the BWM are as follows:

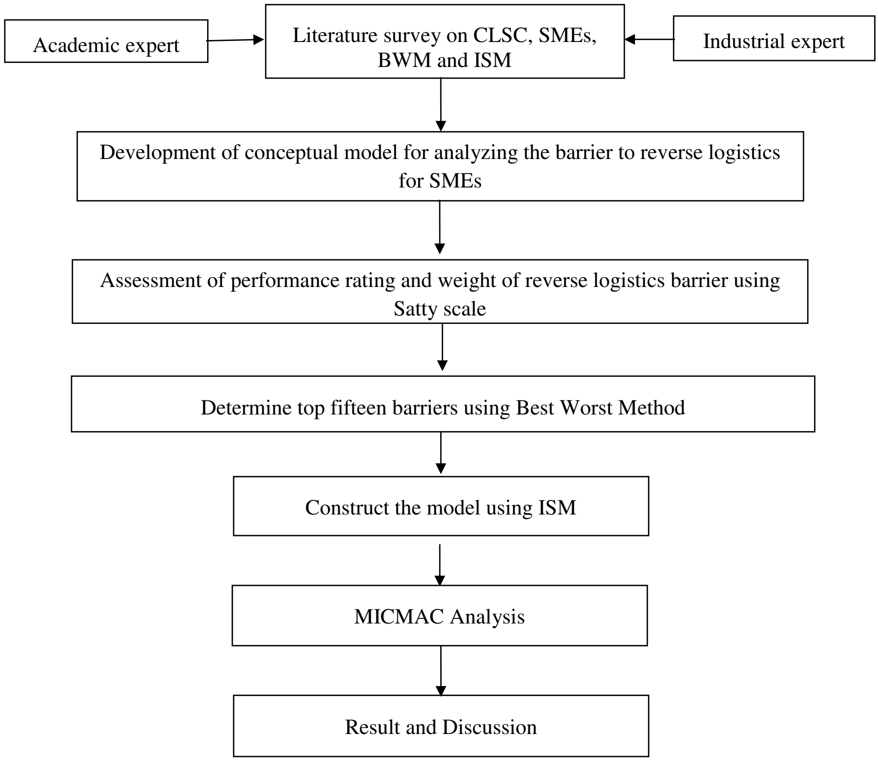

Fig. 1 Framework of the proposed methodology

(1) Lack of economic benefit;
(2) Lack of initial capital;
(3) High cost of the process of environmental adaption;
(4) Lack of implementing green practices;
(5) Lack of in-house facility (storage and handling);
(6) Lack of funds for storage and maintenance;
(7) Inappropriate environmental regulation on the part of the government;
(8) Lack of government support;
(9) High running and operating cost;
(10) Lack of IT implementation;
(11) Less experience about changing customer preference;
(12) Lack of coordination of 3PL provider;
(13) Lack of waste management practice;
(14) Underdevelopment of recycling technology;
(15) Lack of trained personnel.

Initially, the structural self-interaction matrix is formulated with the expert's opinion on the corresponding relation between each sub barrier by using the four

Table 2 Optimal weights of barriers and sub-barrier

Main barriers	Weights (Main barriers)	Sub-barriers	Weights (sub-barriers)	Global weight	Global ranking
Management barriers	0.06930693	MB1	0.30769452	0.0212	19
		MB2	0.07692308	0.0253	15
		MB3	0.15384615	0.0106	24
		MB4	0.46153846	0.0319	13
Infrastructure barriers	0.09240924	INF1	0.55	0.0506	5
		INF2	0.1	0.0092	29
		INF3	0.35	0.0322	12
Policy barriers	0.13861386	PO1	0.5128643	0.0452	8
		PO2	0.2000001	0.0138	23
		PO3	0.1257144	0.0083	26
		PO4	0.1172342	0.0056	33
Environmental barriers	0.13861386	ENV1	0.43478261	0.0598	3
		ENV2	0.33043478	0.0455	7
		ENV3	0.06956522	0.0095	28
		ENV4	0.16521739	0.0227	17
Social barriers	0.13861386	S1	0.14016064	0.0053	34
		S2	0.50522085	0.0420	10
		S3	0.16261044	0.0197	26
		S4	0.18425703	0.0208	25
Economic barriers	0.25462046	E1	0.2521560	0.0982	1
		E2	0.1544225	0.0452	8
		E3	0.0589872	0.0066	31
		E4	0.1584973	0.0906	2
		E5	0.2423562	0.0222	20
		E6	0.1212458	0.0220	21
		E7	0.1458458	0.0489	6
Technological barriers	0.09240924	T1	0.40160643	0.0368	11
		T2	0.3052208	0.0280	14
		T3	0.15261044	0.0139	22
		T4	0.06425703	0.0058	32
		T5	0.07630522	0.0559	4

(continued)

Table 2 (continued)

Main barriers	Weights (Main barriers)	Sub-barriers	Weights (sub-barriers)	Global weight	Global ranking
Organizational barriers	0.0330033	O1	0.6177	0.0254	16
		O2	0.2813	0.0226	18
		O3	0.1000	0.0062	30

symbols, which are shown in Table 3. Then, the initial reachability matrix is established, which is shown in Table 4. For the construction of the initial reachability matrix, we need to consider the following point:

(i) If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
(ii) If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
(iii) If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
(iv) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

The reachability matrix obtained from the previous step is used to form the final reachability matrix by checking it for transitivity, as shown in Table 5. The transitivity of the contextual relation is a basic assumption in ISM, which states that if element A is related to B and B is related to C, then A is related to C. In the subsequent steps,

Table 3 Structural Self-Interaction Matrix (SSIM)

Barrier	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	O	V	V	O	V	O	O	O	O	O	V	V	O	O
2	O	V	V	O	V	O	O	O	O	V	V	V	O	
3	O	O	O	O	O	O	O	X	X	O	O	V		
4	O	O	O	O	O	O	O	A	A	O	O			
5	O	O	O	O	O	O	A	O	O	O				
6	O	O	O	O	O	O	A	O	O					
7	O	O	O	O	O	O	O	X						
8	O	O	O	V	O	O	O							
9	O	V	V	O	V	O								
10	V	O	O	O	O									
11	V	O	O	O										
12	A	O	O											
13	A	A												
14	A													
15														

Table 4 Initial reachability matrix

Barrier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	1	1	0	0	0	0	0	1	0	1	1	0
2	0	0	0	1	1	1	0	0	0	0	1	0	1	1	0
3	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0
8	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0
9	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0
10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0

Table 5 Final reachability matrix

Barrier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Driver power
1	0	0	1*	1	1	0	0	1*	0	0	1	1*	1	1	1*	9
2	0	0	0	1	1	1	0	0	0	0	1	1*	1	1	1*	8
3	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	1	1	0	0	0	1	0	0	0	1*	0	0	0	4
8	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	4
9	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1*	5
10	0	0	0	0	0	1	0	0	0	0	0	1*	1*	1*	1	5
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3
Dependence power	0	0	3	5	3	2	2	3	0	0	3	6	6	5	5	

the level partition is carried out on the final reachability matric with several iterations through reachability set, antecedent set, and intersection set is shown in Tables 6, 7, 8, 9, and 10. During the iteration for level partition, once the level 1 element is found out, it is removed from the other element. Similarly, the other levels are identified with further iterations. The reachability set includes criteria itself and others which it may help to achieve, and the antecedent set consists of itself and another criterion that helps in achieving it. Finally, the ISM model is developed based on the barriers level is shown in Fig. 2. After developing the model, a MICMAC analysis is carried

Table 6 Level partition of final reachability matrix—iteration 1

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1,3,4,5,8,11,12,13,14,15	1	1	
2	2,4,5,6,11,12,13,14,15	2	2	
3	3,4,7,8	1,3,7,8	3,7,8	
4	4	1,2,3,4,7,8	4	1
5	5	1,2,5,9	5	1
6	6	2,6,9	6	1
7	3,4,7,8,12	3,7,8	3,7,8	
8	3,4,7,8,12	1,3,7,8	3,7,8	
9	5,6,9,11,13,14,15	9	9	
10	10,12,13,14,15	10	10	
11	11,15	1,2,9,11	11	
12	12	1,2,7,8,10,12,15	12	1
13	13	1,2,9,10,13,14,15	13	1
14	13,14	1,2,9,10,13,14,15	13,14	1
15	12,13,14,15	1,2,8,9,10,15	15	

Table 7 Iteration 2

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1,3,8,11,15	1	1	
2	2,11,15	2	2	
3	3,7,8	1,3,7,8	3,7,8	2
7	3,7,8	3,7,8	3,7,8	2
8	3,7,8	1,3,7,8	3,7,8	2
9	9,11,15	9	9	
10	10,15	10	10	
11	11,15	1,2,9,11	11	
15	15	1,2,8,9,10,15	15	2

Table 8 Iteration 3

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1,11	1	1	
2	2,11	2	2	
9	9,11	9	9	
10	10	10	10	3
11	11	1,2,9,11	11	3

Table 9 Iteration 4

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1	1	1	4
2	2	2	2	4
9	9	9	9	4

Table 10 Levels of barrier for closed-loop supply chain

Sub-barriers	Level
1	4
2	4
3	2
4	1
5	1
6	1
7	2
8	2
9	4
10	3
11	3
12	1
13	1
14	1
15	2

out to identify the drivers and dependence power of each sub barrier, which is shown in Fig. 3.

MICMAC Analysis

The MICMAC analysis is shown in Fig. 3, where the Y-axis represents the driving power, and X-axis represents the dependence of the variable of each sub barrier. The barriers of lean and green closed-loop supply chain are classified into four clusters:

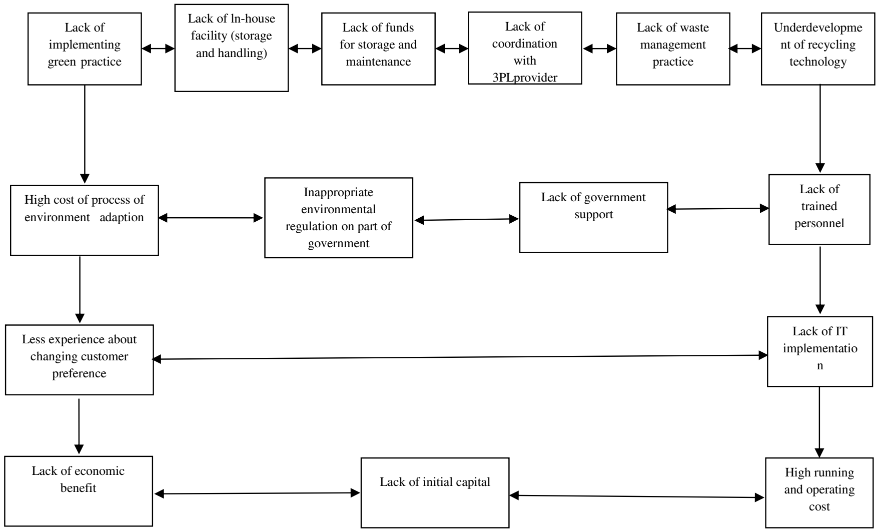

Fig. 2 ISM model

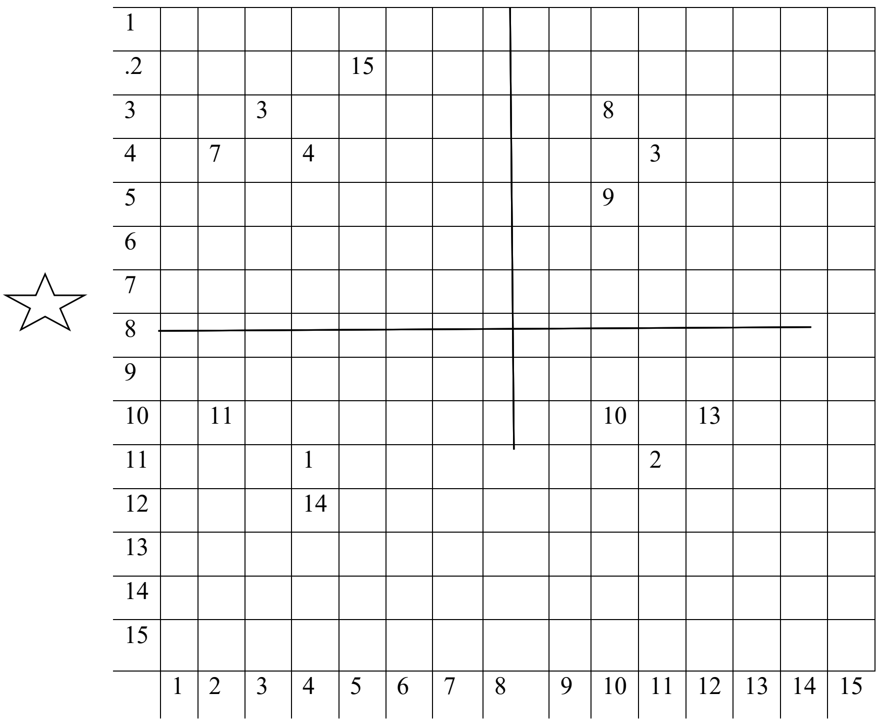

Fig. 3 MICMAC analysis

(i) The first cluster consists of autonomous variables that have weak driver power and weak dependence. These variables are disconnected from the system with which they have only a few but strong links.
(ii) The second cluster consists of the dependent variable that has weak driver power but strong dependence.
(iii) The third cluster has the linkage variables that have strong driving power and also strong dependence. These variables are unstable in that any action on these variables will affect others and also feedback effect on themselves.
(iv) The fourth cluster includes the independent variables having strong driving power but weak dependence.

6 Discussion and Conclusion

This study examines lean and green CLSC practices in a developing country like India. First of all, through the literature review, we came to know about 34 sub-barriers and nine main barriers. Then through the best–worst method (BWM), the ranking of the top 15 barriers out of 34 barriers is determined. Then interpretive structural modeling (ISM) is applied to find the different levels and relationships between the barriers. Finally, by MICMAC analysis, a 2D graph has been found out to determine the relationship between the dependence power and driver power of the barrier. The managers can get an insight into these barriers and understand their relative importance and interdependencies. Some of the barriers are identified and are put into an ISM model to analyze the interaction between them. The driver dependence diagram gives some valuable insight into the relative importance and interdependencies among barriers. From Fig. 3, we can conclude that barriers 6, 5, 4, 11, and 14 are autonomous barriers because they are in cluster 1. Barriers 10 and 13 are dependent variables that have weak driver power but strong dependence because they lie in cluster 2. Barriers 8 and 9 belong to the third cluster that has strong driving power and also strong dependence. These variables are unstable in that any action on these variables will affect others and also feedback effect on themselves. Barriers 1, 2, 3, 7, and 15 belong to the fourth cluster are the independent variables having strong driving power but weak dependence. Thus, the ISM-based model proposed for the identification of barriers of closed-loop supply chain can provide the decision-makers a realistic representation of the problem in the course of implementing lean and green closed-loop supply chain. This can help in deciding the priority to take steps in combating these barriers proactively.

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Assessing the Drivers and Challenges to Deploying Lean-Green Practices the in Indian Manufacturing Sector

Srijit Krishnan, K. Mathiyazhagan, and Andrea Appolloni

Abstract **Purpose**: With a rapid growth in the Indian manufacturing sector, the assessment of the sector is necessary for various aspects. The present study focused on identifying and assessing the drivers and challenges pertaining to current practices of lean-green deployment in Indian manufacturing based on the recent literature and experts in the manufacturing space. **Design/methodology/approach**: The study was conducted in three phases. Phase 1 involved literature review and expert consultation. Phase 2 includes a three-step data collection procedure whereby 44 experts provided responses that formed the basis for the assessment of the factors. Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) was used to rank the drivers and challenges with respect to the perspective of the consumer, industry, and the government. Phase 3 involved validating the relevance of our study based on the experts and literature. **Outcome**: The top-ranked driver and top-ranked challenge was identified. Insight into the present scenario of lean-green deployment in manufacturing is facilitated by factors identified from recent literature. **Originality:** There is very little literature assessing the factors pertaining to lean-green deployment in Indian manufacturers. Most work focus specifically on SMEs or MSME, and not the entire manufacturing sector. Accordingly, respondents selected for the study were those with diverse experience in the sector.

Keywords Lean-green manufacturing · Sustainability · Indian manufacturing sector

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1 Introduction

The removal of non-value added activities and improvement of enterprise efficiencies is the targeted business strategy by 'lean thinkers'. This strategy has expanded to the consideration of lean-green thinking, which focused on optimizing the resources and encouraging to do more with less (Simons & Mason, 2003). It is proclaimed that manufacturers can make sustainability a value rather than a cost, and take advantage of the process and structural changes applicable throughout the product and service delivery chain (Garetti & Taisch, 2012; Martínez León & Calvo-Amodio, 2017). The practice of 'green' in manufacturing refers to the practice of reduction in negative impacts on the environment (Rusinko, 2007). Research has provided well-documented case illustrations of the lean-green synergy (Kurdve et al., 2014). For example, Jabbour et al. (2013) confirmed the positive impact that lean practices had on environmental management considering the influences between lean manufacturing and environmental management. Chiarini (2014) confirmed the positive impact that lean tools (such as value stream mapping, 5S analysis, cellular manufacturing) had on waste and energy management through their empirical study in an automotive component industry.

Further, the current environmental degradation blueprint propels the nations worldwide to consider environmental strategies as operational strategies. The depleting natural resources and the improved customer awareness in green technologies and products are developing the transition of operational activities into sustainable ones.

This study pertains to assessing the drivers and challenges of lean-green implementation in Indian manufacturers. We include identified the recent studies only and assess the dominant driver and challenge of lean-green implementation. Motivation.

The Indian manufacturing sector has emerged as a fast-growing sector due to the rapidly increasing population in the country. The robust demand for manufacturers is enabled by the massive domestic market with an increasing population specifically in the middle class. IBEF (2020) reported an investment in fixed assets for manufacturing of about USD 615 billion as of August 2020. With government initiatives such as 'Make in India" and incentive provisions for manufacturers, the Indian manufacturing sector is set to be a global manufacturing hub. This is further enabled by the pull of various manufacturers from China due to sanctions being imposed on them (as of October 2020). Therefore, this sector has the potential to reach USD 1 trillion by 2025. Manufacturers are, therefore, going to face immense competition in India. In addition to achieving a competitive advantage over rivals, manufacturers would also have to bear the increasing cost of energy and resources due to the rise in demand and limited supply.

In this study, we provided a taxonomy of drivers establishing lean-green thinking as an approach to enable sustainable manufacturing practices. Further, a taxonomy of barriers to driving lean-green in the manufacturing context is also explored. We also noted that recent literature provides very little in terms of showcasing enablers and barriers of lean-green in the Indian manufacturing concept. This work is therefore motivated to answer the research questions—"How lean-green practice drives to achieve sustainable business practice", and "what the barriers to sustainable performance of lean-green practice?" We address these questions within the context of research conducted pertaining to enablers and barriers for lean-green in manufacturing in India from 2016 to 2020. We select these four years to give a well-suited backing for the report generated by IBEF (2020) that provides data for the aforementioned years.

2 Theoretical Background

Lean practices in manufacturing are focused on eliminating all wastes within the system by improving resource utilization, minimizing human effort, and ensuring on-time delivery to a client. Lean thinking tackles eight types of waste: transportation, inventory, motion, waiting, over-processing, over-production, defects, and skills—commonly abbreviated as TIMWOODS (Ohno & Bodek, 2008). The green manufacturing paradigm helps to minimize the environmental impact of manufacturing by pushing the need for pollution control and minimizing natural resource utilization thereby branding their manufacturing processes as 'green'. Green thinking can tackle eight environmental wastes: pollution, greenhouse effects, eutrophication, rubbish, excessive power utilization, excessive water utilization, excessive resource utilization, and poor health and safety (Hines, 2009). Caldera et al. (2017) suggested a variety of tools for waste reduction and efficiency improvement under the context of lean-green. Caldera et al. (2019) presented process tools applicable under the lean and green waste streams. Gandhi et al. (2018) pointed that implementation of the various lean tools has green benefits, and that green practices are often a cause for improved lean practices. Dües et al. (2013) declared that lean practices are beneficial in the practice of green implementation. It was asserted by Hajmohammad et al.(2013) that deploying 'green' practices mediate the influence of lean execution in the performance of environmental and supply chain and management. Further, Hajmohammad et al. (2013) also cited various literature indicating the positive influence that practicing 'green' has on existing lean practices employed. Dhingra et al. (2014) revealed that environmental benefits should be viewed as targeted outcomes so as to harness productivity enhancements, and further called upon researchers and practitioners to investigate ways to incorporate economic and efficiency factors when green tools are created and deployed. In fact, Thanki and Thakkar (2019) investigated the performance of lean-green in manufacturing and found that to improve operational and environmental performance, manufacturers could encourage technological innovation and a holistic adoption of manufacturing excellence initiatives such as lean-green.

The combined efforts of lean and green principles have been observed in the literature to reap quantifiable results. For example, Diaz-Elsayed et al. (2013) illustrated a case study on lean green implementation in an automotive company, the result being a significant reduction in production costs by about 11 percent. On the other hand, studies have shown that the lean-green strategy has shallow penetration in the manufacturing sector (Garza-Reyes, 2015). This variability in research insights can be observed throughout the literature. We, therefore, structure this section to provide insights into the enablers and challenges to lean-green practice in the Indian manufacturing sector.

The research we referred to for identifying relevant enablers and challenges were papers between 2016 and 2020. This is to further gain insights into the reported data of the manufacturing sector published by IBEF (2020). IBEF (2020) reported growth in the Indian manufacturing market size from 2016 at about USD 328 billion GVA to about USD 403 billion GVA in 2019. This trend would have continued through 2020 if it were not for the COVID-19 pandemic that has affected manufacturing in the entire world. However, the Indian economy is set to recover speedily. Accordingly, we have reviewed papers between 2016 and 2020 for identifying the drivers and challenges relevant for our study.

2.1 Drivers of Sustainable Lean Practices

The Indian government has been showing concern in enhancing operational and environmental performance in manufacturing through the provision of reimbursement schemes for implementing ISO 9001 and ISO 14000 standards, and the establishment of the Lean Manufacturing Competitive Scheme (LMCS). This verifies the study by Thanki et al. (2016) whose study revealed that *government support* is a major enabler, considering that the establishment of various schemes and initiatives is poised to drive the Indian Manufacturing market into a global leader. Gandhi et al. (2018) further validated that the Indian government's support in the global arena for sustainable energy utilization and consumption has already been leading to various investments from foreign countries. Their study also identified that *leadershipcommitment*, *current legislation*, *future legislation*, *technology up-gradation,* and *green brand image* are top enablers. Singh et al. (2021) further validated the importance of top management in enabling lean green initiatives, however, they also validated the importance of *initiatives to producing green products* and *employee rewards and incentives* in driving the push toward leaner and greener manufacturing practices in India. Further, the importance of legislation as concluded by Gandhi et al. (2018) was verified by (Jaiswal & Kumar, 2018), whose study also identified that *market competitiveness* is a major driver. (Jaiswal & Kumar, 2018) also stress the fact that the *need to reduce manufacturingcosts* necessitates the implementation of sustainable practices such as lean-green. The enablers/drivers discussed in this subsection, are listed along with their corresponding references, and described in Table 1.

Table 1 Drivers and challenges to lean-green manufacturing

	Factor	Description	Reference
Drivers	Government support (D1)	Support via schemes and incentives to support development and the manufacturing sector	(Gandhi et al., 2018; S. Thanki et al., 2016)
	Leadership commitment (D2)	Industry leaders are primary decision-makers, and directly affect the growth of the industry	(Gandhi et al., 2018; M. Singh et al., 2021)
	Current legislation (D3)	the present legislative scenario affecting the industry	(Gandhi et al., 2018)
	Future legislation (D4)	The effect of future governments is required to be planned and strategized by industry	(Gandhi et al., 2018)
	Technology up-gradation (D5)	Improving the technological facets of the industry to deliver a more sustainable manufacturing practice	(Gandhi et al., 2018)
	Green brand image (D6)	The image that the manufacturer projects onto the market have great effects on sales, and growth	(Gandhi et al., 2018)
	Initiatives to producing green products (D7)	Releasing products projecting sustainable or green outcomes while practicing lean to reduce wastes in manufacturing	(M. Singh et al., 2021)
	Employee rewards and incentives (D8)	Motivate employees on effective practice of lean-green	(M. Singh et al., 2021)
	Market competitiveness (D9)	An economical and consumer-centric standing among other manufacturers	(Jaiswal & Kumar, 2018; Zhou, 2016)
	Need to reduce manufacturing costs (D10)	A requirement to deploy lean-green practices to reduce costs, and subsequently retail/wholesale prices	(Jaiswal & Kumar, 2018)

(continued)

Table 1 (continued)

	Factor	Description	Reference
Challenges	Lack in tactful operational and management know-how (C1)	Upcoming manufacturers are dominated by less experienced leaders. This results in a misalignment in deploying various practices, especially lean-green	(Gandhi et al., 2018)
	Lack of financial resources (C2)	Lean-green practices require investment. A financial input is, therefore, required	(Bhanot et al., 2017)
	Weak regulatory environment (C3)	Weak regulations to control pollution and waste disposal	(Hasan, 2016)
	Low leadership*priority to* undertake sustainable practices (C4)	Manufacturing leaders do not have the means and so do not prioritize sustainable practices	(Cagno et al., 2017)
	Aligning environmental and economic objectives (C5)	Ensuring that project deployment and development practices with the aim of economic benefits go in tandem with environmental benefits	(Caldera et al., 2019)
	Lack of human creativity and innovation (C6)	Less quality innovation facilitates lean and green thinking	(Caldera et al., 2019)
	Lack of knowledge of the spread of toolkit (C7)	With a vast selection of lean-green tools available, practitioners may overlook the right one to correctly align with the objective	(Krishnan et al., 2020)
	Resistance to change (C8)	The reluctance a system to continue its present behavior, despite pressures to change that attitude	(C. Singh et al., 2020)
	Lack of awareness about government initiatives (C9)	It so happens that though government provides incentives and schemes, they may go overlooked by manufacturers	(S. Thanki & Thakkar, 2019)

2.2 Challenges of Implementing Sustainable Lean Practices

Implementing lean-green in manufacturing is a challenging task for managers. In fact, (Gandhi et al., 2018) stated that this is due to a *lack in tactful operational and management know-how*. Some researchers have documented various other constraints to the sustainable performance of manufacturers. Some of these include a *lack of financial resources* (Bhanot et al., 2017), *weak regulatory environment* (Hasan, 2016), and *low leadershippriority to undertake sustainable practices* (Cagno et al., 2017). (Caldera et al., 2019) interviewed leaders of 13 manufacturers, and revealed that *aligning environmentaland economic objectives* is considered a major challenge because of the non-linearity in aligning profits with sustainable practice to stop support environmental protection. They also exemplified that *lack of human creativity and innovation* was a major challenge for sustainable practices due to the way the bureaucratic management system is structured. Similarly, (Krishnan et al., 2020) indicated that *lack of knowledge of the spread of toolkit* is a barrier because most practitioners in manufacturing are accustomed to a set of tools, and are resistant to change or apply newly developed tools in their projects. In fact, this would point to the insights of (Singh, Singh, & Khamba, 2020), who ranked *resistance to change* as a prominent barrier to employing lean-green practices in manufacturing. (Thanki & Thakkar, 2018) conducted research similar to our present one and identified government support to be a significant challenge to lean-green implementation. However, considering the vast provisions that the Indian government has been giving manufacturers and upcoming businesses through various schemes and initiatives such as 'Make in India', it is not a conclusive result. In fact, (Thanki et al., 2016) stated that the Indian government's push toward greener manufacturing has paved the way for lean green practices. (Thanki & Thakkar, 2019) adds to the previous point that though such provisions have been provided by the Government, it was identified from their study that *lack of awareness about government initiatives* is a major issue among manufacturers. Table 1 provides a listing of the challenges mentioned in this section, along with their description and corresponding reference.

3 Methodology

The methodology of the study to assess the drivers and challenges of implementing lean-green practices in Indian manufacturing is exhibited in Annexures 1 and 2. The methodology was broken down into three phases. Phase one involved reviewing literature between 2016 and 2020 due to the reasons previously indicated in the manuscript, upon which drivers and challenges were identified with suggestions from experts in the field of manufacturing and project management. Four experts were consulted, two from the relevant industry, a university professor, and a research scholar studying sustainable lean practices. Phase two of the present study involved collecting data and assessing the drivers and challenges on three perspectives, viz.

consumer, industry, and government. The last phase involved validation of the results with the aforementioned experts through feedback and literature.

3.1 Phase 1: Identifying Drivers and Challenges of Lean-Green Implementation

The factors relevant for this study were identified from the literature. The span of search strings in 'Google scholar' database was from 2016 to 2020 with search phrases that include the exact words like 'lean', 'green', 'lean-green manufacturing India', 'sustainable lean practices India', 'sustainable manufacturing', 'enablers lean-green India', 'drivers lean-green India', 'barriers lean-green India' and 'challenges lean-green India'. Subsequently, 10 drivers and 9 challenges were identified and selected after discussions with the experts aforementioned.

3.2 Phase 2: Assessing the Factors Pertaining to Lean-Green Implementation in India

The factors were assessed by employing TOPSIS under fuzzy environments. TOPSIS is a multi-criteria decision-making (MCDM) technique that does not limit the number of alternatives and criteria in the decision-making process. This technique is based on the notion that the selected factor/criteria should have the shortest geometrical distance from the positive ideal solution (PIS) and the longest geometrical ideal distance from the negative ideal solution (NIS). TOPSIS is advantageous as it requires very few data points such as weights and linguistic preference of factors/alternatives from experts (Gupta, 2018). Though this MCDM technique requires the expert to give ratings to the factors (be in drivers or challenges), it is often difficult for experts to give precise ratings. To consider the vagueness and non-linearity in the decision-making process, a fuzzy set is employed in achieving a realistic assessment of a situation. Therefore, fuzzy TOPSIS is applied to rank the factors with respect to perspectives of the consumer (P1), the industry (P2) and the government (P3). The steps to applying Fuzzy TOPSIS are presented in Table 2. The steps iterated under Table 2 are applied to the responses for the analysis of both factors, that is, drivers and challenges of lean-green deployment. Annexure 1 and Annexure 2 provide the detailed matrixes and tables illustrating calculations as per the Fuzzy TOPSIS methodology under Table 2.

Table 2 Fuzzy TOPSIS methodology

Step 1	The present study uses a linguistic fuzzy scale -Table 3, and follows the rule that the triangular fuzzy set lies in the [0, 1] range. The respondents follow the scale to fill the pair-wise decision matrix with the linguistic variables. Data collection took place in three stages and is elaborated in the data collection subsection. For the MCDM problem, the factors (F1, F2, F3…, Fn) rated with respect to perspectives (P1, P2, P3). The pair-wise matrix is formulated with the TFN. The pair-wise matrix consists of the comparison of the factors identified with respect to the perspectives of the study. The averaged matrix of the plurality of matrixes obtained from 'k' number of respondents is then averaged to obtain the integrated matrix $X = (x_{ij})_{m*n}$. Let W1, W2 and W3 be the weights of perspectives P1, P2, and P3, respectively
Step 2	Matrix X is normalized by calculating r_{ij}. r_{ij} is the normalized factor/perspective rating For minimization, $r_{ij} = \frac{\frac{1}{x_{ij}}}{\sqrt{\sum_{i=1}^{m} \frac{1}{x_{ij}^2}}}$, where i = 1, 2,…m and j = 1, 2, 3,…,n For maximization,$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} \frac{1}{x_{ij}^2}}}$, where i = 1, 2,…m and j = 1, 2, 3,…,n Accordingly, the normalized matrix R is thereby obtained. Further, the weighted normalized matrix V for each criterion is subsequently calculated: $V = [v_{ij}]_{m*n}$ for i = 1,2,3,…,m and j = 1,2,3,…,n. Where, $v_{ij} = r_{ij} * w_j$
Step 3	The fuzzy positive (A +) and fuzzy negative (A-) ideal solutions are determined: $A+ = (v_1^+, v_2^+, \ldots v_n^+)$, where $v_j^+ = (max_i(v_{ij1}), max_i(v_{ij2}), max_i(v_{ij3}))$ and $A_- = (v_1^-, v_2^-, \ldots v_n^-)$, where $v_j^- = (min_i(v_{ji1}), min_i(v_{ji2}), max_i(v_{ji3}))$ for i = 1,2,3,…,m and j = 1,2,3,…,n
Step 4	Calculate the fuzzy distance of each factor from fuzzy positive and the negative ideal solution: $D_i^+ = \sqrt{\sum_{j=1}^{n}(v_j^+ - v_{ij}^+)}$ and $D_i^- = \sqrt{\sum_{j=1}^{n}(v_j^- - v_{ij}^-)}$ for i = 1,2,3,…m
Step 5	The fuzzy closeness coefficient $CC_i = \frac{d_i^-}{d_i^+ + d_i^-}$ for i = 1,2,3,…,m. Fuzzy closeness is the distance to the fuzzy positive and fuzzy negative ideal solution simultaneously
Step 6	The fuzzy closeness coefficient is then de-fuzzified $CC_i = \sqrt[3]{CC_{i1} * CC_{i2} * CC_{i3}}$. CC_i values are determined to rank the factors

Table 3 Linguistic scale for rating factors with respective to perspective

Linguistic variable—level of importance	Triangular fuzzy Number (TFN)
Very Low (VL)	[0,0,1]
Low (L)	[0,1,3]
Rather Low (RL)	[1,3,5]
Fair (F)	[3,5,7]
Rather High (RH)	[5,7,9]
High (H)	[7,9,10]
Very High (VG)	[9,9,10]

3.2.1 Data Collection

As part of our data collection efforts, we conducted the same in three stages. Stage 1 involved identifying a set of individuals whose work revolves around the context of the present study. The suitable respondents were identified from available contacts whose field of work mostly revolved around project execution in a manufacturing setting in India. Table 4 summarizes details pertaining to respondents identified for our study. 74 potential respondents were identified within the known circles of the author, and an attempt to contact them via phone call or e-mail was made. 59 of the contacts who were reached out to, responded to the communication. Further, the context of the present study was explained.

Stage 2 involved sending out a carefully drafted survey questionnaire to the above-mentioned respondents. The survey was prepared and electronically sent to the respondents, as it was not possible to meet them personally due to the COVID-19 pandemic ongoing as of October 2020. The survey questionnaire was carefully prepared based upon suggestions from university professors specialized in operations and/or projection management. The survey was prepared with e-mail and mobile numbers considered as the unique identifier for the respondent. This was done to avoid duplicate responses from the same respondent.

Table 4 Respondent details

Respondent profile	Average tenure (years)	Industry	Count of respondents	Count of responses received
Project champion (Lean six sigma)	28	PCB manufacturer/Pharmaceutical/FMCG	3	2
Production head	19	PCB manufacturer/Pharmaceutical/Auto-parts manufacturer	3	3
Quality Head	26	PCB manufacturer/ Auto-parts manufacturer/FMCG	3	1
Production line manager	13	Tool manufacturer/Wire harness production line	6	5
Production supervisor	3	Wire harness production line/FMCG	3	3
Quality associate	4	Tool manufacturer/Wire harness production line	23	17 (Incomplete – 3)
Project associate	5	PCB manufacturer/Auto-parts Manufacturer/Pharmaceutical	18	16
		Total =	59	47 (Received), 44 (Useable)

Stage 3 involved sending follow-up emails to respondents to fill out the survey. A time deadline of 1 month for sending back responses was recommended. At the end of the deadline, we collated the responses received and processed the list using SPSS software to remove duplicate responses from a single respondent and remove other anomalies. Out of the 59 surveys sent, 47 responses were received, of which 3 responses were not usable due to incomplete information in filling out the questionnaire. The 3 incomplete responses aforementioned were those from the quality associate profile indicated in Table 4.

4 Results and Discussion

The Fuzzy TOPSIS steps—Table 2 applied to the responses pertaining to drivers is illustrated in Annexure 1, and the same steps applied to assess challenges are illustrated in Annexure 2. The results of factors ranked are provided in Table 5 for drivers and Table 6 for challenges.

Table 5 Rank of drivers

Driver		Rank
D1	0.765868	3
D2	0.844986	1
D3	0.606743	6
D4	0.439132	8
D5	0.79925	2
D6	0.382185	9
D7	0.602249	7
D8	0.086703	10
D9	0.741008	4
D10	0.693498	5

Table 6 Rank of challenges

Challenge		Rank
C1	0.529967	6
C2	0.747899	4
C3	0.386814	7
C4	0.891716	1
C5	0.879863	2
C6	0.273106	8
C7	0.228077	9
C8	0.876857	3
C9	0.716645	5

The drivers ranked in Table 5 based on expert responses and further assessment reveal that *leadershipcommitment* (D2), *technology up-gradation* (D5), *government support* (D1) are the top three drivers. Leadership: When compared with literature, it is identified that *Leadershipcommitment* (D2) is the most critical driver, and it may be reasoned that this is because of the prominence of the leadership's or top management's decision in the firm. The leadership commitment reflects with the organizational operations and the performance output. When the organizational leadership aims for achieving a target, it is passed down right to the operators in manufacturing. This means the lean-green thinking is first instilled into the leadership of the firm before it is passed down to the subordinates. The result from this assessment is further validated by (Ghazilla et al., 2015), exemplified that the leadership and their commitment is responsible for transforming manufacturing practices from conventional to sustainable ones. The *technology up-gradation* (D5) driver is ranked second based on our assessment. (Mittal & Sangwan, 2015) stressed that the availability of new, resourceful, and efficient technology drives smooth deployment of sustainable practices such as lean-green in manufacturing. The present ranking of D5 validates a similar ranking by (Gandhi et al., 2018) who also attested the prominence of upgrading technology to achieve sustainable manufacturing. The thirdly ranked driver is *government support* (D1). The Indian government under the National Manufacturing Competitiveness Programme (NMCP) enforces manufacturers to reduce environmental impact, to develop the global competitiveness of the Indian manufacturing sector. Consequently, Indian manufacturers are compelled to not only produce eco-friendly products, but also undergo eco-friendly processes and practices. (S. Thanki et al., 2016) stressed the value addition that the pressures imposed by the government in driving the deployment of sustainable practices to achieve a leaner and greener manufacturing.

looselines-1The challenges of lean-green deployment in Indian manufacturing ranked in Table 6 based on expert responses and further assessment reveal *low leadershippriority to undertake sustainable practices* (C4), *aligning environmentaland economic objectives* (C5), *resistance to change* (C8) are the top three challenges. Though leadership commitment is a critical driver, *low leadershippriority to undertake sustainable practices* (C4) is considered the most challenging factor. In fact (Nambiar & Chitty, 2014) validated the claim C4 being a major challenge is attributed to a poor understanding of the complexity of sustainability. This further reflects on the poor *alignment of environmentaland economic objectives* (C5). As a result, projects deployed in manufacturing may fail even before they are initiated. (Caldera et al., 2019) in fact emphasized the need 'to align lean and green strategies with organizational strategic objectives'. (Krishnan et al., 2020) further validated the importance of deploying practices such that they align with economic and environmental objectives. *Resistance to change* (C8) is ranked third in our assessment of the challenges pertaining to our study. Developing countries like India face cultural obstacles in comparison to developed countries. Certain management practices in the Indian subcontinent stress the value of the karma doctrine that includes principles such as duty and loyalty to others. Sindhwani, Mittal, Singh, Aggarwal, & Gautam, 2019 revealed that employees show resistance and unease for any changes in daily routine due to the nature of unpredictable outcomes. The criticality of C8 as a major challenge is further validated by (Singh et al., 2020).

5 Conclusion and Implication

The present study aimed to identify and assess the drivers and challenges of deploying lean-green practices in the Indian manufacturing sector. The factors were identified in conjunction with recent papers. Ten drivers and nine challenges were identified with expert advice. Data was collected and subsequently assessed using Fuzzy TOPSIS to rank their criticality in deploying lean-green in Indian manufacturing from the perspective of consumer, industry, and government. The results indicate that *leadershipcommitment* is a major driver and interestingly *low leadershippriority to undertake sustainable practices* is a major challenge. This is because the major driver and major challenge both imply the criticality of leadership in implementing lean-green manufacturing in India. It is well established in previous sections that leadership commitment is a major driver toward lean-green practices, however, our results indicate that their commitment to undertake sustainable practices in manufacturing is not on par with major markets such as Germany and Japan whose primary focus is on development of manufacturing toward a greener and leaner process.

With a large portion of the manufacturing market in India dominated by medium and small-scale industries, it is possible that these industries do not possess the means to consider a lean-green strategy. Though the lean-green strategy reduces wastes and positively impact the environment, Indian leaders are more interested in immediate economic benefits. This outcome is the only motivator for leaders toward lean-green thinking. However, the sustainability factor that impacts the environment is not a major consideration for Indian manufacturers due to their inability in investing in sustainable practices. Implementing sustainable practices may require investments to upgrade manufacturing systems and redesign their processes to align with a sustainable, environmentally friendly manufacturing setup. The present study is based on a recent study and provides insights that may be referenced by both academia and industry. The present study brought about an academia–industry collaboration to give insights into lean-green implementation in Indian manufacturing. The present work may be developed further by assessing an integrated lean-green-agile, or a lean-green six sigma scenario in Indian manufacturers. The work may also be expanded to assess factors in other countries as well.

Annexure 1

Integrated Matrix

Driver	W1			W2			W3		
	0.85	0.9	0.85	0.85	0.9	0.85	0.85	0.9	0.85
	P1			P2			P2		
D1	5.363636	6.977273	8.204545	8.454545	9.727273	10	8.863636	9.931818	10
D2	6.5	8.113636	9.113636	8.454545	9.727273	10	8.727273	9.863636	10
D3	3.363636	5.159091	6.931818	7.681818	9.318182	9.977273	8.954545	9.977273	10
D4	3.454545	5.181818	6.909091	5.454545	7.363636	8.977273	8.727273	9.863636	10
D5	7.5	8.954545	9.704545	8.136364	9.5	9.931818	7.181818	9.045455	9.954545
D6	2.886364	3.818182	4.5	7.227273	8.863636	9.704545	8.681818	9.840909	10
D7	3.818182	5.727273	7.5	6.863636	8.75	9.818182	8.954545	9.977273	10
D8	1.477273	3.181818	5.181818	5.772727	7.727273	9.340909	5.5	7.454545	9.204545
D9	5.863636	7.659091	8.909091	8.659091	9.886364	10.15909	7.227273	9.113636	10
D10	8.181818	9.431818	9.840909	8.772727	9.886364	10	4.818182	6.727273	8.386364
MAX	8.181818	9.431818	9.840909	8.772727	9.886364	10.15909	8.954545	9.977273	10
MIN	1.477273	3.181818	4.5	5.454545	7.363636	8.977273	4.818182	6.727273	8.386364

Normalized Matrix

	W1			W2			W3		
	0.85	0.9	0.85	0.85	0.9	0.85	0.85	0.9	0.85
	P1			P2			P3		
D1	0.545035	0.739759	1.002778	0.832215	0.983908	1.139896	0.886364	0.995444	1.116751
D2	0.660508	0.860241	1.113889	0.832215	0.983908	1.139896	0.872727	0.98861	1.116751
D3	0.341801	0.546988	0.847222	0.756152	0.942529	1.137306	0.895455	1	1.116751
D4	0.351039	0.549398	0.844444	0.536913	0.744828	1.023316	0.872727	0.98861	1.116751
D5	0.762125	0.949398	1.186111	0.800895	0.96092	1.132124	0.718182	0.906606	1.111675
D6	0.293303	0.404819	0.55	0.711409	0.896552	1.106218	0.868182	0.986333	1.116751
D7	0.387991	0.607229	0.916667	0.675615	0.885057	1.119171	0.895455	1	1.116751
D8	0.150115	0.337349	0.633333	0.568233	0.781609	1.064767	0.55	0.747153	1.027919
D9	0.595843	0.812048	1.088889	0.852349	1	1.158031	0.722727	0.91344	1.116751
D10	0.831409	1	1.202778	0.863535	1	1.139896	0.481818	0.67426	0.936548

Weighted Normalized Matrix

	P1			P2			P3		
D1	0.463279	0.665783	0.852361	0.707383	0.885517	0.968912	0.753409	0.8959	0.949239
D2	0.561432	0.774217	0.946806	0.707383	0.885517	0.968912	0.741818	0.889749	0.949239

(continued)

(continued)

	P1			P2			P3		
D3	0.290531	0.492289	0.720139	0.642729	0.848276	0.96671	0.761136	0.9	0.949239
D4	0.298383	0.494458	0.717778	0.456376	0.670345	0.869819	0.741818	0.889749	0.949239
D5	0.647806	0.854458	1.008194	0.680761	0.864828	0.962306	0.610455	0.815945	0.944924
D6	0.249307	0.364337	0.4675	0.604698	0.806897	0.940285	0.737955	0.887699	0.949239
D7	0.329792	0.546506	0.779167	0.574273	0.796552	0.951295	0.761136	0.9	0.949239
D8	0.127598	0.303614	0.538333	0.482998	0.703448	0.905052	0.4675	0.672437	0.873731
D9	0.506467	0.730843	0.925556	0.724497	0.9	0.984326	0.614318	0.822096	0.949239
D10	0.706697	0.9	1.022361	0.734004	0.9	0.968912	0.409545	0.606834	0.796066

Mvij

	P1	P2	P3
D1	0.660475	0.853937	0.866182
D2	0.760818	0.853937	0.860269
D3	0.500986	0.819238	0.870125
D4	0.50354	0.665513	0.860269
D5	0.836819	0.835965	0.790441
D6	0.360382	0.78396	0.858297
D7	0.551822	0.77404	0.870125
D8	0.323182	0.697166	0.671223
D9	0.720955	0.869608	0.795217
D10	0.876353	0.867639	0.604148
MAX	0.876353	0.869608	0.870125
MIN	0.323182	0.665513	0.604148

	P1			P2			P3		
A +	0.706697	0.9	1.022361	0.724497	0.9	0.984326	0.761136	0.9	0.949239
A−	0.127598	0.303614	0.538333	0.456376	0.670345	0.869819	0.409545	0.606834	0.796066

D+

	P1	P2	P3
D1	0.616554	0.05594	0.021333
D2	0.343772	0.05594	0.051678
D3	0.968084	0.17597	−6.7E-16
D4	0.973404	0.612451	0.051678
D5	0.131231	0.128845	0.313822
D6	1.806832	0.301411	0.06138
D7	0.82987	0.313245	−6.7E-16

(continued)

(continued)

	P1	P2	P3
D8	1.393354	0.52121	0.668992
D9	0.435954	−4.4E-16	0.292866
D10	0	−4.4E-16	0.893538

S1+	0.693827
S2+	0.45139
S3+	1.144054
S4+	1.637534
S5+	0.573898
S6+	2.169623
S7+	1.143115
S8+	2.583557
S9+	0.72882
S10+	0.893538

D-

	P1	P2	P3
D1	0.828339	0.569829	0.871408
D2	1.051616	0.569829	0.839105
D3	0.432267	0.439314	0.893538
D4	0.443004	0	0.839105
D5	1.248029	0.507072	0.529768
D6	0.173618	0.339958	0.828568
D7	0.538046	0.299244	0.893538
D8	1.11E-16	0.078832	0.166435
D9	0.930588	0.612451	0.542208
D10	1.393354	0.628384	0

S1−	2.269577
S2−	2.460551
S3−	1.76512
S4−	1.28211
S5−	2.284869
S6−	1.342145
S7−	1.730828
S8−	0.245267
S9−	2.085247
S10−	2.021739

Annexure 2

Integrated Matrix

	W1			W2			W3		
	0.85	0.9	0.85	0.85	0.9	0.85	0.85	0.9	0.85
	P1			P2			P3		
C1	2.181818	4.181818	6.181818	6.772727	8.477273	9.590909	7.045455	8.75	9.727273
C2	7.136364	8.886364	9.795455	7.454545	9.022727	9.795455	5.204545	7.045455	8.568182
C3	3.340909	5.295455	6.977273	4	5.931818	7.727273	6.318182	7.681818	8.454545
C4	7.545455	9.272727	10	8.227273	9.431818	9.818182	7.295455	8.840909	9.545455
C5	5.931818	7.659091	8.704545	9.227273	10.34091	10.43182	7.5	8.909091	9.659091
C6	6.954545	8.818182	9.840909	2.681818	4.568182	6.545455	1.590909	3.363636	5.363636
C7	2.272727	3.954545	5.75	5.590909	7.159091	8.409091	2.909091	4.704545	6.272727
C8	8.090909	9.318182	9.704545	7.318182	8.931818	9.772727	7.363636	9.068182	9.886364
C9	5.681818	7.681818	9.340909	7.772727	9.25	9.863636	5.568182	7.5	8.840909
MAX	8.090909	9.318182	10	9.227273	10.34091	10.43182	7.5	9.068182	9.886364
MIN	2.181818	3.954545	5.75	2.681818	4.568182	6.545455	1.590909	3.363636	5.363636

Normalized Matrix

	W1			W2			W3		
	0.85	0.9	0.85	0.85	0.9	0.85	0.85	0.9	0.85
	P1			P2			P3		
C1	0.218182	0.44878	0.764045	0.649237	0.81978	1.039409	0.712644	0.964912	1.29697
C2	0.713636	0.953659	1.210674	0.714597	0.872527	1.061576	0.526437	0.776942	1.142424
C3	0.334091	0.568293	0.86236	0.383442	0.573626	0.837438	0.63908	0.847118	1.127273
C4	0.754545	0.995122	1.235955	0.788671	0.912088	1.064039	0.737931	0.974937	1.272727
C5	0.593182	0.821951	1.075843	0.884532	1	1.130542	0.758621	0.982456	1.287879
C6	0.695455	0.946341	1.216292	0.257081	0.441758	0.70936	0.16092	0.370927	0.715152
C7	0.227273	0.42439	0.710674	0.535948	0.692308	0.91133	0.294253	0.518797	0.836364
C8	0.809091	1	1.199438	0.701525	0.863736	1.059113	0.744828	1	1.318182
C9	0.568182	0.82439	1.154494	0.745098	0.894505	1.068966	0.563218	0.827068	1.178788

Weighted Matrix

	P1			P2			P3		
C1	0.185455	0.403902	0.649438	0.551852	0.737802	0.883498	0.605747	0.868421	1.102424
C2	0.606591	0.858293	1.029073	0.607407	0.785275	0.90234	0.447471	0.699248	0.971061
C3	0.283977	0.511463	0.733006	0.325926	0.516264	0.711823	0.543218	0.762406	0.958182
C4	0.641364	0.89561	1.050562	0.67037	0.820879	0.904433	0.627241	0.877444	1.081818

(continued)

(continued)

	P1			P2			P3		
C5	0.504205	0.739756	0.914466	0.751852	0.9	0.960961	0.644828	0.884211	1.094697
C6	0.591136	0.851707	1.033848	0.218519	0.397582	0.602956	0.136782	0.333835	0.607879
C7	0.193182	0.381951	0.604073	0.455556	0.623077	0.774631	0.250115	0.466917	0.710909
C8	0.687727	0.9	1.019522	0.596296	0.777363	0.900246	0.633103	0.9	1.120455
C9	0.482955	0.741951	0.98132	0.633333	0.805055	0.908621	0.478736	0.744361	1.00197

Mvij

	P1	P2	P3
C1	0.412932	0.724384	0.858864
C2	0.831319	0.765007	0.705927
C3	0.509482	0.518004	0.754602
C4	0.862512	0.798561	0.862168
C5	0.719476	0.870937	0.874578
C6	0.825564	0.406352	0.359498
C7	0.393069	0.617754	0.47598
C8	0.869083	0.757968	0.884519
C9	0.735409	0.782336	0.741689
MAX	0.869083	0.870937	0.884519
MIN	0.393069	0.406352	0.359498

Fuzzy Positive and Fuzzy Negative Ideal Solution

	P1			P2			P3		
A+	0.687727	0.9	1.019522	0.751852	0.9	0.960961	0.633103	0.9	1.120455
A-	0.193182	0.381951	0.604073	0.218519	0.397582	0.602956	0.136782	0.333835	0.607879

D+ (Fuzzy distance from the fuzzy positive ideal solution

	P1	P2	P3
C1	1.083636	0.551987	0.063044
C2	0.108881	0.432577	0.372654
C3	0.895628	1.116463	0.29739
C4	0.011955	0.341476	0.047863
C5	0.414085	0	0.033075
C6	0.122442	1.42118	1.046631
C7	1.192577	0.923995	0.847705
C8	3.33E-16	0.452483	2.22E-16
C9	0.349943	0.377194	0.296735

Fuzzy Closeness co-efficient defuzzified

S1+	1.698667
S2+	0.914112
S3+	2.30948
S4+	0.401294
S5+	0.44716
S6+	2.590253
S7+	2.964277
S8+	0.452483
S9+	1.023872

D−

	P1	P2	P3
C1	0.049825	0.869408	0.996028
C2	1.005314	1.011616	0.694939
C3	0.288056	0.299919	0.868905
C4	1.078281	1.18943	1.036934
C5	0.781791	1.42118	1.071965
C6	0.973199	1.11E-16	1.11E-16
C7	0	0.604714	0.271129
C8	1.192577	0.982767	1.046631
C9	0.748256	1.080557	0.7607

S1−	1.915261
S2−	2.711869
S3−	1.45688
S4−	3.304645
S5−	3.274936
S6−	0.973199
S7−	0.875843
S8−	3.221975
S9−	2.589513

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Performance Evaluation of Lean-Green Healthcare Manufacturing Plants: A Fuzzy TOPSIS Approach

Arshia Kaul and Anindo Bhattacharjee

Abstract In the recent past, the whole world has been affected by the pandemic, COVID-19. Under the conditions of the pandemic, the healthcare industry came to the fore. The focus has become primarily to understand how to enhance the healthcare sector in order to ensure that it provides for a better system for the patients. There are many facets under the umbrella of the healthcare sector. The healthcare sector can also be taken analogous to the supply chain of any firm wherein broadly it starts from the supply side and ends up providing to the end customers. The supplier provides raw materials for manufacturing, the manufacturers in this sector produce medical equipment and other medicines. Further, the finished products are distributed by various channels to the end-users which are the patients in this case. In this research, the aim is to focus on the manufacturing of medical equipment and the evaluation of the manufacturing plants. Keeping all other factors constant, the evaluation is carried out on the lean-green strategy utilized of the manufacturing plants. The case of a healthcare manufacturing firm is considered, which has multiple plants. The evaluation of the plants is carried out based on the performance and based on the implementation of lean-green strategies. There are many conflicting factors that help in the implementation of the lean-green strategy. To evaluate which of the plants of the firm has been able to implement the lean-green strategy in manufacturing of medical equipment, the fuzzy-technique for order preference with similarity to ideal solution (F-TOPSIS) is utilized. F-TOPSIS is a multi-criteria decision-making tool that helps in the evaluation of the plants by considering the conflicting criteria for evaluation. A case of a small-scale medical equipment manufacturing firm is considered.

Keywords Lean · Green · Health care · Manufacturing · F-TOPSIS

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1 Introduction

With the rise of awareness of maintaining better health and with the ability of the end-users to pay for better healthcare, it becomes imperative for healthcare professionals to provide better treatments for the end-users. There are many developments that are taking place in the healthcare industry. The healthcare industry is composed of drugs, hospitals or clinics (providing patient treatments), healthcare manufacturing, to highlight the major ones. Each of the components of the industry has expanded and is on the road to further expansion each day. More so, with the pandemic COVID-19 affecting all parts of the world, the effective and efficient development of the healthcare sector is important in all dimensions. The concentration of the current research is on the medical manufacturing sector in a developing country such as India (Sood, 2020).

The medical device industry globally was estimated to be about 228 billion in 2015. It was further suggested that there would be growth at a CAGR of 7.8% from 2010 to 2020 (World Health Organization, 2017). The medical devices sector can be broadly categorized into seven broad categories, viz. diagnostic imaging, orthopedic and prosthetic devices, patient aids, consumables, dental products, IV diagnostics, and others. The segment-wise division shows that diagnostic imaging constitutes 26% globally of the medical device market. The medical devices market is largest globally with the Americas (North and South) with 45%, followed by 27% from the Western Europe of the total and Asia having the third-largest share of 21% (World Health Organization, 2017).

In India, the medical device market has grown from USD 2.02 billion (INR 13,130 crores) in the year 2009 to USD 3.9 billion (INR 25,259 crores) in 2015 which was at a CAGR of 15.8% (World Health Organization, 2017). The market was estimated to grow to USD 8.16 (INR 53,053) in 2020 at a CAGR of 16% (World Health Organization, 2017). Moreover, the COVID-19 situation and the focus of the government to become self-reliant has given impetus to many sectors, of which healthcare device manufacturing in India is one of them. It can be observed that the cost of healthcare in India is 35% more competitive than that of the USA and the UK. There are many who visit India to get treatments at an affordable cost. Though the Indian healthcare market is trying to be competitive, yet there are large portions of imports especially in the sophisticated healthcare device sector. In the year 2019–2020 itself, medical equipment worth INR 4560 crores was imported from China. The government is now wanting to focus on the self-reliance of each sector and the same is the case of the Indian medical device sector. The Indian market for medical devices is currently worth USD 11 billion which makes it among the top 20 countries in the world providing affordable healthcare. This market is further expected to grow to about USD 50 billion in the next 5 years. There are many initiatives by the government for the promotion of the medical equipment sector. The government has allowed for a 100% Foreign Direct Investment (FDI) for medical devices. There are many state governments that have decided to set up many of the manufacturing parks and have approval from the central government. There are about six medical device clusters that are being planned to be set up in Andhra Pradesh, Kerala, Telangana, Tamil Nadu, Maharashtra, and Sikkim. The pandemic has brought in an excessive surge in demand for PPE kits, ventilators, and life-saving equipment and brought in a manufacturing opportunity. The growth opportunities in this sector, as can be seen, have made it imperative to concentrate on this sector. Therefore, the focus of this research becomes apt (Sood, 2020).

To ensure that there is effective and efficient manufacturing, there needs to be a supply chain in place which is able to cater to the demands of the end-users (patients). If we were to consider the healthcare manufacturing sector as a supply chain of health devices, there are suppliers of the raw materials of manufacturing of the medical equipment, which are connected to manufacturing plants, subsequently to distribution centers, and then to the end-user. It is essential to understand that to ensure that the medical devices of the healthcare supply chain are delivered to the end-user, each partner of the supply chain must individually improve their performance, which will eventually lead to the performance improvement of the overall supply chain in medical equipment sector in India.

It is, therefore essential, to minutely monitor each small niche aspect of each actor and each node. The current research would consider the evaluation of manufacturing plants in order to ensure that there could be improvements made if and when required. The improvements will need to be made in order to satisfy the needs of the end users. There are many criteria for the evaluation of a manufacturing plant. In general, the manufacturing plant for any sector should be able to carry out production in an effective and efficient manner such products are able to satisfy the needs of the end user. The same holds true for the healthcare sector as well. Moreover, one has to be more careful since the medical equipment and medicines are responsible for ensuring the recovery of patients. There is no scope for any errors. In recent times, there is more scope of evaluation of manufacturing plants in terms of quality production. Moreover, though the case for evaluation considered is that of manufacturing under the pandemic situation, but that cannot discount the quality in terms of performance of the manufacturing plants. Thus, there needs to be a proper evaluation of the manufacturing plants.

Further, with end users becoming more aware of the environment and with government regulations in place, the manufacturing plant must focus on the production process being environmentally friendly to remain competitive in the market (Wang et al., 2016). This leads to considering greening the process involved in manufacturing. Another way to ensure that one remains competitive is by reducing production and operation waste (Paul et al., 2014). There are many manufacturers that have applied lean strategies for the same to remain competitive. Lean is famous and there are multiple definitions which are given by many authors (Parker & DeLay, 2008). As stated by Bicheno (2004), lean is a philosophy rather than only a set of tools for quality improvement of production. There are others that focus on waste reduction during the process of production (Pettersen, 2009). The lean approach encompasses all tools, strategies, and practices for an efficient production system with lesser resource consumption and generation of waste. The integration between lean and green (L&G) approaches can help in the enhancement of the operational performance by value creation and by waste reduction which is environmentally friendly. There are many researchers who have wanted to address the implementation of the L&G integrated strategy. There is still a challenge of implementing the same, especially in the healthcare sector. There is a lack of understanding of the strategy in the industry (Cherrafi et al., 2017). In this paper, the aim is to address this concern and evaluate the implementation of the L&G strategy in the healthcare manufacturing sector. The healthcare sector is of concern today and thus it is essential to improve the healthcare ecosystem.

Studies in countries with well-developed healthcare systems (e.g., Sweden) have established the importance of lean processes and lean production in better performance, health outcomes, and better working conditions in hospitals and healthcare service facilities (e.g., Dellve et al., 2015; Eriksson et al., 2016). Further, studies do exist on the implementation of the lean approach in a green supply chain management in various different sectors such as textile, food packaging, automobile, etc., using techniques such as pressure analysis through analytical hierarchy process or taking an interpretive structural modeling for barrier analysis in implementing green supply chains (e.g., Mathiyazhagan et al., 2014; Diabat et al., 2014; Mathiyazhagan et al., 2013; Wang et al., 2016; Li & Mathiyazhagan, 2018 etc.). However, there are a few researches that have concentrated on the healthcare manufacturing sector and also fewer studies of implementing a lean-green approach in a healthcare value-chain using a multi-criteria decision-making (MCDM) method. To the best of our knowledge, there is no such research that has focused on the evaluation of the healthcare manufacturing sector quantitatively for implementing the L&G integrated strategy. Moreover, there is a conflict that arises in the nature of decisions that have to be taken into consideration. If we were to ensure that the manufacturing process is lean it would reduce non-value-adding activities and reduce cost. On the other hand, if the manufacturing has to produce in an environmentally friendly manner then there would be a rise in cost. This quantitative evaluation of medical equipment manufacturing plants focusing on the conflicting nature of the integrated lean-green strategy can be tackled by using evaluation through multi-criteria decision-making (MCDM) method fuzzy-technique for order preference with similarity to ideal solution (F-TOPSIS). The fuzzy nature of the MCDM technique is taken in order to include subjectivity in decision-making.

To highlight the details of the current research, we can express it as the following research questions as follows:

1. What are the criteria influencing the implementation of the lean-green strategy in the healthcare manufacturing plant?
2. What are the importance weights given by the decision-makers for each criterion for evaluation of the manufacturing plants?
3. What is the final relative ranking of the manufacturing plants for implementation of the lean-green strategy under consideration in terms of criterion?

The rest of the research paper is presented in the following sections: Sect. 2 describes the extant literature in the healthcare manufacturing sector and develops the research gap that exists in the area in terms of implementation of lean-green strategies. Section 3 describes the real-life case for the implementation of the proposed strategy and the evaluation of the manufacturing plants in the healthcare sector. Section 4 describes the managerial and theoretical implications of the study. Section 5 concludes the paper and also provides the future scope of the study.

2 Literature Review

In the extant literature, there are many different ways in which a supply chain is defined. The supply chain is a set of all the processes that help to modify the raw materials in the form which are required by the end customers. There are many processes that are involved which create value for the customers and there is a two-way communication flow between the supply end to customer end (Meijboom et al., 2011). The healthcare supply chain can be considered as all the activities, which will help in providing for the patients of different nature (McKone-Sweet et al., 2005; Parker & DeLay, 2008). Even in the case of a healthcare supply chain, there are manufacturers, distributors, wholesalers, and retailers (Haszlinna Mustaffa & Potter, 2009). In this section, we broadly consider the literature which has looked at the healthcare supply chain operations. Whether it may be manufacturing, distribution, or retailing. When we consider manufacturing, manufacturers can be classified into primary and secondary. In the case of the medical industry primary manufacturer is that institution that produces medical material. They utilize a large amount of time in cleaning in order to prevent contamination of the medical materials. There are secondary manufacturers, which use the material to produce tablets or capsules (Kim & Kim, 2019). There is another section which deals with medical equipment manufacturing (Vries & Huijsman, 2011). An extensive literature review (Dobrzykowski et al., 2014) discusses the various studies which consider the healthcare supply chain management from the year 1982 to 2011. It was suggested by the authors that the studies on healthcare have been increasing over time. There are other studies that have discussed healthcare supply chain strategies and objectives (Rivard-Royer et al., 2002; Shah et al., 2008; Niziolek et al., 2012; Uthayakumar & Priyan, 2013). Rivard-Royer et al. (2002) discussed in their paper about the healthcare supply chain strategies and objectives. Particularly, they discussed the effective and efficient hybrid-supplement model by stockless replenishment in the case of a Canadian supplier of medical supplies. There is an important role of the packaging formats of manufacturers, which will decrease the cost of storing and improves the performance of the healthcare supply chain. Niziolek et al. (2012) discuss the model for determination of delivery frequency and delivery amount to minimize the cost of transportation and inventory by direct shipping in the medical supply chain. Uthayakumar and Priyan (2013) discussed that the inventory and supply policies of medical supplies must be such that there is no lack of medical supplies in the supply chain in the healthcare supply chain. Further, the parallels which can be drawn between any industrial sector supply chain and the healthcare service supply chain have been discussed. They further discussed the details of the future scope of the studies.

From the extant literature, it can be observed that that are many researchers which have tried to understand the details of the healthcare sector supply chain as a parallel to an industrial sector supply chain. There are some researchers who have also tried to consider the manufacturing in the health sector, yet there is no research that has considered it as a multi-criteria decision-making (MCDM) model with conflicting criteria for evaluation for analyzing the operations of the healthcare sector, so also the manufacturing of medical equipment. Further, another aspect that has not been considered in enhancing the supply chain in the healthcare sector. There are many ways to improve the quality of the output of a supply chain. One such way is to make the supply chain leaner by reducing the non-value-adding activities. Additionally, there are many concerns for the environment these days and therefore it is necessary to consider the greenness in the supply chain outputs. Even the concept of lean and green aspects of the supply chain can be further considered as conflicting in nature.

Considering the extant literature presented above, the research gap to the best of our knowledge is owing to the following:

- Limited consideration of operations in healthcare manufacturing as a multi-criteria decision-making model;
- Limited or no consideration for the lean-green strategies in the manufacturing of healthcare equipment to improve the quality of the supply chain;
- Limited consideration of uncertainties in the healthcare manufacturing sector.

3 Research Framework and Case Study

With the current concerns for the healthcare sector with the advent of COVID-19, it is seen that both the developing countries and developed countries have been affected without discrimination. This life-threatening virus has forced us to evaluate healthcare closely with or without reason. It has become imperative to thus keep a thorough check on the future developments in the healthcare sector. It is necessary to ensure thus that all the processes perform at the highest level of performance, especially in the case of healthcare. The stakes of performing well in all aspects of the healthcare sector are essential.

In this research, the aim is to evaluate the case of manufacturing firms that are currently producing masks for the current soring market demands. The case for an Indian firm that has shifted to manufacture the masks in order to ensure that they are still in the business and do not lose out and compulsorily declare bankruptcy. The firm has many plants at different locations. In order to survive for a long term, it is necessary for them to implement strategies such that manufacturing is enhanced and the firm can sustain for a long term. It is in this relation we bring in the evaluation of the level of L&G strategies in the mask manufacturing plants of the firm. Each plant is evaluated on the basis of the criteria of evaluation which are given in Table 1. The criteria have been established based on the details obtained from the literature

Table 1 Criteria for Evaluation of Manufacturing Plant

Criteria for evaluation	Working definition	References
Increased amount of goods delivered on time (C1)	More delivered in one go will ensure less pollution	(Mardani et al., 2020; Rostamzadeh et al., 2015)
Policy Initiatives for reduction of carbon emissions	Firm ensures that it instils the policies top-down for reduction of carbon emissions	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Environmentally friendly packing of products (C3)	The packaging will be environmentally friendly	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Top management support to produce green products (C4)	There is support in terms of finances and overall support for the production of environmentally friendly products	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Practices of green design (C5)	The design of the product produced (or raw material) are more environmentally friendly	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Environmentally friendly transportation (C6)	The mode of transport used is more environmentally so that emissions are less	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Cleaner production area (C7)	The cleanliness and environmentally friendly surroundings of the production plant	(Mardani et al., 2020; Rostamzadeh et al., 2015; Govindan et al., 2015)
Working together with customers to reduce environmental impact of operations (C8)	The customers help in maintaining environmentally friendly surroundings by returning products for refurbish	(Mardani et al., 2020; Singh et al., 2020)
Awards for green Image (C9)	The awards for maintaining green images influences to achieve greener manufacturing	(Mardani et al., 2020; Rostamzadeh et al., 2015)
Project selection and prioritization (C10)	The projects selected maintain that lean-green strategies	Mardani et al. (2020)
Understanding lean green strategy (C11)	The less waste-based strategies which are also environmentally friendly	Mardani et al. (2020)
Lean green awareness program and training (C12)	Training the staff for the lean-green manufacturing	(Mardani et al., 2020; Singh et al., 2020; Govindan et al., 2015)
Financial benefits sharing among employees due to lean-green (C13)	Employees are given incentives for helping achieve the overall lean-green strategy	(Mardani et al., 2020; Singh et al., 2020)
Decrease scrap rate and promote products quality (C14)	The waste is reduced to improve the manufacturing and leading to lean	(Mardani et al., 2020; Singh et al., 2020)

(continued)

Table 1 (continued)

Criteria for evaluation	Working definition	References
Improved capacity utilization (C15)	The capacity for production is utilized to minimize the waste	(Mardani et al., 2020; Singh et al., 2020

review and subsequent discussion on the same with the decision-making body of the firm. In the section that follows we give the details of the criteria which are used for the evaluation of the manufacturing plants. The details of the criteria are given for a better understanding of how to evaluate the manufacturing plants based on the criteria.

3.1 Methodology

In this research, the evaluation of manufacturing for mask production is considered. There are many researchers who have used multiple ways of evaluation for evaluating alternatives as well as manufacturing plants, but there are limited studies that have considered the evaluation of newly established small-scale manufacturing plants. Moreover, there are a limited number of studies that have considered the evaluation based on L&G strategy in the healthcare sector. To have a comprehensive evaluation, one must evaluate on the basis of multiple conflicting criteria. Here we are using the Fuzzy-Technique for Order Preference with Similarity to Ideal Solution (F-TOPSIS) a multi-criteria decision-making (MCDM) tool. There are many researchers who have used the F-TOPSIS in different areas of research for evaluation based on conflicting criteria (Wang & Chang, 2007). This method was given by Chen (2000), which was the extension of the earlier proposed MCDM TOPSIS incorporating subjectivity in the nature of the real-life decision-making. The vagueness in the scenario of real-life decision-making comes into play because there are many details that are not available in exact measure. To the best of our knowledge, there are no studies that have evaluated quantitatively the manufacturing plants in the small-scale sectors in the healthcare industry. Moreover, the fuzzy decision-making scenario has also not been included in many situations. Figure 1 gives the detail of the F-TOPSIS framework of evaluation.

4 Steps of F-TOPSIS for Ranking Manufacturing Plants

The readers may further refer to Chen (2000) to understand in detail the F-TOPSIS. The details of Fuzzy Sets as well as the detailed steps of F-TOPSIS are given in Chen (2000). Here we describe how F-TOPSIS is used in detail for the particular case of evaluation of plants which manufacture masks, currently required on an urgent basis

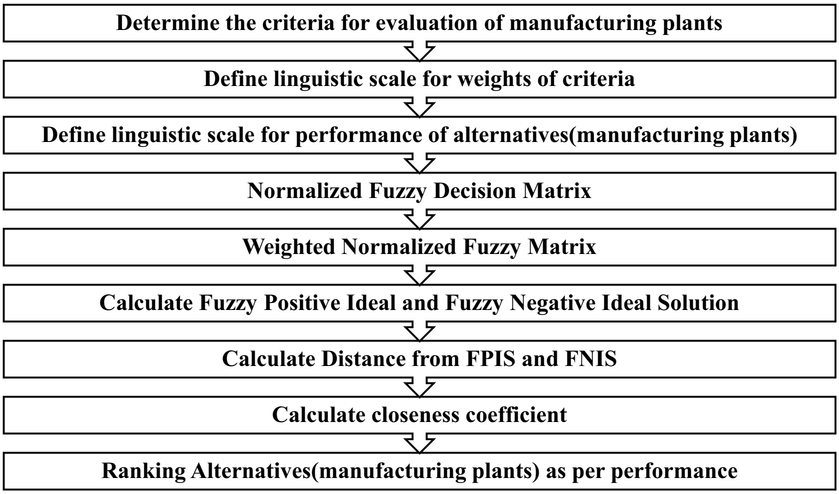

Fig. 1 Fuzzy-TOPSIS methodology. *Source* Adapted from Chen (2000)

in the market. The urgency cannot discount the fact that the performance levels of the manufacturing plant have to be met. Additionally, it is noteworthy that the current evaluation is carried out on the basis of the implementation of L&G strategy in the manufacturing plants.

- ***Step 1***: Initially, it is essential to determine the criteria for evaluation carefully. Here the criteria are selected as discussed in the earlier section and we have determined the ($j = 1,2,\ldots,n'$) criteria and (where $n' = 15$) for evaluating the ($i = 1,2,\ldots,m'$) alternatives (where $m' = 6$). These criteria are determined based on the literature and in discussion with the decision-makers of the firm. The ranking is done in decreasing order of performance in terms of implementation of the L&G strategy in the manufacturing plants at a small scale.
- ***Step 2***: The next step is to determine the linguistic scale for evaluation of the criteria and then subsequently the alternatives. The scale used for evaluation is given in Tables 2 and 3 and is as proposed by Chen (2000). Table 2 gives the scale for evaluation of weights to criteria and Table 3 gives the scale for performance evaluation of manufacturing plants. The scales are defined in terms of triangular fuzzy numbers (TFNs). It is essential to note that the use of triangular fuzzy numbers (TFNs) is because of ease of calculations for decision-makers and it is also an established fact that it is more effective for the case when imprecise data is available (Chang & Yeh, 2001; Bozbura et al., 2007).
- ***Step 3***: The decision is taken based on the evaluation of a group of k decision-makers (here assessment based on plant managers and other personnel of the firm) ($k = 1,2,\ldots,K$) ($K = 20$). The group of 20 is asked to give suitable weights for all the j criteria. The average weights for each criterion and performance of

Table 2 Linguistic scale for weights of criteria

Linguistic variables for giving order of preferences of criteria	Corresponding TFN
Very Low (VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Medium Low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium High (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1.0)
Very High (VH)	(0.9,1.0,1.0)

Table 3 Linguistic scale for performance of manufacturing Plants

Linguistic variables for determining the performance of the manufacturing plant with respect to the criteria	Corresponding TFN
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium Poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very Good (VG)	(9,10,10)

manufacturing plants with respect to each criterion from the group are obtained based on the average value for 20 decision-makers.

- ***Step 4***: On the basis of average performance values of each manufacturing plant from the group of 20 decision-makers, we obtain the final fuzzy decision matrix as well as the corresponding vector of weights as given in Table 4.
- ***Step 5(a)***: To ensure that the TFN lies in the range [0,1] the process of normalization is carried out. Table 5 gives the normalized matrix. For details of the process of normalization refer to Chen (2000).
- **Step 5(b)**: Each criterion is assigned a weight. These weights are multiplied by the normalized performance matrix values obtained for the manufacturing plants. This calculation is carried out using the rule of fuzzy multiplication. The matrix obtained is the weighted normalized fuzzy matrix. Table 6 gives the details of the normalized weighted matrix (refer (Chen, 2000))
- ***Step 6***: Subsequently the Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS) values are calculated
  FPIS = $A* = (1,1,1)$
  FNIS = $A^- = (0,0,0)$
- ***Step 7***: d_i^* and d_i^- are the is the distances calculated from the FPIS and FNIS respectively for each of the manufacturing plants which are given in Table 7.

Table 4 Initial decision matrix (Fuzzy)

Weights	(0.69,0.865,0.97)	(0.49,0.69,0.865)	(0.79,0.935,0.99)	(0.78,0.94,1)	(0.28,0.48,0.68)	(0.6,0.8,0.95)	(0.3,0.5,0.7)
	C1	C2	C3	C4	C5	C6	C7
A1	(7.7,9.35,10)	(6,8,9.5)	(4.1,6.1,8.1)	(6.1,8.1,9.55)	(6,8,9.5)	(3.9,5.9,7.9)	(2,4,6)
A2	(7.7,9.35,10)	(5.8,7.8,9.4)	(3.9,5.9,7.9)	(3.8,5.8,7.8)	(4.1,6.1,8.1)	(3.8,5.8,7.8)	(3.7,5.7,7.7)
A3	(8.1,9.55,10)	(8.1,9.55,10)	(8.3,9.65,10)	(6,8,9.5)	(8,9.5,10)	(6.2,8.2,9.6)	(5.9,7.9,9.45)
A4	(5.8,7.8,9.4)	(4,6,8)	(6,8,9.5)	(3.9,5.9,7.9)	(4.9,6.9,8.6)	(5.5,7.5,9.1)	(6.2,8.2,9.6)
A5	(6,8,9.5)	(3.1,5.1,7.1)	(3.7,5.7,7.7)	(6.1,8.1,9.55)	(2.9,4.9,6.9)	(1.9,3.9,5.9)	(2.3,4.3,6.3)
A6	(6,8,9.5)	(6.2,8.2,9.6)	(3.9,5.9,7.9)	(4.9,6.9,8.55)	(2.1,4.1,6.1)	(1.8,3.8,5.8)	(2.3,4.3,6.3)

(0.58,0.78,0.94)	(0.8,0.95,1)	(0.43,0.63,0.83)	(0.035,0.17,0.37)	(0.05,0.2,0.4)	(0.2,0.4,0.6)	(0.6,0.8,0.95)	(0.6,0.8,0.95)
C8	C9	C10	C11	C12	C13	C14	C15
(7.9,9.45,10)	(4,6,8)	(3.9,5.9,7.9)	(6.1,8.1,9.55)	(6.1,8.1,9.55)	(8,9.5,10)	(5.5,7.5,9.05)	(6.1,8.1,9.55)
(7.8,9.4,10)	(6,8,9.5)	(4.2,6.2,8.2)	(5.2,7.2,8.9)	(6,8,9.5)	(8,9.5,10)	(6.9,8.65,9.7)	(6.3,8.1,9.45)
(6.2,8.2,9.6)	(4,6,8)	(5.9,7.9,9.45)	(5.8,7.8,9.4)	(8.1,9.55,10)	(7.9,9.45,10)	(6.1,8.1,9.55)	(6.1,8.1,9.55)
(5.4,7.4,9)	(4,6,8)	(5.9,7.9,9.45)	(5,7,8.7)	(5.1,7.1,8.8)	(5,7,8.7)	(4,6,8)	(5,7,8.7)
(5.3,7.3,8.95)	(5.9,7.9,9.45)	(4.4,6.4,8.25)	(2.2,4.2,6.2)	(4.2,6.2,8.2)	(5.9,7.9,9.45)	(4,6,8)	(6,8,9.5)
(6.1,8.1,9.55)	(2.6,4.6,6.6)	(3.5,5.5,7.5)	(6.2,8.2,9.6)	(5.9,7.9,9.45)	(5.6,7.6,9.3)	(2.1,4.1,6.1)	(2.1,4.1,6.1)

Table 5 Normalized fuzzy decision matrix

Weights	(0.69,0.865,0.97)	(0.49,0.69,0.865)	(0.79,0.935,0.99)	(0.78,0.94,1)	(0.28,0.48,0.68)	(0.6,0.8,0.95)	(0.3,0.5,0.7)
	C1	C2	C3	C4	C5	C6	C7
A1	(0.77,0.935,1)	(0.6,0.8,0.95)	(0.41,0.61,0.81)	(0.63,0.84,1)	(0.6,0.8,0.95)	(0.40,0.61,0.82)	(0.20,0.41,0.62)
A2	(0.77,0.935,1)	(0.58,0.78,0.94)	(0.39,0.59,0.79)	(0.39,0.60,0.81)	(0.41,0.61,0.81)	(0.39,0.60,0.81)	(0.38,0.59,0.80)
A3	(0.81,0.955,1)	(0.81,0.955,1)	(0.83,0.965,1)	(0.62,0.83,0.99)	(0.8,0.95,1)	(0.64,0.85,1)	(0.61,0.82,0.98)
A4	(0.58,0.78,0.94)	(0.4,0.6,0.8)	(0.6,0.8,0.95)	(0.40,0.61,0.82)	(0.49,0.69,0.86)	(0.57,0.78,0.94)	(0.64,0.857,1)
A5	(0.6,0.8,0.95)	(0.31,0.51,0.71)	(0.37,0.57,0.77)	(0.63,0.84,1)	(0.29,0.49,0.69)	(0.19,0.40,0.61)	(0.23,0.44,0.65)
A6	(0.6,0.8,0.95)	(0.62,0.82,0.96)	(0.39,0.59,0.79)	(0.51,0.72,0.89)	(0.21,0.41,0.61)	(0.18,0.39,0.60)	(0.23,0.44,0.65)

(0.58,0.78,0.94)	(0.8,0.95,1)	(0.43,0.63,0.83)	(0.035,0.17,0.37)	(0.05,0.2,0.4)	(0.2,0.4,0.6)	(0.6,0.8,0.95)	(0.6,0.8,0.95)
C8	C9	C10	C11	C12	C13	C14	C15
(0.79,0.945,1)	(0.42,0.63,0.84)	(0.41,0.62,0.83)	(0.63,0.84,0.99)	(0.61,0.81,0.955)	(0.8,0.95,1)	(0.561,0.77,0.93)	(0.638,0.84,1)
(0.78,0.94,1)	(0.63,0.84,1)	(0.44,0.65,0.86)	(0.54,0.75,0.92)	(0.6,0.8,0.95)	(0.8,0.95,1)	(0.71,0.89,1)	(0.65,0.84,0.988)
(0.62,0.82,0.96)	(0.421,0.63,0.84)	(0.62,0.83,1)	(0.60,0.81,0.97)	(0.81,0.955,1)	(0.79,0.945,1)	(0.62,0.83,0.98)	(0.63,0.84,1)
(0.54,0.74,0.9)	(0.421,0.63,0.84)	(0.62,0.83,1)	(0.52,0.72,0.90)	(0.51,0.71,0.88)	(0.5,0.7,0.87)	(0.41,0.61,0.82)	(0.52,0.73,0.91)
(0.53,0.73,0.895)	(0.621,0.83,0.99)	(0.46,0.67,0.87)	(0.22,0.43,0.64)	(0.42,0.62,0.82)	(0.59,0.79,0.945)	(0.41,0.61,0.82)	(0.62,0.83,0.99)
(0.61,0.81,0.955)	(0.27,0.48,0.69)	(0.37,0.58,0.79)	(0.64,0.85,1)	(0.59,0.79,0.945)	(0.56,0.76,0.93)	(0.21,0.42,0.62)	(0.21,0.42,0.63)

Table 6 Weighted normalized fuzzy decision matrix

Weights	(0.69,0.865,0.97)	(0.49,0.69,0.865)	(0.79,0.935,0.99)	(0.78,0.94,1)	(0.28,0.48,0.68)	(0.6,0.8,0.95)	(0.3,0.5,0.7)
	C1	C2	C3	C4	C5	C6	C7
A1	(0.53,0.80,0.97)	(0.29,0.55,0.82)	(0.32,0.57,0.80)	(0.49,0.79,1)	(0.168,0.384,0.646)	(0.243,0.49,0.7)	(0.062,0.208,0.437)
A2	(0.53,0.80,0.97)	(0.28,0.53,0.81)	(0.30,0.55,0.78)	(0.31,0.57,0.81)	(0.11,0.29,0.55)	(0.23,0.48,0.77)	(0.115,0.296,0.561)
A3	(0.55,0.82,0.97)	(0.39,0.65,0.86)	(0.65,0.90,0.99)	(0.49,0.78,0.99)	(0.22,0.45,0.68)	(0.38,0.68,0.95)	(0.184,0.41,0.68)
A4	(0.40,0.67,0.91)	(0.19,0.41,0.69)	(0.47,0.74,0.94)	(0.31,0.58,0.82)	(0.13,0.33,0.58)	(0.34,0.62,0.90)	(0.193,0.427,0.7)
A5	(0.41,0.69,0.92)	(0.151,0.35,0.61)	(0.29,0.53,0.76)	(0.49,0.79,1)	(0.08,0.23,0.46)	(0.11,0.32,0.58)	(0.071,0.22,0.459)
A6	(0.41,0.69,0.92)	(0.30,0.56,0.83)	(0.30,0.55,0.78)	(0.400,0.67,0.89)	(0.05,0.19,0.41)	(0.11,0.31,0.57)	(0.071,0.223,0.457)

(0.58,0.78,0.94)	(0.8,0.95,1)	(0.43,0.63,0.83)	(0.035,0.17,0.37)	(0.05,0.2,0.4)	(0.2,0.4,0.6)	(0.6,0.8,0.95)	(0.6,0.8,0.95)
C8	C9	C10	C11	C12	C13	C14	C15
(0.4582,0.7371,0.94)	(0.336,0.6,0.84210)	(0.177,0.393,0.693)	(0.022,0.1434,0.368)	(0.0305,0.162,0.382)	(0.16,0.38,0.6)	(0.3402,0.618,0.886)	(0.383,0.678,0.95)
(0.4524,0.7332,0.94)	(0.505263157894737,0.8,1)	(0.191111111111111,	(0.1911,0.413,0.720)	(0.03,0.16,0.38)	(0.16,0.38,0.6)	(0.4268,0.713,0.95)	(0.395,0.678,0.940)
(0.3596,0.6396,0.9024)	(0.3368,0.6,0.842)	0.526666666666667,	(0.268,0.526,0.83)	(0.0405,0.191,0.4)	(0.158,0.378,0.6)	(0.37,0.668,0.9353)	(0.383,0.67,0.95)
(0.3132,0.5772,0.846)	(0.336,0.6,0.84)	0.83)	(0.268,0.526,0.83)	(0.0255,0.142,0.352)	(0.1,0.28,0.522)	(0.247,0.4948,0.78)	(0.314,0.586,0.865)
(0.3074,0.5694,0.8413)	(0.496,0.79,0.994)	0.724603174603175)	(0.200,0.426,0.724)	(0.021,0.124,0.328)	(0.118,0.316,0.567)	(0.247,0.494,0.783)	(0.376,0.670,0.9450)
(0.3538,0.6318,0.8977)	(0.218,0.46,0.694)	0.658730158730159)	(0.159,0.366,0.658)	(0.0295,0.158,0.378)	(0.112,0.304,0.558)	(0.129,0.338,0.597)	(0.131,0.34,0.606)

Table 7 Distance from FPIS and FNIS

Manufacturing Plant	d_i^*	d_i^-
M1	8.121	8.11
M2	8.09052	8.14
M3	7.31972	8.94
M4	8.41085	7.82
M5	8.85744	7.33
M6	9.37085	6.76

Table 8 Closeness Coefficient

Manufacturing Plant	CC_i
M3	0.49977
M2	0.5014
M1	0.54993
M4	0.48188
M5	0.45295
M6	0.41925

- ***Step 8(a)***: In the final step the closeness coefficient (CC_i) for each manufacturing plant is calculated and given in Table Ü.
- ***Step 8(b)***: The closer the value of CC_i is to unity the better the alternative. Arranging (CC_i) values in descending order we obtain the top-ranked alternatives. The F-TOPSIS method is an MCDM method that has been used in this research in order to preferentially rank the manufacturing plants in the healthcare sector based on the level of implementation of the lean-green strategy. The fuzzy nature helps to incorporate the vagueness in decision-making in the real life. The idea of TOPSIS is to achieve the ranking of the alternatives by evaluating their performance with respect to the criteria (here based on the lean and green criteria). The closeness coefficient value for a particular alternative signifies how well it is performed as close to the ideal alternative (here manufacturing plant with the best value). The alternative with the highest value of closeness coefficient is the best alternative for manufacturing with respect to the implementation of lean-green strategy. The alternative with the lowest value of closeness coefficient is the worst performing alternative. The final results show that the M3 is the best performing manufacturing plant followed by M2 and so on up to M6.

5 Managerial and Theoretical Implications

The research in this paper has the following implications:

- **Incorporating lean and green strategies for evaluation of manufacturing plants in the healthcare sector**: The lean and green strategies used for the evaluation of manufacturing plants in the healthcare sector are conflicting in nature. The criteria incorporated in the decision-making help the decision-makers of the company understand where they must invest. The individual evaluation of the manufacturing plants with respect to the criteria can show which manufacturing plant is doing better in terms of which criteria. This will help in deciding how to improve the particular manufacturing plant. For example, manufacturing plants is leaner as it provides the best performance in providing products in time. The MCDM used in this research helps to determine the best possible trade-off between the conflicting criterion.
- **Fuzzy evaluation of manufacturing plants in the healthcare sector:** The proposed methodology with fuzzy evaluations helps in making real-life decisions with ease. Quantification of the vagueness of the real life is done and it helps to determine the best decision for adopting the strategies. In this case the adoption of lean-green strategy in mask manufacturing plants. The vagueness in real-life situations is assessed through the fuzzy numbers in calculations.
- **Growth of efficiency and effectiveness for small-scale manufacturing plants in the healthcare sector:** There is a growth in manufacturing in the healthcare sector. In turn, there is a need for efficiency and effectiveness in manufacturing. The evaluation in this research helps the decision-makers in making informed decisions on the factors they must work towards in each manufacturing plant.

6 Conclusion and Future Scope

The aim of the current research was to evaluate the manufacturing operations of a healthcare supply chain. The evaluation of the healthcare operations is done based on the implementation of a lean-green strategy in the manufacturing plants of healthcare equipment. The lean-green strategy is used to improve the operations. Since lean focuses on removing non-value-adding activities and green focuses on manufacturing which is more environmentally friendly, it may be considered to be conflicting in nature. To ensure the evaluation of the quality of implementation of lean-green strategy in the manufacturing of the healthcare sector. In this research, the aim was to evaluate the small-scale manufacturing plants of a firm on the basis of the implementation of integrated lean-green strategies. The MCDM methodology F-TOPSIS has been used for the evaluation of the manufacturing plants based on the conflicting criteria. The fuzzy nature of the MCDM is considered to incorporate the subjectivity of the decision-making. The research is current, given the concentration on high-quality production of medical equipment and accessories in the pandemic. The pandemic had forced certain companies to change their line of production and those already in the field to scale up the level of quality attainable while production. The future scope of this research is to develop a mathematical model to obtain a trade-off between the quality levels achievable due to the lean-green strategy and the cost involved in the process. Moreover, other MCDM techniques could be used which would try and analyze the relationship between the cause factors and the effect factors on the implementation of the integrated strategies. This has not been done for small-scale firms in developing countries, thus it will provide a tool for decision making. Further, there could be consideration of analyzing the implementation and assessing the process improvement in healthcare manufacturing.

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Impact of Policy Change on Sustainability Initiatives by Indian Firms

Nagarajan Chandrasekaran and M. Ramasubramaniam

Abstract Traditionally, sustainability was referred to as the steady growth of a firm in sales, market share, and profit over a long period. This paper presents a novel conceptual framework that can be used to classify a firm's operations strategic initiatives by blending its Corporate Social Responsibility (CSR) initiatives of a firm and its adoption of ethical standards to classify a firm's operations strategic initiatives. Further, through illustration of a CSR spend analysis for an Indian firm, the paper discusses how a firm can strategically position its sustainability spend for achieving competitive advantage.

1 Introduction

'Sustainability' has become a buzz word in an environmental context for all businesses. The former Norwegian Prime Minister Gro Harlem Brundtland in 1987 first highlighted the word 'sustainability' in a United Nations report (WCED, 1987). Brundtland defined sustainable development as '*meeting the needs of the present without compromising future generations' ability to meet their own needs. This relates to the sustainabilityof the environment, resources of all kinds, social and cultural systems, as well as economic development*.' Before this, in the business world, sustainability was always referred to as the steady growth of a firm in terms of profit, market share, and shareholder value.

Sustainability meant consistent performance and survival of the organization in the long run (Luo, 2005; Sekhon & Kathuria, 2019). This would mean that a firm must ensure a sustainable supply of resources to match market demand and challenges. In

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contemporary business, corporate refers to sustainability that is used to describe CSR works related to protecting the environment. This includes planting trees, restoration of lakes and ponds, and initiatives to reduce carbon footprint.

This has led to several discussions on CSR spend. In India, since April 1, 2014, based on amend in The Companies Act, 2013, the companies are mandated to provide at least two percent of three years' average profit toward CSR (Gopalan & Kamalnath, 2014). This is, however, seen as corporate philanthropy. One may note that imbibing the value of sustainability is mainly through Safety, Health, and Environment (SHE) initiatives. Again, the Government has made stringent laws to enact the same. Global operations and business strategy have also mandated the adoption of Responsible procurement and ethical supply chain practices (Cousins et al., 2019). This includes focusing on product/component/material recovery, recycling and reuse, low emission, and carbon footprint. The companies have started disclosing through social accounting policies, both CSR initiatives as well as sustainability initiatives.

We will address sustainability from two perspectives. First, at a firm level, how operations strategy can contribute to the sustainability of the environment, resources of all kinds, social and cultural systems, and economic development. This is highly related to the definition given by Brundtland. Second, we will discuss a case study on how policy change has impacted the CSR spend and relate to a public company's CSR spend.

2 Conceptual Framework

Some of the theories and frameworks have been discussed in various academic works. Some of them include 'Responsible Procurement,' 'Ethical Supply Chain,' 'Ethical operations and production management,' and 'Approach to managing through the triple bottom line,' to mention a few. Most of the business excellence framework like the Malcolm Baldridge award and the European Foundation of Quality Management has also given a framework for capturing a business and its sustainability conditions.

Ethical supply refers to providing goods and services to the ultimate customers of a focal firm so that all constituents of the supply network practice 'ethical behavior' in decision-making toward the product/service. The ethical supply chain encompasses all players among the nodes and flows of the supply network. For a firm it would be from designing the product, sourcing of materials and components, manufacture, distribution, and post-sale service. The objective of Environmentally-Conscious Supply Chain Management (ECSCM) is to consider the *total immediate and eventual environmentaleffects* of all products and processes to protect the natural environment.[1]

Beamon (2005) mentions that the questions arise when applying engineering ethics to environmentally conscious supply chain management and design. Such dilemmas would include 1. Ethical considerations in design element and management decisions; 2. Levels at which decisions are taken that are operating, tactical and strategic; and 3. Potential conflicts that may arise due to design features.

Fig. 1 Stages of ethical responsibility

According to Worrell and Appleby (2000), ECSCM is '*the responsible use of natural resources in a way that takes full and balanced account of the interests of society, future generations, and other species, as well as private needs, and accepts significant answerability to society.*'[3] This is a broad definition encompassing the future needs of the generation, the need for the current business and stakeholders to be conscious about the future while making the current decisions. This could be a tall demand as many firms cannot assess the future generation, which may take very long period to happen. Unless public administrators, researchers, and policymakers guide corporate decision-makers toward the same, '*sustainabilityfocus*' in this context is unlikely to happen easily.

On levels of ethical responsibility, Beamon (2005) mentions the commonly used levels as follows (Fig. 1):

However, this is applicable for any professional standards as well as corporate firms. The levels can be further elaborated more concerning the competitive advantage it can gain in the market. One may argue whether such a focus is required while discussing a sustainability perspective for firms. It may be important because firms are fundamentally established for profit-making as they pursue risks, and they make decisions on the near-term future of any investment. Though firms would like to be in the market for eternity, their decisions keep changing based on changing conditions. From that perspective, the levels of ethical responsibility can be classified.

It may be broadly at four levels instead of the three discussed above. They are as follows:

a. The threshold level of ethical standards: Firms may have to necessarily follow what is required by the law in the geography wherever they are operating. A local firm producing and selling in a local market, say, district or a state in a federal system may be concerned with laws pertaining ethical responsibility only within the market it operates. This category of firms could be doing what is required as per standard operating procedures and secure documentation from the respective authorities. The problem arises when a firm fails to fulfill the requirement. It can get into legal entanglement and face closure as well. In India, there had been a few cases. One of the most recent cases widely discussed in media was a copper smelter plant at Tuticorin. In this case, the conflict arose to the extent that the court had to pass a judgment ordering closure of the plant. Though one may have to check the recourse available to the plant, it is better to avoid such conflicts on legality and social requirement while following ethical business standards.

A few firms are still possible when they are into the international business that can operate at a threshold level of fulfilling the local requirement and the geography in which they are operating. This is possible only those with high bargaining power and competitive strength and yet operate at the threshold level. However, such corporate behavioral traits are unlikely to have extended competitive sustenance.

Superior in class level of ethical standards: These are firms in the industry who demonstrate ethical consciousness supply chain responsibility of higher standards than the threshold requirement as per the regulations. Such a firm's strategy helps in winning stakeholders' support in business and helps them have some distinctive or unique competitive advantage. There is a likelihood that such an approach also provides long-term economic gains for the firm and help them realize a higher supply chain profit. For example, in Chennai, an automotive car manufacturing company, when it started plant construction, the locals expressed concerns over many aspects, including the likely impact on the environment in and around the plant. This included the quality of air and water. The firm that went ahead did an exemplary work with the immediate society on improving water bodies, strengthening water resources, and extensive campaigns to clear myths about the locals' fear. It generated programs to help locals pursue employability by harnessing their skills, which was not necessarily toward employment in its plant. As a stakeholder, the locals appreciated the ethical standpoint the company had taken and gone beyond the threshold requirement in engaging with the local community. It has cost the firm resources, but it has won many, including its suppliers and customers. This is what is termed as superior in class level of ethical standards, though it was focused on ensuring firm investment and growth. This encouraged many other multinationals and domestic firms in that industrial corridor to pursue such an approach.

b. ***Best in class in the market level of ethical standards***: These are firms in the industry who demonstrate the highest standards' ethical consciousness than the threshold requirement as per the industry's regulations and practice. In this class, select firms go beyond to set a high corporate standard toward their commitment to the environment and society. This is more akin to self-actualization stage of individual professionals who set a champion status for inspiring others. These companies may be doing well in their industry, and the stock market must be giving good valuation. The fact that it has reached the pinnacle of performance and corporate sustenance from the economic profit perspective, these firms have gone with exceptional practices through their CSR trusts. Such a demonstration of involvement by these firms had been there even before the legislation was brought on mandatory CSR spend and disclosures. It is interesting to understand the drivers of these firms' ethical consciousness practices toward society and the environment.

(Fernandes, 2020) study on Top 20 companies in Indian CSR spend in 2019 reveals that a large share of CSR funding is deployed for managing the impact of

COVID-19. According to a study conducted by Futurescape, Tata Chemicals Ltd. ranked the number one company for Sustainability and CSR practice in Responsible Business Ranking 2019. This company has achieved this consecutively for the third year. One may note that such firms are well respected among society's stakeholders, including retail investors, the employment market, and the immediate community through brand recognition. It is pertinent to mention that the firms' ethical standard is not motivated by such stakeholders' views, but the corollary is true as a matter of recognition. Hence, such firms are the best in class.

World-class level of Ethical Standards: While following ethical standards in supply chain management and business, certain firms may have an exemplary practice that is a strategic asset for these firms. Others may not be able to imitate for a considerable period of the term. Why and how such practice is established in these firms? Clearly, why part can be answered because these firms have core values and beliefs in ethical standards toward society and built it. Though the business could be profitable and contribute to society, the ethical standards are far more ingrained in philosophy and approach toward the business. For example, Anand Milk Producers Cooperative Union Ltd (AMUL) in Gujarat, India, was established as a cooperative firm with the complete value and belief of fairness and openness toward dairy farmers in transactions like product quality, quality-based pricing, quick payment of product price and extension support (Makwana, 2017). All these are like normal business transactions toward generating an economic surplus. How can one call the same as World-class ethical standards? It is because the firm sets the standard as a differentiator. They served farmers through complete linkages of dairy farming activities, empowering women mainly involved in dairy farming and educated society and milk consumers about the appropriate milk distribution system. This led to the formation of the dairy development board and international funding support to evolve the Indian dairy sector. Such practices helped millions of dairy farmers across India and consumers of milk and other dairy practices in India. It has now established a new norm in the industry and others in similar agriculture and allied activities-based industries to follow. Further, the business itself arose from the industry's lack of ethical standards and required a strong-willed initiative to recreate the industry structure. Hence, AMUL's ethical standards are World-class, which would inspire other firms across the industry to absorb the same. When it came to Jewelry retailing, a TATA group company clearly established ethical standards by testing the quality of gold and gave customers the option to check gold even if it is not bought from the brand. This requires an extraordinary commitment to value and belief in ethics and putting customer value ahead of its profitability. Table 1 summarizes the ethical standards level that is adopted by firms.

Table 1 Classification of ethical standards adopted by firms

Level	Brief description
Threshold level	Adhering to the law of the geography in which the firm operates
Superior in class	Demonstrate ethical consciousness supply chain responsibility of higher standards. Values and beliefs as a differentiator to stakeholders which wins the support
Best in class	Go beyond to set a high corporate standard toward their commitment to the environment and society. Not limited to the geography and industry provide exceptional support
World-class	Unique firms where object business arises from high ethical standards chosen by the firms

3 Methodology

The methodology adopted for this paper included shortlisting the appropriate keywords for review in this article. During our discussion, we came up with the following keywords: 'Corporate Social Responsibility', 'Ethical Supply Chain Management'. We searched the google scholar and scopus database. After the first set of search results we used the keywords 'operations strategy' to finalize the results. We present the process in a schematic diagram in Fig. 2.

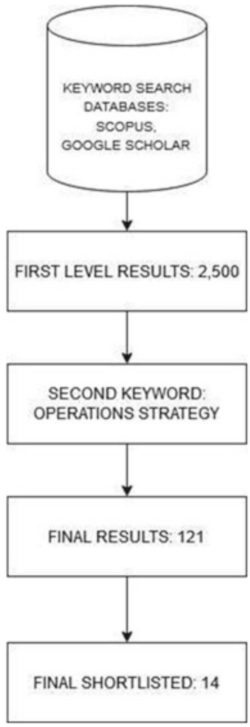
The search process resulted in 121 articles. But most of these articles were not close to our topic of the paper. In the end, we shortlisted 14 articles. The conceptual framework discussed here is based on the understanding and analysis of the same. Further, we looked at the secondary data on CSR spend in India and have analyzed the same. A short case analysis using the public information on a company is considered for completing the discussion.

4 A CSR-ESCM Framework

A framework has been suggested incorporating the above description of Ethical Consciousness Supply Chain Management (ECSCM) levels toward Corporate Social Responsibility (CSR). (Cousins et al., 2019) categorizes CSR into four groups, namely:

- Economic responsibilities fulfilling market forces.
- Legal responsibilities fulfilling the legal requirement.
- Ethical responsibilities being morally consistent. Though the law may not be mandating the same, the beliefs of society drives the same.
- Humanitarian responsibilities by engaging in activities beyond charter of law and expectation of stakeholders.

Fig. 2 Literature search process



The difference in grouping which is being recommended is that contextualizing to industry and competition as sustainability initiatives are followed or forced to be followed as new norms arise. However, firms in the industry who are visionary in their social and environmental commitment go beyond the industry and market in which it operates.

4.1 Firm's Operations Strategy and Sustainability

Operations strategy is an area of study and a professional engagement wherein there are opportunities and challenges to build a firm. Any firm that has transcended over years of competition and sustained in the market would have certainly built competence and demonstrated excellence through operations strategy. Firms' strategic initiatives around the business environment would impact its long-term growth. Discussions in this section are focused on strategic initiatives in operations toward the conversion of inputs into outputs (Fig. 3).

Broadly, firms focus on sustainability, and strategic operations dimensions are as shown in Fig. 3.

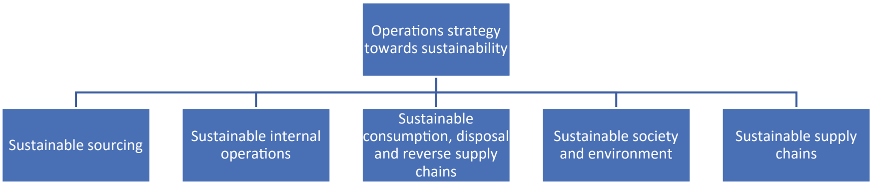


Fig. 3 Operations strategy and sustainability

4.2 Sustainable Sourcing

Ethical Supply Management (ESM) is a business practice that enables firms to manage their suppliers and supply relationships through different strategic initiatives and vendor relationship plans. Such plans are to be managed by aligning business conduct with procurement standards. The main objective is to synchronize supplier conduct with buyer's standards in three major corporate integrity areas: ethics, corporate responsibility, and compliance.

As part of their global operations strategy, many leading global brands outsource products being manufactured from emerging economies. They have a network of external suppliers for products. Some of the assembly plants procure components from suppliers of emerging and developing economies. Most buying firms have implemented standard operating procedures to be followed with the degree of ethics and need to maintain compliance documents. They have ensured that suppliers are trained. This has been across their supply network. Such training on ethical standards is important from risk management as any failure could affect these companies' financial health, firms' reputation and their customers loyalty.

Government regulations, focal firms, and supply networks, including the consumers, have driven supplier management ethics. The changes include stronger foreign trade standards, rules relating to safety of products, packaging, and labeling. These have assumed much attention post terror attacks and proliferation of technology on track and trace. An apparel brand producer has implemented track and trace right from the source of procurement of cotton from the agricultural land. Such tracking helps to know the level of sustainability initiatives in the land the crop is grown.

Some of the commonly followed processes include the following:

- Supplier selection process document must detail ethics and compliance requirements
- Create and maintain profiles of qualified sellers with such ethical standards
- Assign ethics and compliance training and support initiatives to major suppliers
- Conduct regular supplier audits of covering ethical standards which are being documented
- Evaluate supplier ethics performance regularly and share it with them.

Some of the commonly observed issues are.

(a) *Plant related*: indiscriminately polluting air, water bodies, and land and poor safety standards
(b) *Employee related*: poor labor standards, poor wage rate, and working conditions and employment of child labor
(c) *Community and environmental*: Poor relationship with the immediate community; impact on rights of tribes, community, and socially disadvantaged people and Environmental issues like the destruction of forests, flora, and fauna, and water bodies.

Hence, sourcing sustainability is a key competitive factor in the period ahead and must for those who serve developed markets.

4.3 Sustainable Internal Operations

Sustainability in product design will consider efficient manufacture by reducing or minimizing waste; efficient tracking and tracing of all components and material used and ensure that they have followed appropriate mechanism, ease of remanufacturing by reusing/recycling the material, and ease of disposal without pollution where the product needs such careful disposition.

Further, one can achieve sustainability in the process, including lean management, small teams for kaizen, employee health and safety, no child labor, strict adherence to The Factories Act, and going beyond conserve resources. The plants must also engage with the local environment to dispel any fear of the discharge of pollutions and degradation of natural resources, including the water bodies around. Wherever possible, it may be a good idea to encourage visits by the plant stakeholders and see the internal production process safely to satisfy themselves of ethical standards followed by the firm. AMUL, the leading milk producers, used to have a time window for such visits.

4.4 Sustainable Consumption, Disposal, and Reverse Supply Chain

Firms produce and market products and services as there are ultimate customers. It is a demand which drives production. In operations planning, one would start discussing the Sales and Operations Plan for the tactical period and long-term strategies. It is always based on projected demand. While consuming the product or service, the firm must ensure sustainability with respect to consumer behavior in terms of how they use the product and how they dispose of the product after use. Customer awareness needs to be provided on product use and disposal. Certain products like processed food, pharmaceuticals, and industrial machinery, and in services like banking, finance and insurance, hospitality and healthcare, and customer education are of paramount importance.

Linked to the above is the reverse supply chain. If any firm is required by regulation or due to economic sense, it may have to engage the appropriate reverse flow of components and material.

The reverse supply chain is focused on recovering used products. Such products or components may be recycles, remanufactured and / or properly disposed if both are not possible. This has been common in certain industries like paper and pulp manufacture using recycled paper, metal scarp, especially secondary steel and other metals, beverages, and beer bottles. Certain industries have been mandatory, like in the case of automotive and power back up batteries. In some industries, reverse flow is a good practice yet to be mandated in a country like India. This includes a computer, home electronics, and CPG industry, to name a few. Some of the conditions that favor reverse flow are as follows:

1. Government and international trade bodies Regulation related to the disposal
2. Possibility to gain value from the used components and products as in the case of consumer electronics, consumer durable goods, home appliances, and computers.
3. Prospect of remanufacturing returned-products and reach out secondary markets
4. Showcase as an environment-friendly firm which goes well with the different stakeholders.

The logistics industry has opportunities and challenges on sustainability in business, especially reverse material handling equipment, as mandated by law like the use of returnable crates. Such processes are difficult in Indian retail and other businesses.

4.5 Sustainable Society and Environment

The social and community sustainability of a firm is done by engaging with the local community and employees. It is not an employee's welfare at work-station but providing good housing, access to good water, a healthy environment, schooling, and healthcare. Most of these can be enhanced through Corporate Social Responsibility (CSR) activities. Such activities make the firm seen more favorably in treating sustainability. That strategy also creates synergy and harmony between the firm and its environment, the immediate community, and nature. As part of the operations strategy, firms must choose to do. The public sector companies in India have been doing this since their promotion from 1956. The effects were seen in the 1970s. Similarly, large corporate groups like Tatas, Birlas, Reliance, ITC, Hinduja Group, Goenka's, TVS group, Shriram Group, Essar, Eicher, new generation one's like Adoni group, Bharati Enterprises, and Technology companies like Infosys, Wipro, and HCL to name a few.

4.6 Sustainable Supply Network

A supply network firms strategically connected in storing and moving goods/services across a focal firm's network toward fulfilling its ultimate customer demand. This involves a few nodes and flows wherein a node the product stays, and while on flow, it moves to the next stage. In these supplier engagement processes, internal supply chain, and customer relations, it engages in warehouse operations and transportation. Both are generally outsourced in a contemporary large business. Hence such operations need to follow a sustainability approach toward the focal firm business. For example, a fire accident in an outsourced partner engagement wherein several workers died affected a leading apparel firm's brand.

Transportation is the largest energy consumer in the supply chain. Incidentally, it contributes to air pollution and noise pollution in the supply chain. There are also possibilities of adhering to ethical standards in transportation because of overloading, bribing, and unauthorized trips. There could also be issues concerning labor and remuneration disbursement in this segment as they are likely to be over engaged to maximize trip-based returns.

Road freight transport vehicles share roads and highways with other road traffic, including passenger movements like cyclists and other passenger automotive vehicles and pedestrians. The risk of being involved in accidents is higher than rail or water transport in India. The issue sustainability comes when such accidents happen because of non-adherence to vehicle maintenance standards, aligning with transport rules, and unruly behavioral aspects like drunken drive. With the better application of technology, track, tracing, and educating stakeholders, truck drivers are likely to improve ethical behavior standards.

According to industry experts, it is estimated that about 15% of all supply chain emissions stem from logistics buildings. The activities like inside warehouse movements of material handling equipment, temperature control equipment, and lighting are the major contributors. A further inefficient warehouse also leads to a poor turnaround of trucks for loading and unloading the goods. Despite management initiatives like 'just-in-time' and other inventory reductions in the modern supply chain, warehouses are required in the supply chain because of demand and supply variations, need to fill through intermediary operation even for JIT and several value-added activities like kitting and packing, order sizing, maintenance, oiling, and maintenance. The environmental effect of warehousing consists of two levels: the emission from the warehouse's construction and the operational emission.

The most widely practiced popular standards for assessing warehouse design sustainability are the Leadership in Energy and Environmental Design (LEED) framework from the US green building council, and the Building Research Establishment Environmental Assessment Method (BREEAM) from the Building Research Establishment (BRE) based in the UK. LEED suggests the following weighted factors for warehouse sustainability:

- Water Efficiency
- Material and resources

- Indoor environmental quality
- Sustainable sites
- Energy and atmosphere

As part of the operations strategy, the focal firm across the supply network must insist its partners to authenticate the adoption of sustainable activities as prescribed by any certification assessors can be implemented by warehouses to reduce emissions.

Thus, one may observe the sustainability approach in its production system through the effective deployment of the operations strategy. The same must be monitored and consistently reported at the board level using a balanced scorecard.

4.7 Sustainability and Role Agents

Though in the above section, the role of a focal firm and its constituents in the supply network is clearly visible toward sustainability practice, the responsibility at which level, namely to the level of threshold to the world-class practice, is something the focal firms in production system must define. Responsibility for maintaining sustainability is collectively orchestrated by the focal firm. The risk of failure to fulfill the same is spread across, though the impact will be on the focal firm, the incidence will be distributed. The reward for achieving sustainability would vary to the level of adoption from threshold to world-class. While those who adopt the mandatorily required threshold requirement level may earn only normal profits, the others on the hierarchy level of adoption may earn premium returns as reflected in profitability or stock returns for the listed companies.

Apart from the firm-level driver of sustainability, one may note that government policy-level changes drive sustainability initiatives that could impact the production system. Whether such spend impacts/support the production system directly or indirectly is another question. If one considers CSR expenditure mandated in India since 2014, one may argue that firms spend 2% of their three years' average profits toward CSR, and hence, it is profitability that was realized out of the production system. The other way of looking at it is that good CSR spending encouraged the production system to manufacture and distribute efficiently. Hence, CSR spending supports future growth and profitability. Determinants of this relation are kept outside this study for our future research. It is pertinent to note here that the Government policy change toward CSR impacts the Indian corporate sustainability initiatives, and we provide an overview of the same.

5 CSR Spend in India

There is a strong linkage of CSR activities with sustainable development of the society and environment. The concept of sustainable development hinges on protecting the environment and a country's natural resources, which is of paramount importance. One may also note that the United Nations' Millennium Development Goals[9] (MDGs) and the WEHAB (Water, Energy, Health, Agriculture, and Biodiversity) agenda of the UN Secretary-General are key essentials for bringing about a solution to the fundamental problems facing society. Consequently, if corporate actions are to target the more significant issues facing society in developing countries, then the MDGs components are the focus areas of spend.

It is important to understand where big corporations should be spending their CSR resources. There are three streams of value drivers, related purpose, and intended impact, as shown in Table 2.

If one looks at the above Table 2, CSR philosophy as philanthropy is a more passive approach toward linking CSR and business strategy. It contributes to the larger society through donations and contributions for public policy initiatives where

Table 2 CSR value drivers and benefits

Value	Purpose	Impact	Benefits and limitations
CSR as corporate philanthropy	To provide fund and skill development	strategic and operational impact likely to be limited	• Short-term benefits, if at all any • Impact diluted because spread across charities • Competencies and assets are not likely to be used effectively • Alignment between business and social responsibility strategies and functions is likely to be limited
CSR as risk mitigation/management	Compliance	Strategic and operational impact is likely to be medium to high	• Mitigates operational risk • Supports external relationships
CSR as value creation	Innovative and promotes a sustainable business model	Oriented toward strategic and operational impact	• Shared values among all stakeholders, from investors to a large community • Promotes sustainable business model • Develops human capital through CSR • Aligned with business strategy

Source A handbook on Corporate Social Responsibility, Institute of Directors, 2017

Government and other Development Financial Institutions, along with NGOs, would be participating. This requires minimal managerial efforts, and the board committee's monitoring of CSR may not be that challenging.

The second philosophy discussed here that of CSR as 'risk mitigation or management.' The purpose could be for compliance as per the law. And approach could align compliance with the immediate addressable concern of operations within the ambit of the law. For example, a company built a large warehouse in a village close to a metropolitan city to serve the market. It was a huge facility and expected to operate on a day more than 300 inbound and outbound trucks. It must pass through dwellings of the village. It was a concern to villagers on the safety of children and women living there. The company was legally not bound to spend on fulfilling the village's requirement as it was approved by regulators to build a warehouse in the specified location. It created employment and supported small businesses like food eatery and related companies. However, the CSR committee decided to invest in relaying the road in the village along with the local Government, provide better lighting, toilets, and conduct regular health camps. This was received by the villagers and supported the initiatives. Hence, this approach was based on the requirement to spend the money as per the law, and at the same, it was spent in a location where it reduced operational risks.

The third philosophy could be to involving CSR as 'value creative activities.' Such philosophy drives innovative approaches in designing programs and facilitate a sustainable model. The approach is based on fundamental strategic orientation toward the business and, at the same time, contributes to society fulfilling spend from CSR funds. The committee must carefully ensure that the CSR spend is not deployed toward the business's routine operations as it may not qualify for the same. CSR can promote competitiveness and innovation if the company carefully chooses CSR strategy deployment of the fund so it qualifies by the law as CSR expenditure. It builds the company's brand image. For example, a company that uses natural resources like forestry or land may be required by law to spend a certain amount of money on the business's reciprocity. This may a pulp manufacturing plant using natural forest vegetation and does replantation as part of business strategy. While doing so, the company may invest in other social aspects of the community there like for Education, eradication of poverty, and healthcare, which would impress upon the company's intentions to be closely working on the welfare of the community and thereby cooperate for business strategy. This can be practiced by many industries, especially those who use natural resources like mining of metals and minerals, manufacture of cement and derivatives of petroleum products, etc. This may relevant in individual service businesses like operations of a port where they may intrude into fisherman livelihood because of growth in port operations. This is one of the best value creators of CSR spend, and it could be difficult for all companies to catapult on this. It demands the board's commitment, CSR committee and top management, and operating resources who implement CSR projects. The amount of managerial resources required for this is high and needs to be committed over the long term. Such a requirement is possible only for large and consistently profit-generating companies.

The above is also supported by The Porter and Kramer framework (2006), which illustrates a strategic approach toward CSR initiatives. Table 3 captures the same.

Table 3 The Porter and Kramer framework (2006) on CSR

Generic social issues	Value chain social impacts	Social dimensions of competitive context
Social issues and a company's operations could be decoupled. CSR activities will not materially affect its long-term competitiveness	Issues could be relevant as a company's activities in the ordinary course of business may affect the society	Social issues in the external environment significantly affect the underlying drivers of a company's competitiveness in the locations where it operates
Good citizenship	Reduce or do away with activities that hurt society from the value chain activities	Strategic focus on capabilities that improve salient areas of competitive context especially with those that interface with society and business
Responsive CSR	Focus on value chain activities toward benefit of the society while reinforcing strategy	Strategic CSR

Source IICA publications, New Delhi

It may be seen above that the strategic approach choices from being responsive CSR to transformational and, finally, strategic CSR. It is not that a company would graduate, starting from responsive to being strategic over the years. The approach depends upon the Board, type of business, size, location, and many other factors. Analysis of choices is beyond the scope of this paper but merit a research study that would help firms to evaluate the choice of an approach. However, to strengthen discussions here, stakeholder power and interest grid influence in CSR approach.

One may look at the CSR spend by the Indian companies across the development sector as per the approved guidelines. It may require a detailed study on the impact of these spending and their changing pattern. The question to be addressed is would the development agenda need such a changing trend? However, that is beyond the scope of this paper.

It may be seen from Table 4 that education, livelihood, health, poverty alleviation, and sanitation take about nearly 35 per cent of the total spend. Clearly, the companies are keen spend on building future of quality of human resource. It is mainly important from the fact that India has high youth quotient.

When one looks at the distribution of companies across various range of amount spent, it can be observed from Table 5 that nearly 80% of companies are spending less than 1 crore on CSR activities. This could be natural that the average profit earned may be lower and hence the amount spent. This will to the next possible question whether everyone qualified to spend is incurring expenditure on CSR budget and to the extent required.

This helps us to draw an inference that large amount spend is happening in many small size public utility projects undertaken by the firms. These firms align with their operational goals. We also found from our discussions with the experts that those spend high ticket amount distribute across social projects in different regions

Table 4 Development sector-wise spend on CSR by companies in India

S No	Development sector	2014–15	2015–16	2016–17	2017–18
1	Education, Differently Abled, Livelihood	3188.09	4942.55	5554.66	5768.54
2	Health, Eradicating Hunger, Poverty And Malnutrition, Safe Drinking Water , Sanitation	2525.92	4607.51	3640.19	2664.88
3	Rural Development	1059.34	1379.08	1554.79	1477.33
4	Environment, Animal Welfare, Conservation of Resources	854	971.08	1317.65	1361.1
5	Gender Equality , Women Empowerment , Old Age Homes , Reducing Inequalities	189.92	342.46	463.49	460.28
6	Heritage Art And Culture	117.37	119.08	304.42	283.81
7	Encouraging Sports	57.62	140.11	180.35	227.58
8	Swachh Bharat Kosh	113.86	325.52	184.07	213.79
9	Prime Minister's National Relief Fund	228.18	217.23	157.58	158.23
10	All others	1731.63	1472.75	802.04	359.94
	Grand Total (in Cr.)	10065.93	14517.37	14329.78	13623.62

Source https://www.csr.gov.in/developmentlist.php. Accessed on February 19, 2020

Table 5 Distribution of companies by CSR spend over different ranges

Year	0–50 L	50 L–1 cr	1 Cr–10 cr	10 cr–100 cr	100–500 cr	Above 500 cr	Total
2014–15	4282	4779	842	145	16	1	10,065
2015–16	6743	6483	1090	175	24	1	14,516
2016–17	7471	5287	1368	180	20	2	14,328
2017–18	6372	5758	1292	184	16	1	13,623

Source https://www.csr.gov.in Accessed on September 19, 2020

which deserves such help. However, according to our understanding the spend that may be required need to be analyzed relating the development fund requirement and corporate contribution along with the government and multilateral agencies. The role corporate in such projects could be bring more accountability to project initiatives and alignment of spend.

6 Case Study: Neyveli Lignite Corporation (NLC)—CSR Spend Analysis

NLC India Limited which is under the Ministry of Coal is categorized as a Navratna Company. It was established in 1956 as part of industrialization pursued during the second five-year plan by Jawahar Lal Nehru Government under the socialistic pattern of investment. Thus, it has a history of over 60 years. Its Present Mining Capacity is 30.6 MTPA (Lignite). The main activity of NLC India is Mining (Coal and Lignite) and Power Generation (Thermal and Renewable Energy). There are four open cast lignite mines, namely Mine I, Mine II, Mine IA, and Barsingsar Mine. It may be noted that open cast mining will have an impact on the immediate society. However, economic benefits are phenomenal as it generates employment, electricity, and fuel for small plants. Thus, direct and indirect benefits and costs are associated with the project.

The lignite mined out is used as fuel to the linked Pit head power stations. The company has five power stations at the pithead aggregating to 3240 MW. It has also footprint in wind power as it has installed 32 wind turbines. There are 34 turbines of each 1.5 mw capacity. It has commissioned 440 MW Solar Photo Voltaic Power plant in Neyveli. Thus, the overall power generation capacity is 3731 MW (excl. JVs). Also, raw lignite is being sold to small scale industries to use it as fuel in their production activities. Since it has mineral resources, namely lignite, it comes under the Ministry of Coal, and electricity generated using the same is being shared some southern states as it is a central government project. Tamil Nadu gets an allocation of 47.4% of the power generated by NLC, while other southern states and Puducherry got smaller amounts. Now the company is listed in the stock exchange.

One would expect that NLC spends its CSR budget in the local area as it would impact the immediate society through pollution; it may generate as well as potential ecological degradation. The other argument could be that other state consumers also buy power and hence expect CSR benefits. The company could spend locally as well as on Pan India.

As per the company published sources, the thematic areas where CSR activities are involved include.

1. Eradication of Hunger, Poverty, Malnutrition
2. Preventive Healthcare, Water, and Sanitation
3. Education, employability, and livelihood enhancement
4. Gender equality and women empowerment, Senior citizens care
5. Environmental sustainability
6. Heritage conservation, Promoting Art, craft and culture, Public libraries
7. Promoting national and rural sports, Paralympic, Olympic sports
8. Rural development

Table 6 shows CSR spend by NLC over five years.

It may be observed that the company's CSR spend is more than required as per the The Company Law. Especially in the year 2015–16, the company has spent almost

Table 6 CSR spend by Neyveli Lignite Corporation Ltd.

Year	2014–15	2015–16	2016–17	2017–18	2018–19
Average net profit	2,080.22	2213.37	2,172.77	1,865.87	2258.5
CSR prescribed Expenditure	41.60	44.27	43.46	37.32	45.17
CSR spent	47.49	81.93	37.18	43.58	49.46
Local area spent	47.49	0	37.18	0	

Source https://csrbox.org/India_Company_NLC-India-Limited.-Tamil-Nadu_5690

80% more than the requirement. This shows that the company has proactively spent money using the provisions in the law.

One may note that NLC has spent directly and through partners in Tamil Nadu (local area) and Pan India for creating social good. There was a pattern of alternating between regional and local spend along with Pan India spend over the years.

By looking at the spending pattern and the projects, NLC has done responsive CSR, which may not be directly relating to business to value-creating CSR by impacting spend in the local area of business, namely the district in which it is located. By and large, NLC has substantial spend to impact social causes of the district in which located and across other states. Education, healthcare, and rural development have got the majority of share over the years. One may not be able to arrive at its relevance with the available data but certainly shows that such initiatives are more of responsive CSR rather than Strategic CSR. Moreover, even before this enactment came in to rule, NLC has initiated many socio-economic investments in developing the Neyveli Township and further in the nearby towns. The Act has helped to streamline spend and do reporting in the prescribed format. Further, the listing of the company in the stock exchange has necessitated more formal management of projects and reporting.

7 Conclusion

Sustainability initiatives by the firms by leveraging their operations strategy is an essential part of corporate planning and growth. Sustainability was originally confined to perpetual growth in sales, market share, and profits. However, since the 1980s, firms have started focusing on sustainability from the environment and protecting future generations' resources. Increasingly corporates have sought to include this in their operations strategy. In this paper, there have been discussions on how firms' operations strategy focuses on sustainability initiatives. Such focus is right from the product design stage, material and component build, production processes, distribution activities like managing distribution centeres, packaging, and transportation. Firms have been managing reverse flows and engage their supply chain networks toward sustainability initiatives. The scope of sustainability now extends to the supply network.

Government regulation and directives also guide sustainability initiatives in operations. More importantly, the policy changes like the mandatory CSR spend required the need to be aligned with the overall development agenda. Corporate social responsibility has been practiced selectively by the Indian firms. Mainly large corporate houses and business groups have started practicing the same. The introduction of CSR law has brought in better alignment with the development agenda and improved sustainability initiatives' overall awareness.

Firms can strategize sustainability spend and use it for positioning among the competition. These firms can use the proposed CSR-ESCM framework which is geared toward the same. While a few firms may follow a threshold requirement to meet basic competitive conditions, firms may practice more than what is mandated or trend in the industry. Such firms view sustainability initiatives as a competitive differentiator. Stakeholders in the market also recognize the same either through loyalty or higher valuation of the stock or both. We further discuss the trends in CSR spend in India and show how a few firms spend more than required as per the statute. A case analysis of Neyveli Lignite Corporation, which is a government company, has been done. It is inferred that this company has spent more than what the required and has been spending across geography on the development agenda.

The paper opens-up different research directions. The study is currently limited to a conceptual framework. Future studies may take this for empirical testing. Also, it may be difficult to generalize the conclusion from the case study to other firms. Thus, one may study the influence from other companies' perspective. In addition, our study is limited to addressing operations strategy from a high-level perspective. It will be of interest to study the influence of short-term and medium-term operational decisions on the long-term sustainability initiatives.

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Trade Prediction Outcomes During Pandemic and Its Impact in Lean Implementation

L. Aravindh Kumaran, P. Anand Inigo, and P. Chandiran

Abstract Majority of the manufacturing and service sectors are enjoying improvement in operational efficiency through Implementation of lean tools in its operations. Operation of these sectors is depending on its supply chain efficiency, which was identified as one of the enablers for lean implementation using various tools in both sectors. Supply chain of most of the industry is becoming complex due to the uncertainty in few of their inputs, like import/export trade variation as a result of pandemic. At present, the pandemic is having an impact in most countries, the containment in trade regions is not removed completely and the trading of goods is affected due to the prolonging lockdown periods. This research is aimed to comprehend variation of the foreign trade in India during pandemic crisis and its impact in lean implementation practices in organization. Trade data collection was done through reliable government sources and the prediction model analysis was done to predict the variation in trade. The research is conducted to measure the variation in international trade using prediction model for few major commodities. This predicted trade variation, and its impact in manufacturing sector is identified as the variation in input resources and restriction of worker movement due to containment. These identified trade prediction outcomes and its impact in few lean implementation practices of manufacturing organizations was discussed. The effectiveness of the few lean implementation practices and disruption in the related process flow, could increase the cost, different manufacturing wastes and cycle time of the manufacturing process. The findings of this research are to give insights and thoughts to the traders that could result in effective and successful trading during crisis times. The prediction of commodities as input resources have resulted into low, medium and high impact on various lean implementation tools.

Keywords Lean implementation · Pandemic · Trade · Prediction model · Import · Export

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1 Introduction

The global economy has seen a subdued growth since 2008 and started showing sign of recovery in 2017. The IMF in 2017 projected that the global GDP might grow from 3.2 to 3.6% and a further of 100 basis points in the next year (IMF report, 2017). Global supply chain has prospered throughout the years because of the numerous advantages it has offered to different nations over the globe (Barry, 2004). Global trading of services, goods and capital among different nations and geographies, through international supply chain has gained the competitiveness. It is significant as trade strengthens the relationship between countries and can also affect the business at a larger scale when there are crisis situations worldwide (Paul et al., 2005). The outbreak of the virus in China has created a crisis and disruption among the nation's trade due to the containment actions, the trade cycles are greatly affected and the supply chain is broken across the globe (Fan et al., 2020).

As per Indian commerce and industry ministry, the Indian foreign trade is plunged by more than 50 percent due to pandemic. The pandemic on India's trade are to be somewhat difficult to be predictable, its long to medium term aftermath are definitely not it. Even some countries are up in business, most of the other countries are under lockdown, it's difficult to find too many buyers in the international market. The WTO predicts that the India's export and import are highly devasting due to impact of pandemic, since Indian trade is highly depending on foreign business (WTO press release, 2020). Moreover, the prediction extends that the country is going to experience a v-shaped recovery in the near future.

Pandemic crisis and the allied disruption in trade, manufacturing and logistics activities have created discernment between upstream and downstream activities in a value chain. Upstream is longing for input material from local or foreign sources, which was completely paralysed due to logistics movement restriction imposed by the respective governments. Upstream supply chain is stagnated due to varied demand responses for different goods and services from diverse locations. Crisis affected food supply chain initially, with the government support, it has partially regained its strength to satisfy the basic needs of the customers. Customers have started using technologies and diverse channels to purchase essentials from hyperlocal market. A system has been created by both vendors and customers to conveniently get products during these crises times, which created huge demand for the agriculture and electronic goods. Supply has taken different channels, caused hoarding, increase in price and instant alternate products. This issue, to be addressed either as a short-term or long-term prediction of demand, could help the stakeholder of supply chain to plan the activities in alignment with the government relaxation in the respective operation area.

Disruption in supply chain has created an imbalance in supply and demand, which is the result of containment zones in supply sources and panic buying of customers in the markets. This imbalance demands a prediction of the supply of inputs for manufacturing and service sectors. Prediction of input resources has become essential for all the operations by the company in the supply chain (Konstantinos et al., 2020).

So, application of prediction model in import and export trade can help the traders to understand the real situation of trade and plan for sourcing inputs and distribution of outputs. There are some trade prediction models using timeseries analysis to predict the import and export of the country (Manifield et al., 2008). Multivariate analysis also is applied for prediction of trade using sourcing data in a specific sector, with minimum variation in output due to similar variation in the input data (Kim et al., 2019). In this paper, forecasting analysis is used for prediction of trade during pandemic crisis with the input data collected from various government sources.

All business entities started realizing the need for lean implementation process as part of their business practices. Like manufacturing sector enjoying the benefit of improving operation efficiency through implementation of various lean tools, service sector also is gaining improvement in their significant service process through lean practices. Each industrial sector demands different frameworks for implementation due to its varying sequence of operations. These operations of most industrial sector are highly influenced by its supply chain, which was identified as one of the enablers for lean implementation. Supply chain of any industry is becoming complex due to the uncertainty in their inputs, like variation in import/export of a country (Mohammed et al., 2017). Most of the Indian industry is depending on atleast few of its input materials are from some foreign countries, similarly the sales are inclined towards exports. However, the global pandemic has created a disruption in supply chain, resulting in interruption in lean implementation process. Thus, it is essential to find the relationship of the impact of trade prediction outcome variation in the form of input resources for implementation of lean process.

As explored by Pearce et al. (2018a), lean implementation process demands knowledge repository and sharing among the shopfloor workers to follow the lean tools devotionally is a significant process faces crisis and demands a system with different inputs for effective implementation. The incentive for lean implementation arises from uninterrupted flow of input resources, which could result from efficient supply chain of both components and services. Waste elimination and reducing cycle time of process with better methods including standardized technologies are focussing on lean implementation practices. It can produce better outcome only when there is smooth inflow of resources to the lean system in manufacturing or service industries (Bajjou et al., 2018). Therefore, it is essential to study the impact of variation in inputs due to the pandemic crisis in lean implementation.

This paper analyses the variation in Indian import and export of few specific products due to pandemic and its impact with lean implementation technique. Initially, the impact of the pandemic in imports and exports of specific product is measured using prediction model. Pandemic created variation in input resources and its impact in lean implementation is discussed. Thus, this study will help the government and individual traders in planning their export/import when such critical situations arise.

2 Review of Literature

2.1 Lean Implementation in Organization

Business transformation in any organization depends on the right balance of improvement practices to be followed. Improvement practices like lean implementation provide unique solution for operational excellence. Lean implementation practices are successful in plants with the culture of good relationship with suppliers, customers and continuous improvement in operations (Bortolotti et al., 2015). Success of lean implementation is depending on its tools and techniques, above all the humanitarian factors like leadership and workers' attitude also contributing to the success (Jadav et al., 2014). Success includes readiness of the organization by matching their capabilities against requirements of tools and techniques (Dorota 2014). Value Stream Mapping (VSM) was one of such techniques which follows mapping process from input stage to output stage by classifying the activities as Value Added activity (VA) and Non-Value Added Activity (Rother et al., 1999). The customer demand can be met by implementing efficient TAKT time to match the available production time. Production line efficiency is improved by removing the waste component in the process through visibility by TAKT time measurement (Duanmu et al., 2004). Bottleneck process, part of lean implementation, is influencing the customer demand by the difference between bottle neck cycle time and TAKT time.

Cellular manufacturing focus on designing the workstations with balance of workloads in each workstation having impact on lean implementation. The technical factors of cellular manufacturing include layout design and worker job related aspects draws inputs from lean. Variation in input resources and incomplete information, like forecasted demand with error component, affects the balance of workloads and few technical factors mentioned above (Askan et al., 2019). Delivery time reduction as a competitive technical factor insists on flexibility through implementing U production line in the lean environment. Lean environment conceives U-shaped production as a solution for worker utilization and waste control in conjunction with pull system (Gil-Vilda et al., 2014). Line balancing in lean manufacturing absorbs irregularities in design of work load-related internal and external factors of production line. Balancing labour and equipment in production line could reduce the irregularities in cycle time and manufacturing-related waste (Nuguen et al., 2016). Single Minute Exchange of Dies (SMED) could address the equipment and machinery balancing issues in lean environment with the goal of rapid tool change by transporting, positioning and fixing tool. SMED technology could yield high return on investment with the better demand forecasting and proper capacity matching (Al-Akel et al., 2018).

2.2 Impact of Pandemic on Global and Indian Trade with the Perspective of Predication Model

Pandemic has demonstrated that scale of cost spent for containment could have been avoided if a greater investment is being made in public fitness systems. Now, the global business has predicted that the focus can be towards health care organization, which are not advanced enough to handle the crisis (Warwick et al., 2020). Crisis is also extended in food deliveries due to disruption in supply chain and agricultural production. It is affected due to the containment measures taken by the government that restricts the workers from harvesting and handling crops, which has created a demand for food and agricultural commodities (Joseph et al., 2020).

Pandemic situation is not only a challenge for the Indian pharmaceutical industry to meet the demand of 1.3 billion inhabitants but also to the remaining world although they have a wealthier economy. Preventing the disruption in this sector and enhancing them for a large-scale production only can help India in assisting the global outbreak (Guerin PJ et al., 2020). The disruption by previous pandemics have created a lesser economic impact but this one has is different in scale. As soon as the cases were reported in countries like China, Korea, US and Germany, about 55% of world supply and demand, 60% of world engineering and 50% of product exports took a hard hit. The US and China are the foremost economies that took a shock in their trade due to the pandemic (Richard Bladwin, 2020).

Indian government is working hard to predict and maintain the supplies of pharmaceutical ingredients. Commodities like pharmaceutical chemicals are mostly imported from China, the Indian government has become concerned over the vulnerability in the pharmaceutical supply chain industry (Patralekha, 2020). Vulnerability due to difficulty in prediction of supply and demand causes the health planning crisis, lockdown schedules and situational factors (Mahendra et al., 2020). Planning crisis as an outcome of trade prediction limitation as observed in Indian context was analysed at micro and macro level to prevent disaster and salvage from collapsing economy (Manish et al., 2020). Indian economy and its supply chain are deliberated with the effect of some critical barriers such as access to transportation facilities, application of touch-free technologies, dependence of suppliers from single geography, efficiency of prediction models and so on (Shruthi et al., 2020).

Indian trade stagnation due to pandemic has created resistance in Indian market, imports and exports of India, industry and infrastructure of India, rise in the economy, present situation of foreign trade and national income levels. Inventory prediction might go up and the industries must look at new methods to reduce their inventories (Paul et al., 2020). It can be controlled by two forms of concern, one is concern for the disease and the other is the economic uncertainty due to the lockdown. The Engineering Export Council along with ASEAN India Centre and Research and Information System has presented 40 important commentaries based on research conducted by Scholars on trade and foreign policy. This paper focuses few of the recommended commodities to apply and analyse the prediction model (AIC-EEPC 2020). Another analysis, specifically in Indian macro-economy, tourism and travel, stock markets, transportation, trade and human capital, has revealed that India has chances of experiencing a health calamity, and the agonizing economic shovelling in the future may cause a variation in implementation of lean and agile practices in manufacturing and service industries (Manish 2020).

The above literatures have discussed about lean implementation and impact of pandemic on the trade of India as a whole. There are studies at global level and Indian level separately. Studies related to lean implementation in manufacturing was discussed, however, the impact variation in input resources as an output of prediction model was not discussed. This paper aims to focus on predictive models to estimate the variation of few commodities and discuss the impact of this variation on lean implementation.

3 Research Methodology

To figure out the waves of the COVID pandemic on the regular import and export cycle in India, COVID pandemic data of top five countries is collected till March 2020 and plotted in the graph. Data on country-wise contribution of trade with India for the year 2019 was taken to identify and compare with top five countries affected with pandemic. USA and China, the countries majorly affected with COVID and contributing maximum trade with India, were selected for further data collection. Top five import and export commodities from India to China and USA are identified for further data collection.

For this research, we have collected 2-year data from the DGFT-Directorate General of foreign trade. The data is scrutinized in various forms like commodity-wise for analysis. Since it is advantageous to have multiple sources to have assurance in the discoveries, the data received from the DGFT portal is cross-checked with FICCI journal and CMIE's Tradedx updates. Since a cross-check for the entire raw data is not possible, the top ten commodities were taken as the pilot lot and verified for contrast. Through in the cross-reference, we were able to find out that the data is consistent with the other sources like foreign trade statistics published by Data Analytics unit of the ministry of commerce and industry.

The five commodities identified and its trade data were collected from the above-mentioned sources for the 2 years (April 2018 to March 2020) and prediction model was generated using the SPSS forecast modelling. This forecast model is built using the time series data that is available, and the model is executed for prediction with upper control and lower control limits for better accuracy.

The pandemic impact as variation in outcome of trade, which is forecasted using the prediction model is discussed in the view of the changes it will make in few specific lean implementation practices such as value stream mapping, TAKT time, inputs for cellular manufacturing, delivery time reduction, line balancing and single minute exchange of dies.

4 Impact of Trade Prediction Outcome on Lean Implementation Practices

In this section, the prediction model of trade in India was established using the data collected from DGFT and COVID data. Next, the prediction model for total imports and exports and also for top five commodities was done using the 2-year data. Finally, the prediction model variation in outcome and its impact on few lean implementation practices was discussed.

4.1 Prediction Model for the Trade in India

Top five countries COVID 19 case data was collected and tabulated below. Table 1 shows the list of month-wise case data for the top five countries that were predominantly affected by the COVID pandemic till May 2020. The major two countries affected initially that is based on the total cases up to March 2020, China and USA, are taken up for analysis purpose.

COVID data is also plotted in a daily graph for the four countries where the cases were maximum in the month of March. Figure 1 shows the case plot for the major countries such as China and USA in comparison with the cases in India.

For the above five countries that were majorly affected by COVID, the ranking of the country based on their corresponding trade percentage is shown below in Table 2. The top 30 countries were taken, and the trade values of import and export with India were collected. Form that it is identified that USA and China have the maximum contribution of trade with India.

Import and Export data of India was collected from the DGFT portal for top five commodities to USA and China, which was compared and arrived as five export commodities and five import commodities from India to be considered for prediction analysis. The commodities are sorted on a 2 digit level HS Code and the data is collected for a duration of 2 years (From Jan-2018 to Mar-2020). The data is updated by the DGFT on a timely basis, and the final revised data was collected till the period

Table 1 Month-wise COVID case data of top five countries

No of new cases						
Month	India	China	US	Russia	UK	Italy
Jan-20	0	11791	0	0	0	0
Feb-20	0	68033	68	2	23	1127
Mar-20	1393	1730	193931	2335	25127	104664
Apr-20	33466	1308	904527	104161	146103	99671
May-20	146964	137	732779	299345	103509	27201

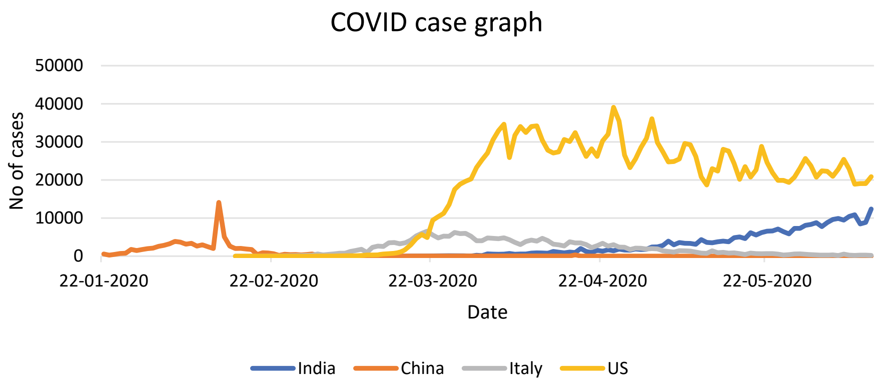

Fig. 1 COVID New case plot for top four countries

Table 2 Country-wise percentage contribution of trade 2019 with India

Rank	Country	Export	%	Import	%	Total Trade	%
1	USA	3,48,494.54	16.9%	2,36,933.00	7.6%	5,85,427.54	11.3%
2	CHINA P RP	1,09,700.19	5.3%	4,40,101.69	14.1%	5,49,801.87	10.6%
3	U ARAB EMTS	1,91,757.21	9.3%	1,99,538.34	6.4%	3,91,295.55	7.6%
11	SWITZERLAND	7,853.04	0.4%	1,13,093.34	3.6%	1,20,946.39	2.3%
12	JAPAN	29,771.80	1.4%	81,803.67	2.6%	1,11,575.47	2.2%
13	MALAYSIA	42,132.43	2.0%	65,590.32	2.1%	1,07,722.75	2.1%
14	UK	57,839.41	2.8%	44,840.45	1.4%	1,02,679.86	2.0%
15	BELGIUM	38,561.03	1.9%	59,192.30	1.9%	97,753.33	1.9%
16	NIGERIA	23,603.84	1.1%	65,771.59	2.1%	89,375.43	1.7%
24	SOUTH AFRICA	26,710.75	1.3%	42,922.86	1.4%	69,633.60	1.3%
25	RUSSIA	20,020.01	1.0%	44,483.76	1.4%	64,503.77	1.2%
26	ITALY	32,302.22	1.6%	29,743.81	1.0%	62,046.02	1.2%
27	BANGLADESH PR	53,183.16	2.6%	8,286.59	0.3%	61,469.75	1.2%
28	NEPAL	46,913.05	2.3%	4,665.28	0.1%	51,578.32	1.0%
29	MEXICO	23,988.64	1.2%	26,984.85	0.9%	50,973.50	1.0%
30	TURKEY	32,510.53	1.6%	13,535.00	0.4%	46,045.53	0.9%
	Total of Top countries	***15,67,382.38***		***26,52,021.99***		***42,19,404.37***	
	India's Total	**20,58,509.23**		**31,23,907.34**		**51,82,322.63**	
	% Share of Top countries	*76.14*		*84.89*		*81.42*	

Jan-2020. The final 2 months of Feb-20 and Mar-20 are provisional data and are subject to minor changes.

Based on the total trade cost, the percentage was calculated for each country, and the ranking of the top two countries that had maximum COVID cases are highlighted in Table 2.

From the above, it is evident that USA and China contribute to a total trade of around 22% to and from India. Hence, they are considered for further analysis.

4.2 Prediction Model for Export for the Next Two Quarters

With the data collected for the past 2 years, we predict the expected export trade using forecast modelling software. An export forecast model is built using the time series data that is available, and the model is executed for prediction with upper control and lower control limits for better accuracy.

From the prediction model in Fig. 2, we can see that the total export value of the next two quarters is expected to fall to about 1.7 Lakh crores irrespective of the impact of COVID. Any deviation from the predicted values can be related to the pandemic. For better clarity, the individual values predicted for each month is shown in Table 3.

As predicted in the earlier sections, the total export value of India and the export value of the individual commodities are tabulated in the above table from the month of April-2020 to September-2020.

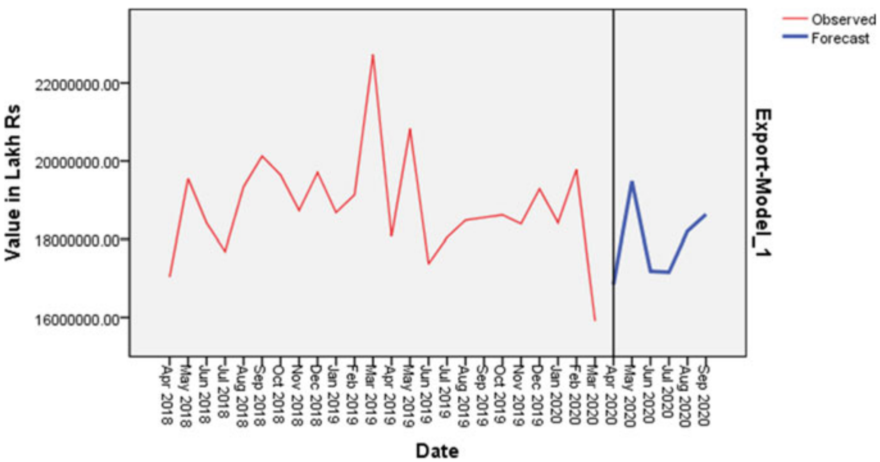

Fig. 2 Prediction of total export value for the next two quarters

Table 3 Prediction table for Total Export and top five export commodities

Month	Export (Value in Lakh Rs)					
Year	Total Export	HS 27	HS 29	HS 39	HS 84	HS 87
Apr-18	17,032,267.86	1,925,488	980,756.6	414,057.7	1,102,319	902,794.4
May-18	19,549,259.47	3,577,065	942,234.5	423,535.7	1,020,051	1,039,607
Jun-18	18,411,300.86	2,672,494	949,855.3	448,570.4	1,174,550	1,011,252
Jul-18	17,691,459.71	2,706,276	950,296.2	431,412.4	1,150,874	1,006,532
Aug-18	19,339,712.05	2,694,707	1,128,837	504,141.9	1,294,600	1,141,151
Sep-18	20,123,495.08	3,150,856	1,141,188	488,333.5	1,391,188	1,142,038
Oct-18	19,640,642.79	3,198,973	1,081,278	494,808.2	1,272,325	1,058,256
Nov-18	18,733,513.96	3,449,224	1,040,679	528,862.2	1,077,355	979,763.7
Dec-18	19,704,475.33	2,918,484	1,126,707	498,722.4	1,275,053	1,192,776
Jan-19	18,680,136.65	2,346,769	1,063,767	474,026.7	1,186,392	977,449.1
Feb-19	19,134,526.32	2,289,834	997,673	411,620.5	1,218,962	1,008,738
Mar-19	22,731,824.75	2,617,270	1,353,402	489,805.6	1,501,560	1,192,979
Apr-19	18,073,792.03	2,562,745	1,172,028	408,720.8	1,155,848	918,515.3
May-19	20,825,688.88	3,551,146	1,112,156	495,265.2	1,290,963	1,026,889
Jun-19	17,371,873.51	1,890,814	905,879.3	428,033.7	1,164,924	965,188.9
Jul-19	18,046,712.92	2,541,890	1,056,752	409,046.3	1,144,408	966,622
Aug-19	18,484,973.69	2,402,923	962,804.2	422,278	1,227,622	1,093,664
Sep-19	18,552,735.64	2,512,007	1,019,570	388,353.9	1,212,213	1,033,683
Oct-19	18,618,830.88	2,499,430	998,835.7	418,291.2	1,251,164	1,003,580
Nov-19	18,391,837.51	2,769,970	1,010,140	434,152.5	1,365,699	960,789.1
Dec-19	19,284,481.56	2,665,746	1,020,792	397,649.3	1,337,615	1,113,619
Jan-20	18,419,231.00	2,340,689	1,060,458	370,145.2	1,165,842	846,177.2
Feb-20	19,780,762.82	2,515,865	1,136,038	396,320.6	1,354,395	1,042,795
Mar-20	15,915,797.25	1,875,314	931,065.4	327,818.6	1,093,069	859,171.6
Apr-20	17,451,363.24	2,074,082	1,059,732	297,375	1,123,960	758,055.7
May-20	20,187,172.37	3,394,072	1,010,535	345,386.1	1,150,385	865,507.9
Jun-20	17,569,143.56	2,111,621	911,207	324,287.7	1,164,614	805,341.3
Jul-20	17,759,365.56	2,454,049	986,864	306,214.9	1,142,518	788,562.4
Aug-20	18,629,685.05	2,378,781	1,029,161	349,195.5	1,255,989	904,262.4
Sep-20	18,921,660.45	2,661,398	1,063,719	324,329.2	1,296,579	859,590

4.3 Prediction of Trade Value for Chosen Export Commodities in Next Two Quarters

From our earlier regression analysis, we have found that the value of the total export of India depends on the export value of individual commodities. Therefore, in this

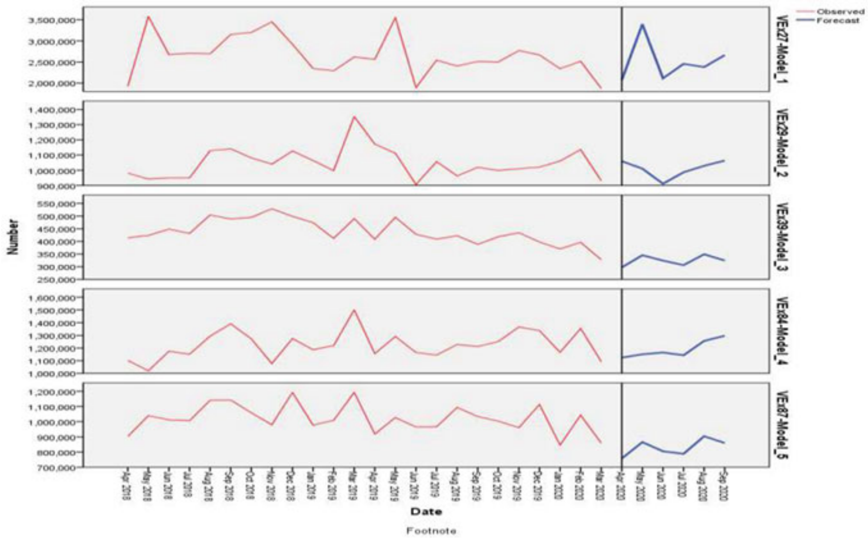

Fig. 3 Prediction of trade value for chosen export commodities in next two quarters

analysis, we created another prediction model for all the export commodities that were selected earlier through their contribution percentage. By predicting the trade value of these individual commodities, we can plan the policies based on the individual sectors and prioritize the commodities based on their total contribution to the export value. For this, we have used the forecasting tool in SPSS and tabulated the readings. Figure 3 shows the prediction chart for the export commodities.

From the predictions shown in Fig. 3, we can clearly identify that Mineral Fuels (HS27) and Machineries (HS84) will see a spike in their trade values, whereas commodities like Organic Chemicals (HS29), Plastics (HS39) and Vehicles (HS87) will have a fall and then revert back to higher trade values.

4.4 Prediction Model for Total Import Value for the Next Two Quarters

The data collected for the past 2 years is used to predict the expected import trade using the SPSS forecast modelling. An import prediction model is built using the time series data that is available, and the built model is executed for prediction with upper control and lower control limits for better accuracy. The predicted results are shown in Fig. 4.

From the prediction model in Fig. 4, we can see that the total import value of the next two quarters is expected to fall to about 2.4 Lakh crores irrespective of the impact of pandemic. Any deviation from the predicted values can be related to the

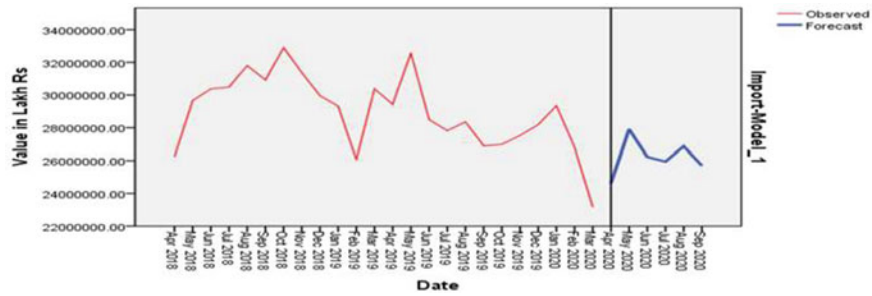

Fig. 4 Prediction of total import value for the next two quarters

pandemic. For better clarity, the individual values predicted for each month is shown in Table 4.

4.5 Prediction Model for Trade Value of Chosen Import Commodities in Next Two Quarters

The earlier regression analysis made for imports show that the value of the total import of India depends on the export value of certain chosen commodities. Therefore, in this analysis, we created a prediction model for all the import commodities that were selected earlier through their contribution percentage. By predicting the import trade value of these individual commodities, we can suggest the policymakers for the individual sectors and prioritize the commodities based on their total contribution to the import value. Figure 5 shows the prediction chart for the import commodities.

From the predictions shown in Fig. 5, we can clearly identify that most of the import commodities chosen, such as Organic Chemical (HS29), Plastics (HS39), Copper products (HS71), Nuclear reactors and Machinery (HS84), will increase irrespective of the pandemic, and only commodities such as Mineral fuels and mineral Oils (HS27) may decrease a little. This data is compared with the export predictions and the findings are discussed in the next chapter.

As predicted in the earlier sections, the total import value of India and the import value of the individual commodities are tabulated in Table 4 from the month of April-2020 to September-2020.

4.6 Influence of Outcomes of Prediction Model in Lean Implementation

Most significant lean tool Value Stream Mapping (VSM) which provides the visualization of production process, specifically material and information flow, could get

Table 4 Prediction table for Total Import and top five Import commodities

Month	Import (Value in Lakh Rs)					
Year	Total Import	HS 27	HS 29	HS 39	HS 71	HS 84
Apr-18	26,232,827.63	8,364,818	1,108,224	806,554.2	3,608,542	2,233,120
May-18	29,661,463.08	9,315,549	1,368,312	892,069.4	4,208,044	2,526,719
Jun-18	30,375,773.33	10,215,468	1,419,672	872,346.6	3,803,436	2,576,385
Jul-18	30,491,675.63	9,966,108	1,329,280	915,407.5	3,912,810	2,467,789
Aug-18	31,804,385.2	9,976,304	1,392,759	941,157.8	4,023,113	3,173,816
Sep-18	30,922,293.24	9,518,793	1,353,601	931,680.2	4,076,696	2,576,862
Oct-18	32,897,355.44	12,091,605	1,495,875	972,982.4	3,050,970	2,569,200
Nov-18	31,368,084.41	11,355,478	1,363,919	894,050.6	3,472,265	2,356,141
Dec-18	29,955,339.55	9,246,984	1,227,548	831,209.6	3,900,756	2,459,225
Jan-19	29,322,536.73	9,595,196	1,276,240	894,660.3	3,037,313	2,629,151
Feb-19	26,060,346.88	8,155,149	1,112,138	797,604.9	3,549,529	2,406,949
Mar-19	30,375,375.9	9,670,033	1,207,588	909,422.1	4,507,035	2,661,485
Apr-19	29,427,889.37	9,701,305	1,295,162	886,579.8	4,468,051	2,472,728
May-19	32,572,423.59	10,466,234	1,386,634	966,909.1	4,824,503	2,752,480
Jun-19	28,492,512.62	9,316,379	1,229,155	880,523.4	3,706,875	2,497,294
Jul-19	27,819,641.41	8,179,701	1,260,610	845,591.4	2,797,440	2,580,908
Aug-19	28,353,043.17	9,116,395	1,273,851	881,906.7	2,300,639	2,913,746
Sep-19	26,888,673.03	7,657,107	1,147,833	823,380.3	2,643,334	2,945,568
Oct-19	26,985,270.95	8,116,711	1,099,311	833,792.9	2,530,370	2,446,867
Nov-19	27,522,449.54	9,154,186	1,076,901	828,858.3	3,664,216	2,449,949
Dec-19	28,184,319.34	8,891,670	1,081,492	744,553.5	3,484,174	2,546,140
Jan-20	29,336,522.69	10,506,552	1,241,656	869,183.5	2,383,605	2,665,295
Feb-20	26,808,087	9,052,237	991,669.9	806,868.2	3,584,892	2,533,113
Mar-20	23,171,091.18	8,689,480	936,173.7	692,304.7	2,125,885	1,902,594
Apr-20	24,621,151.64	8,543,723	1,066,061	778,554.3	3,076,856	2,336,291
May-20	27,907,740.1	9,401,553	1,241,841	861,476.8	3,554,836	2,622,967
Jun-20	26,224,940.11	9,276,585	1,188,782	808,422.6	2,793,719	2,520,208
Jul-20	25,946,455.69	8,583,566	1,159,313	812,487	2,393,688	2,507,717
Aug-20	26,869,511.36	9,057,011	1,197,673	843,519.8	2,200,439	3,027,150
Sep-20	25,696,280.31	8,098,612	1,115,085	809,517.8	2,398,578	2,744,585

affected by the variation in outcomes of prediction model (Singh et al., 2011). Value addition to the material is tracked in each stage of the production process, the related information is processed for further analysis. Classification process like identification of activities which is adding value and nonvalue adding ones to be processed further for production improvements. From Fig. 5, it is evident that pandemic and its impact from trade prediction could definitely cause interruption in the material

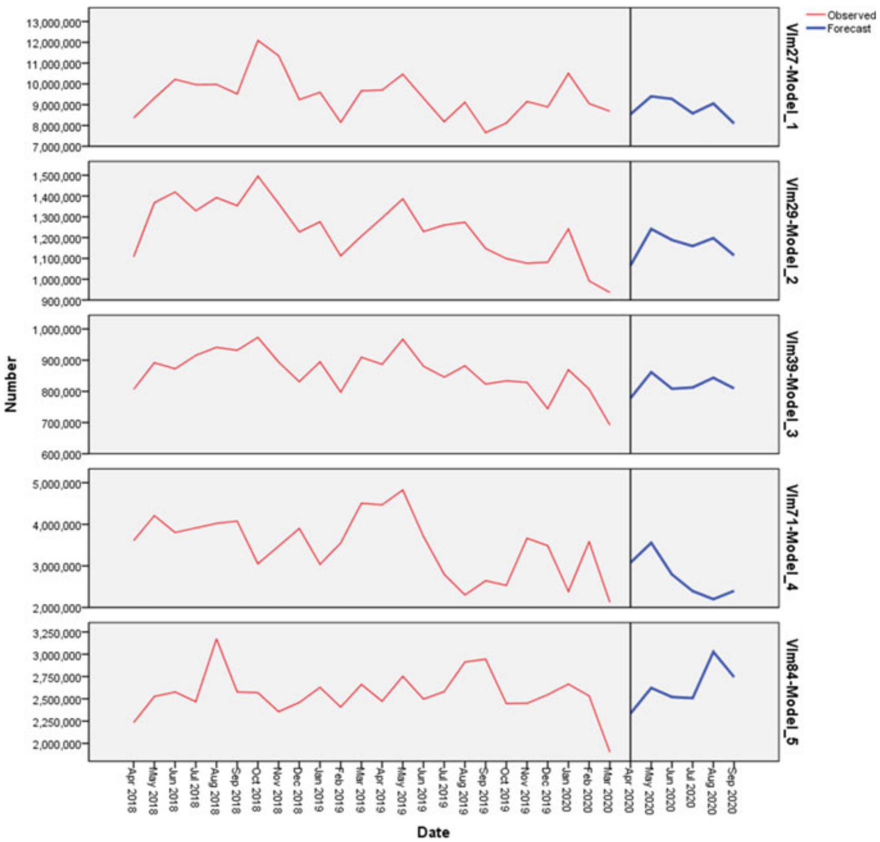

Fig. 5 Prediction of trade value for chosen import commodities in next two quarters

available and flow, the related process activities with human involvement could also get affected.

Work progress in shop floor is measured in terms of TAKT time. All the resources are aligned, and production rate is calculated based on available resources; the TAKT time is calculated by matching a balance among all available resources for an uninterrupted production. TAKT time for the various components could help us to optimize the bottle neck time, machining time and flow time. Efficiency of the TAKT time is getting swayed by the outcome of prediction model, since it is related to customer demand. Demand cannot be met in time as per the model prediction, it will take few months to reach the normal variation. In addition, the input resources supply disrupted could affect the TAKT time calculation (Patnaik et al., 2009). Production line efficiency as part of the lean implementation requirement is getting slanted through variation in TAKT time visibility. Many processes can become bottleneck process as the mismatch is realized in prediction model value (Fig. 4) during pandemic times.

Cellular manufacturing concept relies on group technology in which similar machineries are grouped based on part families. Manufacturing companies gain a benefit of this concept such as inventory reduction in each stages of manufacturing, setup time reduction, stabilized material handling cost and easy scheduling. Each cell in this manufacturing system is depending on upstream supply chain efficiency to balance the work flow in each cell (Patnaik et al., 2009). Impact of pandemic and its effect on trade could disrupt the balance of workloads in each cell due to the interruption in upstream supply chain. The technical factors of cellular manufacturing may demand automation in technology and social distancing in layout design and healthy working atmosphere.

New manufacturing with lean practices with the capacity matching the demand of future should have an efficient procurement team to project the material requirement for at least next 3 years. Pandemic is one of the variables affecting the prediction among many such variables contributing to the prediction model, it should be made before planning for any lean implementation practices (Hobbs, 2004).

Monden et al. (1983) argue that U-shaped production line is essential for line balancing in shop floor as part of lean implementation. Number of work station, flexibility in arranging resources and communication system in the shop floor could be improved using U-shaped production line (Guerriero et al., 2003). Delivery time reduction as competitive factor in U production line is highly affected based on the prediction model outcome (Fig. 5), since the variation in input resources such as equipment and machineries as per the statistics mentioned earlier.

Assembly line in most of the manufacturing companies is getting disrupted by different wastes such as overproduction of finished goods, work in progress inventory and cycle time (Nguyen et al., 2016). Since line balancing in lean manufacturing is depending on balancing labour and equipment in production line to reduce the variation in cycle time of production, it is evident from Fig. 5 that the prediction values could affect highly input resources cycle time of manufacturing.

Fulfilment in delivery of product and services can be achieved by more flexible and efficient process. Elimination of waste in these processes could improve the efficiency and add value to the activities. Optimization of process set up times will reduce the machine repair times which could result in choosing the lean practice as Single Minute Exchange of Die (SMED) (Radu et al., 2018). SMED could address the equipment and machinery balancing issues in lean environment may not get high effect from the outcome of prediction model (Fig. 4) owing to less dependency on input materials and machineries as recorded in earlier chapter. However, the requirement for rapid tool change by transporting, positioning and fixing tool may be modified by this demand and capacity mismatching.

5 Findings and Discussion

Major countries contributing to the total trade in India are China, USA and UAE. Out of which two countries were majorly affected by the pandemic at early stages as per the case details collected. As analysis indicates, the percentage contribution of these two countries towards the commodity is very high denoting that an impact to the trade in these countries will cause a downfall in India's trade targets.

It is identified that the commodities majorly affected due to the pandemic are export commodities, such as mineral oils, organic chemicals, plastics and objects, nuclear apparatuses and electrical machinery, which are major contributors to trade. Thus, using the value of these commodities, we can easily predict the overall export trade. Similarly, for import, commodities such as mineral fuels, organic chemicals, plastics and articles, copper materials and nuclear reactors contribute to major trade. The same can be used to form a prediction model for the overall trade. The import commodities and their value tend to increase year on year, but the exports have not seen a proportionate increase in the prediction model. This indicates that there will be a lag in the trade balance in India.

Based on the prediction model, the overall export trade for the next 6 months will be between 1.7 Lakh crores and 2Lakh crores, and the overall import trade will be between 2.4Lakh crores and 2.8 Lakh crores. Although we have a general notion that there will be a relation between trade and pandemic cases in the particular country, analysis has proved that there is no direct relationship. This can also be because the trade percentages have shifted between the commodities, such as organic chemicals, which created a demand due to the pandemic. It is evident from the prediction model that India's import and export trade will face v shape recovery within few months.

Impact of trade due to pandemics results in variation in the import resources, which is the input for most of the manufacturing and service industries. This input resources variation and restriction of human movement due to government containment activities will affect lean implementation process in the industry. Most significant lean tool, Value Stream Mapping (VSM), which provides the visualization of production process, specifically material and information flow, the related process activities with human involvement, could also get affected. All the resources are aligned, and production rate is calculated based on available resources, the TAKT time is calculated by matching a balance among all available resources for an uninterrupted production. Production line efficiency as part of the lean implementation requirement could get affected through variation in TAKT time visibility.

It is evident that the divergence U production line and SMED are highly depending on foreign trade for its raw materials and machineries, eventually will end up with break in the lean implementation process. Thus, the impact of pandemic in outcomes of trade in India could affect the lean implementation process in both manufacturing and service industries.

6 Conclusion

A comprehensive report on the foreign trade of India and the impact of COVID pandemic on the trade and its impact on few lean implementation practices was discussed. As part of the research, the data was collected from the Department of Commerce through web portal and verified with previous articles on foreign trade. The raw data collected was in abundance in addition to the secondary resources. The data was compiled systematically, assessed and the results are presented in the report. By considering these factors, the department of Commerce can better handle future trades and be sustainable in times of crisis.

This research has shown us the significance of few commodities that will affect the entire trade. The major understanding of the research is that the pandemic has chances of further bringing down the trade values; hence, focus should be more on creating an internal demand for commodities that being processed in other countries. The research identified the impact of trade outcomes as the variation of input resources for manufacturing and service industries. The input resources variation and its impact on few lean implementation practices, like Value Stream Mapping, TAKT time, Cellular manufacturing, U line production, line balancing and Single Minute Exchange of Dies, was discussed.

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Traceability Systems and Technologies for Sustainability in Food Supply Chains

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Abstract The concept of tracking and tracing food products has been a cornerstone for food safety policy since the 1990s (Sarpong, European Business Review 26:271–284, 2014). Since they became mandatory in 2000s with EU food safety laws, traceability has gained significance in the food supply chain. This article underscores the role played by traceability systems, an important driver of sustainability, in the food supply chain and explores the underlying technologies and brief overview of the barriers to their adoption. Thus, this paper paves way for future research in the traceability technologies to enable SSCM practices.

Keywords Sustainability · Food supply chain · Traceability · Traceability technology

1 Introduction

As humans, we have a moral responsibility of ensuring the survival of not just our own species but also ensure the survival of other species on this planet. Unfortunately, this responsibility is disowned by some who are in the business of servicing customers, especially in the food supply chain. The un-relented focus on fast-paced growth for the benefit of their own firms at the cost of consumers is taking its toll on the planet. There is increased incidence of foodborne illnesses and health panics among consumers. Every year, nearly 600 million people fall sick because of consumption of contaminated food, resulting in more than half-a-million deaths, reports World Health Organization.

Globally, there are a lot of documented evidence pointing to rampant food scandals. A recent analysis on 20-year data done by (Robson et al., 2020) unearthed

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413 fraud reports in the global beef supply chains. Such scandals have a debilitating impact on human lives. For instance, in 2011 alone, nearly 50 million people got sick and nearly 3000 of them died due to foodborne diseases (Morris Jr., 2011). The consumption of contaminated bean sprouts had resulted in 37 deaths in Germany and made 3000 lives sick (Marucheck, 2011). One cannot forget the largest food recalls in history in 2008 in US by Peanut Corporation of America after many reported sick and few of them died (Layton, 2009).

China also experienced milk powder adulteration because of which nearly 3 lakh people fell ill and left at least 10 dead (Xiu, 2010). In India, Nestle faced wrath for excessive amounts of heavy metals in its Noodles (Mitra, 2017).

These illnesses occur due to both human-made and non-human-made factors. The human-made factors exacerbate this through self-discovered globalization practices. The producers and consumers are far away from each other in today's globalized world making it difficult for the consumers to be aware of the origins of the food products they consume. The processes and controls of food manufacturing are not generally known to the end consumer. This provides incentive for some of these businesses to play spoilsport in the supply chain resulting in such widespread incidents. In some cases, despite the best intentions of food manufacturing firms, the contamination of food can happen in the distribution part of the supply chain. After the notorious food scandals of 1990s, consumers started feeling the need for understanding the origins and processes of food manufacturing and this gave birth to concept of food *traceability*.

The current pandemic is a good example of non-human-made factor that is having a devastating effect on the food supply chains. Supply chains are strained beyond their capacities because food is an essential commodity (OECD, 2020). This has increased the awareness among consumers to consume safe and hygienic food and has kindled the need to know the origins and processes of food manufacturing.

Thus, traceability has gained enormous significance in recent times and the pandemic has only further reinforced its need. *Traceability*, in general, refers to *tracking*, which is determining the origin and characteristics of a particular product and *tracing*, which is collecting the history of products related to its displacement along the supply chain (Bechini, 2008).

As per the ISO 9000 (2005) standards (ISO, 2005), the definition of traceability is "*the ability to trace the history, application or location of that (product or process) which is under consideration*". The guidelines also cover the complete history of processing and distribution of products even after shipments.

But these definitions are not comprehensive in nature for such an all-pervasive term. (Bosona T, 2013) provides a very comprehensive definition to food traceability:

> Food traceability is defined as a part of logistics management that capture, store, and transmit adequate information about a food, feed, food-producing animal or substance at all stages in the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time.

Given this definition of traceability, we seek to understand the traceability systems and the related technologies in the food supply chain in this article. We first discuss the role of traceability and sustainability in food supply chain in Sect. 2. Then we present the methodology of the research in Sect. 3. We then explore the role played by traceability systems as a strategic and risk management levers in managing the food supply chain in Sects. 4 and 5, respectively. Then a framework on traceability system implementation is discussed in Sect. 6. Section 7 uncovers the various technology standards in use for implementing traceability. Section 8 underscores the challenges in its implementation. In Sect. 9, we highlight some ways of mitigating these challenges and provide a way forward.

2 Traceability and Sustainability in Food Supply Chain

Sustainability as a research topic has gained prominence after the advent of globalization, as well. With supply chains underpinning the era of globalization, it is only but natural that this topic warrants enough attention, especially in the face of the widespread scandals and the focus as outlined above on the profit motive. The adoption of Sustainability focused practices in Supply Chain is termed as Sustainable supply chain management (SSCM).

The need for including the oft-neglected environmental aspects called for a comprehensive definition of this nascent field. Thus, according to (Beske et al., 2014), SSCM can be defined as:

> the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements.

The definition encompasses the length and breadth of the entire supply chain including all the stakeholders in the action. Thus, by nature, the adoption of practices that enable SSCM relies on a very complex relationship between the different stakeholders to ensure that the third dimension—environment—is taken care.

This is all easier said than done. The inclusion of the third dimension generally is viewed as conflicting and goes against the principle of Peter Drucker who strongly propagated the idea that the primary motive of a business is to "*profit*" and nothing else (Drucker, 1973). This also means there is no incentive for a firm to co-operate with another, even if they are meant to interact with one another on a regular basis in the process of engaging in the business. Thus, communication and collaboration between stakeholders in a supply chain emerge as key actions which help supply chains achieve the third dimension and eventually help them attain sustainability.

Our literature review indicates that traceability technologies possess the capability to enable tamper-proof communications and collaborations through enforcement of compatible enforcement standards (Bechini et al., 2008; Germani et al., 2015; Sarpong, 2014; Caro et al., 2018).

Thus, these technologies not only enable supply chain transparency but also have potential to increase *trust* among the supply chain partners which is a key motivating factor for sustainability (Garcia-Torres et al., 2019). Therefore, adoption of traceability technologies offers a promising means for improving the SSCM practices, increasing the SC collaboration and attaining the sustainability goal.

To the best of our knowledge, there are no studies which explore the role played by traceability systems and technologies in the food supply chain and documents the disparate technology standards and discuss their implementation challenges. We attempt to fill this gap.

3 Methodology

The review of literature for this paper started with identifying relevant keywords for database search. After brainstorming, the authors identified the following keywords:

(1) First level search: "Traceability technologies", "Traceability System"
(2) Second level search: "Food supply chain".

The shortlisted keywords were then used to search the prominent databases: Scopus, Google Scholar and Microsoft Academic. The details of the search process are presented in Fig. 1.

The first level keyword search resulted in a total of 6,700 results. Once the second level keyword was applied, the results narrowed down to 346 from all the databases. These articles were then manually reviewed to include peer-reviewed journal articles and other sources that are closely relevant with our topic of research. The final shortlisted 33 sources were included in this study.

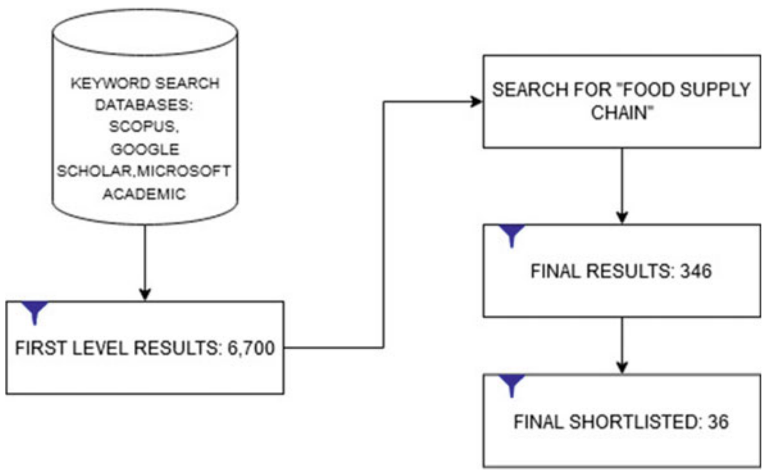

Fig. 1 Literature search process

4 Traceability as a Strategic Tool

Food supply chains in general have a tighter regulation in force. However, even with these regulations, firms which do not explicitly adopt the concept of sustainability in their SCM practices generally end up breaching the social and environmental norms (Ebinger & Omondi, 2020). Traceability can play a significant role in alleviating that because it allows us to measure the extent of social and environmental breaches at any point of the entire supply chain. Food supply chains, therefore, can leverage traceability to achieve the triple bottom line approach and thereby achieve competitive advantage.

Specifically, traceability can be beneficial to the stakeholders involved in the food supply chains through the direct measurement of product and service history. This not only improves the accuracy of record-keeping, but also makes it an effective monitoring tool. Quality control then becomes a natural consequence of traceability. Therefore, we posit that a proper implementation of traceability can significantly improve SSCM's effectiveness.

Traceability also adds a significant benefit to supply chains in terms of tracking product recalls, product safety and optimize reverse logistics processes (Chen, 2014; Hongyan Dai, 2015).

In addition, traceability has other indirect benefits. It can reduce information asymmetry in the supply chains. Indeed, it is known that effective collaboration can be hindered by the asymmetric information propagating in the supply chain (Moises, 2012). The presence of asymmetric information makes the supply chain less transparent. Thus, in the absence of traceability and a consequent less-transparent supply chain, there is an incentive for the supply chain actors to mask their real intentions while reporting the performance to their stakeholders.

4.1 Traceability as a Meta-Capability

On a more abstract level, traceability can become a meta-capability which may be effected through proper governance, collaboration among the supply chain partners and tracking and tracing of products and processes. Governance is a top-down mechanism that relies on both formal and informal controls to achieve SSCM practices. Formal controls are enforced by means of regulations and standards in the food supply chain. On the contrary, informal controls rely on *"trust"* as the delivery mechanism. Many of the studies in the past have shown trust as an important factor in effecting efficient supply chain practices (Cheng, 2008).

It is pertinent to note that governance alone cannot entail such practices. Successful governance and collaboration between supply chain actors work in tandem. Collaboration, can therefore, be viewed as another strategic tool to achieve the meta-capability. In fact, collaboration is documented as a connect between business processes and the structure of a supply chain (Vlajic, 2012). The structure includes all things technical and logistical that bring together the actors of a supply chain and significantly improves the accuracy of information. The nature of such co-operation and development can extend beyond the normal food manufacturing and extend to external processes and technologies.

Beyond governance and collaboration, a third strategic lever for traceability as a meta-capability is tracking and tracing. Of late, tracking and tracing are proving to be essential for a sustainable food supply chain (Fritz, 2009). Indeed, (Anastasiadis, Apostolidou & Michailidis, 2020) show that effective implementation of both of these mechanisms is instrumental for enhancing supply chain visibility leading to a strong sustainable supply chain performance. Recently, tracking and tracing have also been demonstrated to be effective in increasing both the formal-informal controls by reinforcing the trust and increasing the collaboration (Garcia-Torres et al., 2019). Thus, by enabling a host of strategic options, traceability is proving itself to be an effective tool in implementing SSCM practices for firms.

4.2 Tracking and Tracing and Operational Efficiency

Tracking (*forward traceability*) and Tracing (*backward traceability*) refers to the activity of collecting both upstream and downstream information in a supply chain and is effective in controlling the operations in a process, broadly termed as *chain traceability*. According to Moe (1998), chain traceability is the *"…ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales*".

It can identify and locate the historical events involved in manufacturing a food product. However, this activity can be challenging for a food supply chain because of the disconnect between structure of a supply chain and its business processes, demand volatility and incompatible global standards and may also sometimes include absence of skilled actors.

Traceability provides opportunities for firms to re-visit their competencies and knowledge of the business domain in which they operate. For instance, traceability can significantly improve the operational efficiency of a firm. The efficiency is perceived to be amplified through lower inventories, reduced lead times and lesser stock-outs and operating costs (Cousins et al., 2019).

In other words, traceability can be viewed as an all-encompassing strategic tool for enabling an organization's SSCM practices both in short-term as well as long-term.

5 Traceability as a Risk Management Tool

Traceability also acts as an effective risk management tool. Apart from being an effective risk mitigator through monitoring, it can provide a significant protection against lack of adherence to standards or certifications (Sarpong, 2014).

The globally accepted food standards are broadly classified as self-certifications and third-party certifications. Most of these certification standards expect voluntary compliance. If any party in the supply chain violate the norms, there is no legal action for it. One of the prominent self-certification standard in food supply chain is the Hazard Analysis and Critical Control Points (HACCP) (Wallace, 2011).

Organizations like the Food and Drug Administration (FDA) also require food supply chains to maintain history of sources of raw materials and destination of food products that can facilitate compliance in the long run. The objective of these enforcements is to obtain systemic information on the ability to trace a product back to its origin.

Besides these certifications, there are also third-party certifications that examine the safety of food (Codex standard), quality of food (processor standard), Agriculture practices (e.g. ISO 9000 standards). All these are unique to food supply chains.

There are other standards which are applicable for labor practices (e.g. Fairtrade standards, ETI Baseline) and Environment (e.g. IS 14000) which are required for day-day operations in connection with food manufacturing systems.

The presence of so many standards and different forms of certifications with sometimes unclear and incompatible regulations have given rise to a debate whether the certifications really drive the goal of quality control or does it incentivise the supply chain actors to be only a paper tiger (Ling & Wahab, 2020).

This fundamental conflict between governance and self-compliance of supply chain actors can be mitigated through successful implementation of traceability practices. However, one point to keep in mind is, this effectiveness cannot be improved if the implementation is improper. Therefore, a proper implementation is envisaged that can improve the overall effectiveness of the SSCM practices and thereby the sustainability. In this context, the traceability systems and technologies of food supply chain needs to be understood better and this is the focus of the subsequent two sections.

6 Traceability System in Food Supply Chains

A food supply chain consists of different actors namely Farm, Distributor, Factory, Retailer and Customer with product and process flows across their length and breadth. The traceability systems in this entire spectrum comprise of both internal and external traceability systems to enable chain traceability. While *internal traceability* refers to the *"ability to trace a product to one of the steps of a stage in the food supply chain"*, *external traceability* refers to *"ability to trace the product between any two actors or stages of the food supply chain"*. We explore the concept of food traceability system framework in the form of a Food information system which employ various traceability technologies to implement the chain traceability.

The Food Supply Chain Information System (FSIS) used for traceability (Fig. 2), hinges on the tracking and tracing abilities of a food supply chain. Tracing the products and ingredients in a food supply chain requires the use of Unique Identifiers

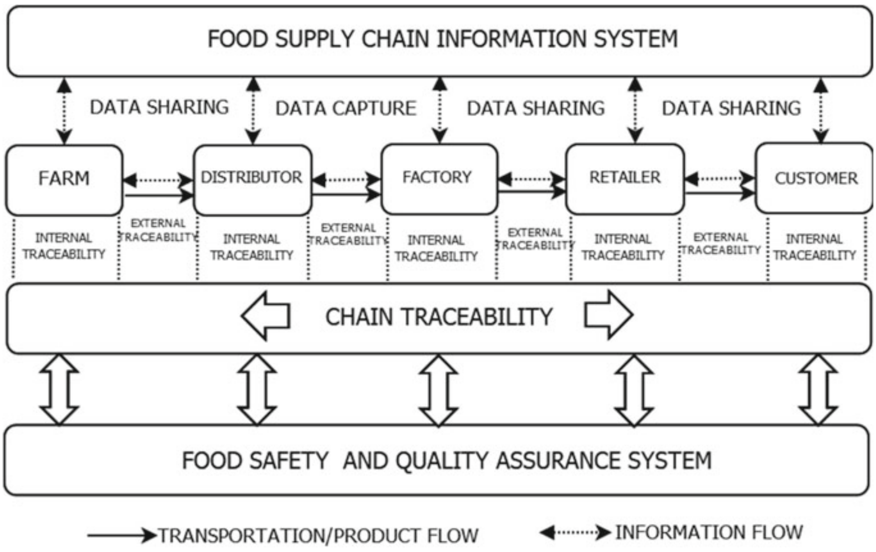

Fig. 2 Food supply chain information system (Adapted from Behnke, 2020)

which has to be defined for each Stock Keeping Unit or a group of SKUs and in general referred to as the Traceable Resource Units (TRU) (Aung, 2014).

Successful implementation of tracing requires addressing three fundamentally different TRUs:

1. Products sent in same batch consisting of same batch number, e.g. Box of cans with milk powder
2. Products which undergo the same process steps, e.g. Tomato Sauce produced with same before and same batch number data values
3. Products which are aggregated together for the purpose of logistics convenience, e.g. Cans of milk powder with different batch numbers.

These definitions imply that a TRU could in fact refer to the same batch unit or several TRUs can refer to a same batch unit if they shared same processing steps.

At the heart of the Governance mechanism, the Food Safety and Quality Assurance System (FSQAS) provides the safety and quality regulations for compliance of the food supply chain actors. The information pertaining to compliance with the regulations are stored in the Food information system.

There is a multitude of factors that determine the overall effectiveness of the traceability system. This includes the nature of business, nature of customers and market and the ingredients which are used in the supply chain. The effectiveness also relies on the extent of complexity of the traceability system. For example, number of suppliers, the characteristics of food production, distribution nature are differentiating factors of a traceability system and impacts the overall effectiveness. Further, another important contributing factor is the country-specific or product-specific systems that warrant a particular food safety regulatory compliance.

The entire Food Information system relies heavily on the technology adoption at various stages of the food supply chain. The technologies that are backbones of the Food supply chain Information System in implementing chain traceability include Data Capture and Data Sharing systems. The subsequent section throws light on these traceability implementation technologies for food supply chains.

7 Traceability Implementation Technologies in Food Supply Chains

Food processing industry by nature is a complex one. Huge volume of information gets generated in this supply chain every day. This makes the implementation a challenging task. Thus, traceability systems require an ICT infrastructure that employ advanced technologies (Fig. 3) which enable capturing such huge volume of data throughout the supply chain (Haleem, Khan and Khan, 2019).

Furthermore, implementation of traceability requires technologies that can share information across disparate networking systems with often different standards of communication. The chain traceability, therefore, is only as good as the extent of integration among these disparate systems.

This section explores the different traceability technologies which involve both data capture and data sharing mechanisms. With their varied nature in terms of

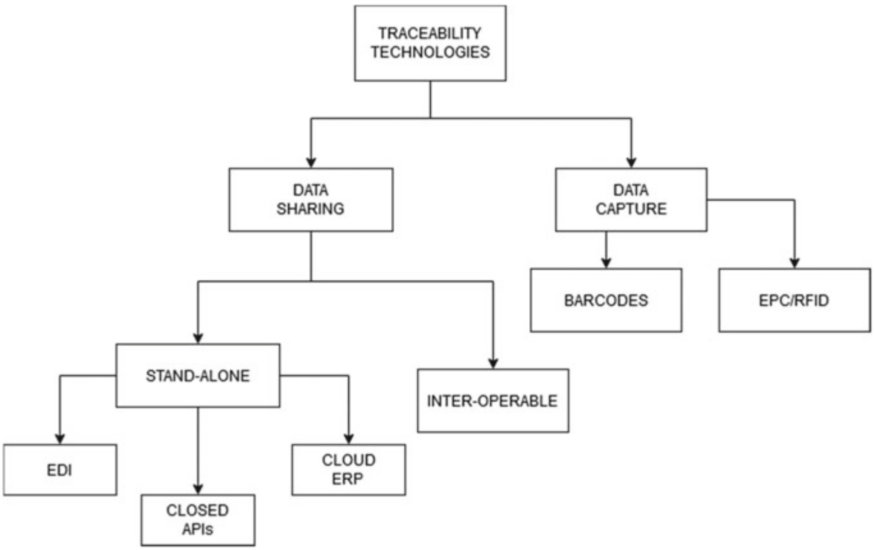

Fig. 3 Traceability technologies in food supply chains

standards, functions, and operations, these technologies complement each other in ensuring a transparent food supply chain.

7.1 Stand-Alone Systems

Stand-alone systems feature technologies that are conventional and are limited to firm-level information sharing in the enterprises. However, these are still prevalent and widely used technologies. Understanding these technologies has laid the foundation of more open and transparent inter-operable technologies.

7.1.1 EDI

The origins of traceability system implementation started with Electronic Data Interchange (EDI) that has been adopted for information sharing across the supply chains. The EDI shares the information through a network called VAN which stands for Value-Added Network. Since the technology is rudimentary, it is expensive to set up and the transaction costs occupy significant portion of the investment.

7.1.2 APIs

API is an acronym for Application Programming Interface. This gained popularity recently because it is often a small custom-built piece of software code that allows two disparate systems to communicate through electronic means. This type of technology adoption is quite popular in the seafood supply chains.

Since they are purpose-built for 2 systems, it is difficult to extend the usage for including any other system. Thus, including a third system into the information system configuration requires significant time and effort and also is an expensive proposition.

7.1.3 ERP

ERP or Enterprise Resource Planning systems have been a stronghold until recently where the internal traceability is good across the firm level. However, because there are a lot of vendors who are offering these systems, the ERP used across the different stages of the food supply chain relies on different ERP systems that are not necessarily compatible with each other.

One way of solving this information sharing problem is to introduce a cloud-based ERP system which will solve this problem to a certain extent. Indeed, many food supply chains have currently adopted these kind of systems.

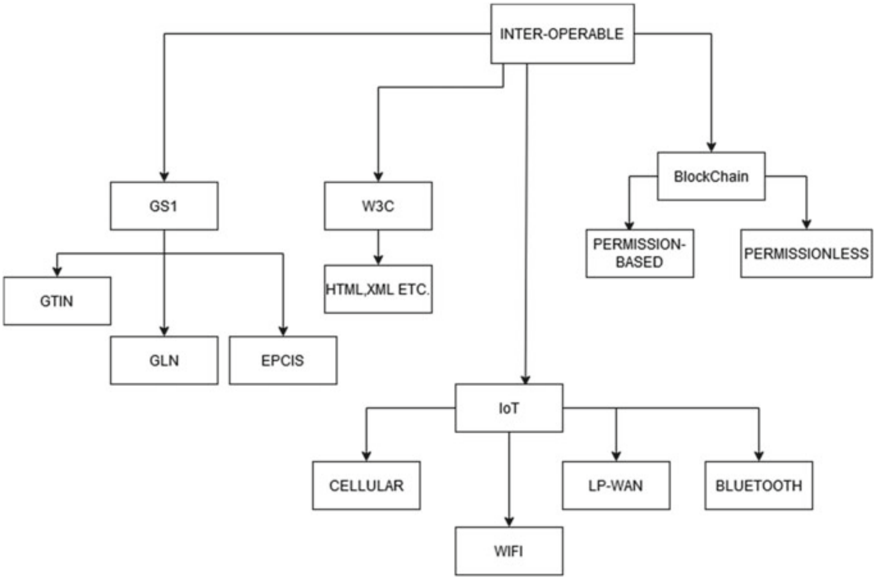

Fig. 4 Inter-operable technologies in food supply chain

In a cloud-ERP, data is entered via a browser that is stored in a cloud database. Often the ERP system is hosted by a third-party technology vendor. While, the cloud systems provide a way of data sharing without a need for a complex information system, the data is still entered manually in the browser which can take significant time and effort. Also, the system is limited in terms of location of data sharing. Any change in the location requires a modification of the information system which can be time-consuming.

7.2 Inter-Operable Technologies

The limitations of the stand-alone systems are overcome by implementing more open and scalable systems to support the tracking and tracing. The following section discusses various such systems (Fig. 4).

7.2.1 GS1

Industry inter-operability with a global connectivity across food supply chains can be enabled by the GS1 standards which precisely allow that. Specifically, the architecture of GS1 allows not only communication among different and hardware and software, they also allow supply chain processes to be integrated. Indeed, the GS1

(2014) standards allow *"interface between system components that facilitate inter-operability from components produced by different vendors"*. The standards are also vendor-neutral and platform-independent system which means a software working in windows can be compatible with a software working in linux.

Currently, SAP and IBM are testing the inter-operability using the GS1 standard. FoodLogiQ, IBM Food Trust, ripe.io and SAP, the four traceability platform providers participating, simulated a seafood supply chain using GS1 standards to identify the item being tracked and transmit the location along the supply chain. (PRN, n.d.)

7.2.2 EPCIS

EPCIS originates from EPCglobal that integrates data capture and data sharing elements. EPCIS is a specific variant of GS1 standard that enables sharing of data on the physical movement of products and ascertain the product status in the food supply chain. By providing this chain traceability, the standards allow compliance to the regulations in place. They also allow capturing different assets in movement such as physical and digital assets.

Since the standard is a variant of GS1, the adoption of this standard requires adoption of the Core Business Vocabulary (CBV) standards emphasized in GS1. The heart of traceability lies in this vocabulary which standardizes the data which is populated in various stages of the food supply chain.

In a pilot test for food traceability called "e-Trace project" (Gunnlaugsson, 2011), it was adopted in a one-day redfish catch for a groundfish processing plant in Iceland through to packaged items for distribution. Taken together, the system allowed integration of various information sources to comply with the food safety standards with provisions for pin-pointing specific points in the production process.

7.2.3 IoT

The **Internet of things** (**IoT**) is a network of physical objects or "things" which have embedded sensors and hardware that connect and exchange data with each other over the internet. In this section, we discuss the various communicative technologies in use for enabling the IoT.

LPWANs

The communication between the different types of IoT sensors is facilitated through Low-power Wide Area Networks or LPWANs which are relatively new technologies. They enable remote monitoring of products, smart metering of things and ensure worker safety and enable building management systems. However, one limitation of LPWANs is they can send only small packets of data and is useful in applications where there is no requirement for high bandwidth or real-time information.

There are many variants of LPWANs that exist today. NB-IoT, LTE-M, MYTHINGS, LoRA, SigFox, etc., are a combination of licensed and unlicensed spectrum of technologies that also have varying degree of performance in network factors.

Cellular Technology

Cellular networks are widely popular and well-tested in the consumer mobile markets. They offer a reliable communication for voice calls and video streaming applications. However, they have high operational costs and consume lot of power.

They are not capable of adoption across all the IoT applications but suited in some specific instances where things are powered by battery-operated sensors. For example, fleet management of food supply chain can be done with route planning, advanced driver assistance systems along with tracking and telematics which consume huge bandwidth of the cellular network. Future supply chain fleets are poised to use the next generation Fifth generation technologies offering significant speeds and low buffering capabilities.

Bluetooth

Bluetooth is a relatively old technology used for short-range applications. However, the advantage is that it is very prevalent and well-positioned in consumer markets with all the gadgets used in entertainment sector adopting this technology. Since, the power consumption of these devices is low, it is ideally suited for IoT applications where things inside a factory need to communicate.

One of the important grouse for widescale Bluetooth adoption was that the deployment of Bluetooth devices was not scalable. However, the Bluetooth Mesh specification which was made in 2017 aims to solve this problem especially useful in the food retail segments. These Bluetooth networks assist customers in navigating the stores and enable customized promotions.

Wi-Fi

One of the important landmarks in wireless communication is the adoption of Wi-Fi standards which provide high throughput data that can be used in enterprise level applications. In the IoT applications perspective, there is still a limitation in terms of coverage, scalability, and power consumption.

Because of the high energy requirements, Wi-Fi is not implementable for large networks with lots of battery-operated IoT sensors which are the mainstay for industrial applications and smart buildings.

But the latest Wi-Fi 6 standards can take this to next level with a greatly enhanced network bandwidth which significantly increases data consumption in dense networks. With this, the infrastructure can transform the customer experience in food supply chains.

EPC/RFID

The **Electronic Product Code** (**EPC**) provides unique identity for products across the entire food supply chain. The EPC is designed as a flexible framework to support different coding schemes including that of barcodes and in a limited way with RFID tags.

Radio Frequency Identification (RFID) transmits miniscule quantity of data pockets from an RFID tag which is read by a RFID reader kept at a close proximity. Each product in food supply chain that is manufactured can be uniquely identified using passive RFID tags.

On the contrary, traditional technologies like bar codes do not have the required capacity for a detailed identification and rather limited to only a group of food products. Attaching an RFID tag to products will enable food supply chains to track their inventory and their assets in near real-time. This greatly enhances supply chain visibility and allows for better production planning and optimizing the supply chain management. RFIDs offer extended capabilities to identify individual SKU-level items that are inside the cartons, eliminating the need for opening them.

RFID currently is widely used in the retail segment and in distribution part of logistics. In a IoT context, this can enable new applications like smart shelves, smart-checkouts and smart mirrors which opens a whole new frontier for consumer experience.

7.2.4 W3C Technology

The **World Wide Web Consortium** (**W3C**) is a consortium of internet standards otherwise termed as the World Wide Web. These standards are useful for web scripting and display of web pages that may contain content ranging from static to dynamic content which are graphic heavy. They also allow compatibility across multiple devices.

W3C standards ensure that the hardware manufacturers and software developers who adopt these standards will have their equipment and programs work on the latest web technologies. Most of the web browsers adopt the w3C standards. For instance, HTML and CSS are formats are widely used in several browsers for consistency in terms of website displays.

Javascript Web APIs, a specific form of W3C standard, are used in client-side Web Application development for Geolocation, XMLHttpRequest, and mobile widgets. To ensure cross-cultural capabilities and languages, HTML and XML are built on Unicode which enable a smooth translation from one language to the other. W3C has also published guidance for authors related to language tags.

7.2.5 BlockChain Technology

BlockChain Technology (BCT) offers a promising means of decentralized and distributed systems for executing supply chain transactions (Ebinger & Omondi, 2020). It was originally used for digital currencies such as Bitcoin and Ethereum. However, since it has the potential for use in other financial services in larger financial companies, it has garnered wide attention and resulted in lots of trials in different industries including logistics and supply chain management.

BCT also holds potential to increase the traceability and transparency of the products in the supply chain by allowing the transactions between two or more supply chain partners to be immutable without a third-party intervention. This enables a tamper-proof digital transaction apart from the decentralization and distribution characteristics. Together, these three characteristics of BCT increase the stakeholders' trust in the entire food supply chain. Trust increases the governance effectiveness through collaboration and thereby BCT plays an important role in achieving a sustainable supply chain (Ebinger & Omondi, 2020).

However, one of the drawbacks of the technology is the limitation on the transaction rates. The permission-less blockchain system limits the size of a block to be a maximum of 1 MB and allows processing rates up-to seven transactions per second. With food supply chains requiring huge volumes of transactions in a second, the current implementation of BCT is not viable. There are current pilots underway in food supply chains to improve this and make it more scalable.

With such a comprehensive set of technologies, we would only expect the food supply chain to have embraced their adoption with open hands. However, as we see in the subsequent section, there are notable barriers to the widespread adoption. Due to the brevity of the article, the authors restrict the discussion to only provide an overview of these barriers.

8 Barriers to Traceability Implementation

The food supply chain is characterised by wafer-thin margins and a lot of competition. The supply chain partners have a scepticism and do not trust the competitors. They tend to guard their SCM practices very closely which creates a lot of information asymmetry. From this context, sharing of information from a traceability perspective is only perceived as very risky venture and goes against their culture. Therefore, implementing Traceability requires a significant level of inter-business collaboration which has not been experienced in the past. Apart from these, there is a multitude of factors that hinder the implementation of traceability technologies (Marah J. Hardt, 2017):

a. *Lack of awareness* of the need for a traceability system and technology at the supply chain level.
b. *Knowledge gaps* of the chain traceability and associated digital technologies.

c. *Resource deficiencies* including that of capacity and funding issues along with technical issues of information technology systems currently in place.
d. *Logistical hurdles* in the operation of traceability systems; Broader adoption requires involvement of multiple stakeholders which makes it difficult.

All these barriers can be addressed through development of a holistic approach towards traceability implementation. Periodic training programmes and creating awareness among consumers will go a long way in overcoming these barriers.

9 Conclusion

SSCM practice adoption is critical for long-term health of humans and for the well-being of the planet. It is worrisome to note that some of the food supply chains engage in fraudulent activities that belie the broader objective with which the SSCM practices were envisaged. The deviations from the regulatory norms need monitoring and managed for potential violations.

Our study reveals that the traceability systems and technologies provide a compatible framework within which such regulations can be implemented leading to SSCM practices. These systems also provide a mechanism of providing chain traceability both internal and external leading to efficient tracking and tracing of food products across the supply chain.

The traceability systems enable tighter monitoring of regulations and at the same time bring in increased supply chain transparency, better collaboration, and increased trust. Technologies like BCT provide promise of tamper-proof supply chain transactions and uphold trust among supply chain partners thus bridging the gap between all the three aspects.

We find that Traceability, in its nascent phase, may also prove to be a significant enabler for attaining the sustainability goals through better governance and increased operational efficiency. There is little doubt that the traceability technology implementation will stand to benefit the food supply chain in the long run.

However, on the downside, the lack of awareness, prevalence of multiple certifications, compliance requirements and number of other factors require significant efforts from the food supply chain actors. In this context, FSIS can play a key role in being a catalyst for traceability implementation. Capturing the origins of product and sharing the data is fundamental at the heart of traceability technologies. The current complexity in the misalignment of various interfaces and standards of the global food supply chain actors can be overcome by increased traceability adoption and standardization by means of inter-operable technologies.

This field offers different avenues for future research. For instance, the traceability systems and technologies in food supply chain provide a ripe opportunity for the researchers to empirically analyse in detail the enablers and the barriers in their adoption which is a limitation of our study. Alternatively, one could explore the empirical connection between traceability technology adoption and the sustainability development goals. Exploring the nature and complexity of challenges in BCT adoption across different country contexts is another research direction.

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Application of Lean Tools in New Product Development: A Case Study from Precision Metrology Manufacturing

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Abstract New Product Development (NPD) constitutes a vital part of every business' strategy to stay ahead of competition, hence companies need to develop standard procedures to incorporate Lean in NPD. Though quite a few firms strive to apply Lean in their NPD processes, they fail to understand how to obtain results par excellence. This knowledge gap could be attributed to the low volume of published works related to Lean NPD. The main objective of this research is to look at the application of Lean tools implementation in various phases of an NPD process in a meteorology instrument manufacturing company and the significant improvements of crucial Key Performance Indicators were analyzed and discussed in detail. Based on the analysis, the study proposes a practical Lean framework for businesses to use. The chapter discusses the lessons learned and the implications for engineering production managers based on the case study. The findings of this study show the impact of implementation of lean tool to improve the business performance.

Keywords New product development · Lean manufacturing · Case study · Precision metrology

1 Introduction

In the globalized industry of today, numerous companies constantly strive to deliver high-quality cost-effective product solutions so as to improve their competitive advantage. In this quest to maximize value and product quality for the customer, as well as reduce lead times and costs, the philosophy of Lean Thinking is commonly adopted by manufacturers as a tool for continuous improvement (Buer et al., 2020). When the concept of Lean Thinking was first introduced by Womack et al. (1990),

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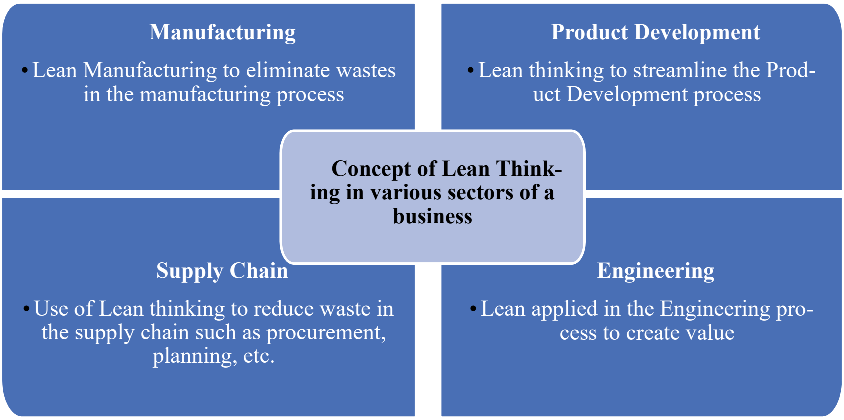

Fig. 1 Concept of lean thinking in a business

it acquired global attention and gained popularity within the manufacturing sector striving to improve its efficiency performance. As years passed and as globalization became more evident, Lean Thinking went on to be accepted into Product Development, Supply Chain, Engineering and other important sectors of businesses in addition to Manufacturing (Fig. 1). Coming to today, as companies continue to use Lean in a pursuit to increase efficiency with minimal resources, it is becoming more and more important to utilize Lean in the Product Development phase itself in order to obtain maximum value and stay ahead of competition (Hao et al., 2020). The application of a Lean approach within Product Development would help to counter several challenges in terms of cycle times and costs related to the development and production of the new product (Nepal et al., 2011).

Product Development is like a driving force for businesses around the world as they are tasked with the responsibility to formulate entirely new products or modify existing product solutions to fulfill consumer demand (Tortorella et al., 2015). The terms New Product Introduction (NPI) and New Product Development (NPD) are often used interchangeably in various industries as part of launching a product solution into the market.

While NPD is concerned with the design and feasibility of a product, NPI is more focused on the manufacture of a viable working product and its consequent release into the market. However, for the purpose of this research, the terms Product Development or New Product Development (NPD) will be used to refer to the entire process of launching a new product into the market i.e. from the preliminary design phase to production until release of the product into the market.

Firms have been attempting to apply Lean in their NPD processes for years using appropriate Lean tools and techniques early on in their product lifecycles. However, some face difficulties in carrying out Lean Product Development (Salgado & Dekkers, 2018) because they fail to understand the fundamental philosophy of the use of these tools and how they can best be used strategically to provide results par excellence. This research will cover a case study to demonstrate Lean NPD practices at one of UK's top manufacturers within the precision metrology industry. Furthermore, this research will seek to identify and provide a practical framework for manufacturers who wish to undertake a Product Development process from a Lean perspective. As more and more industries come up with complex products to compete in their respective markets, the demand for accurate and ultra-precision metrology solutions for production machinery has greatly increased; when machinery become imprecise, production specifications cannot be met. This is where metrology solutions come in to facilitate the inspection process required to assess their fit and performance according to the specifications. Especially in key industries such as aerospace, automotive, defence, etc., where precision is critical, metrology solutions are used to measure components down to the smallest unit of measurement. The purpose of this research is focused on filling this knowledge gap in the area of Lean-related approaches at NPD levels, an area of study which has received very less attention through the years.

The book chapter is structured as follows: next section the literature review conducted is presented in detail. Section 3 presents the details of the case study followed by the analysis of the data obtained from the case study in Sect. 4. In Sect. 5, the findings of this research are concluded.

2 Literature Review

In this section, authors will be presenting the detailed literature review on the considered topic by highlighting key elements and developments in the area of Lean NPD practices.

a. **Origin of 'Lean Thinking'**

Due to the tremendous constraints placed on resources following the Second World War, Toyota, the Japanese-origin automobile manufacturer, experienced in the 1940s enormous difficulty and was on the brink of bankruptcy. It was during this time that a group of Toyota employees, led by the plant manager Taiichi Ohno, took influence from what they had observed during their tour of the US-based Ford manufacturing plant and set to develop a number of tools and techniques to streamline production and eliminate waste at the Japanese plant, which came to be known as the Toyota Production System. All in all, the Toyota Production System was a framework developed by engineers at Toyota which focused on continuous improvement and elimination of non-value adding activities, or wastes (mudas) (Liker and Morgan, 2006).

When it comes to tracing the origins of the concept of Lean, it is a bit of a debate since some researchers see the Toyota Production System as the foundation of the Lean methodology, while others believe the origin of Lean was quite apparent much earlier in the approaches and vision set by Ford (Samuel et al., 2015). Subsequently, it is generally understood and widely acknowledged that the book The Machine That

Changed the World by Womack et al. (1990) led to the introduction and influx of the Lean revolution into the West. The authors in this book used the term "Lean" to describe the Toyota Production System (TPS) which was predominantly implemented and utilized in Japan, especially for mass production. By this time, a number of Japanese manufacturers who had adopted the system and were already using it for more than 20 years had a competitive advantage over other manufacturers around the world.

Additionally, Womack et al. (1990) in their work also covered a study about the US-based New United Motor Manufacturing, Inc (NUMMI) founded in the 1980s which was jointly owned by General Motors as well as Toyota to understand if a classic mass-production plant as implemented by Western economies could be converted into a factory run on the foundation of Lean thinking. In doing this, the authors were successful in obtaining suitable empirical evidence to prove that transformation was very much possible, and that productivity and quality could be drastically higher in a Lean production plant. Further to this, the book also covered various topics related to the essential elements of Lean Production and how it could successfully replace classic mass production methodologies in order to increase quality and flow as well as minimize time.

Following this, in the late 1990s, Lean principles were further described and explored by Womack and Jones (1996) in their book Lean Thinking where the authors described the significance of the advantage of enhanced value to the customer foregoing waste elimination and cost reductions which form as a result of Lean practices. Seven wastes as identified by T. Ohno at Toyota which are usually found in mass production operations plus one waste identified by the authors have been described in this book. In addition to this, five Lean principles mainly related to value, flow, pull systems and establishing perfection were also covered. The book also covered examples of firms such as Porsche and Pratt and Whitney which were successful in introducing Lean thinking and in maintaining an upward path in their business journey. Furthermore, included in this book was a suggested action plan for organizations to use in order to incorporate Lean strategies and thus, transform their businesses. As agreed by various authors (Hines et al., 2004; Womack & Jones, 1996) a vital principle in the Lean philosophy is a focus on value and the act of constantly revisiting what the customer perceives as value is quite necessary, followed by eliminating all tasks which do not add value to the final product or service. The above sources definitely helped companies in the West, especially those in the manufacturing industry, to gain an insight into the Lean methodology and its immense potential benefits, and motivated them to develop and incorporate it into their processes.

b. **Previous research on Lean New Product Development**

Over the years, as the demand has increased for less-expensive innovative products with the highest quality, all products must have to go through a respective NPD process in order to reach the market at the right time and in order for this to happen, every NPD process has to be exclusive. The implementation of Lean in NPD attracts research interest since the beginning of the twenty-first century and though the volume of research in this field has been relatively less compared to the application of Lean in manufacturing, there is a growing interest in this topic (Baines et al., 2007). By applying lean manufacturing in NPD processes, i.e. by the approach of Lean Development, a business is able to eliminate Lean wastes such as waiting time, over-processing and overproduction in the NPD process itself, before the new product is released into the market, thus ensuring an efficient process, while also reducing lead times and saving costs (Lind, 2008). Haque and James-moore (2004) identified ten wastes occurring at various levels within an NPD process—at operational, strategic and project management levels as well as highlighted the importance of cross-functional teams to enhance value of the product. As part of this work, case studies were conducted at aerospace firms like Rolls-Royce and the Weston Aerospace to evaluate the implementation of Lean at different hierarchy levels in the NPD process. Short-term projects to deliver immediate results (the Kaizen-Blitz approach) were contrasted against macro-level projects in the studies of both the firms. Consequently, a link between effective Lean NPD processes and supporting information technology was identified in addition to an absence of a sustainable Lean framework in new product processes which was observed. Various authors such as Morgan and Liker (2006), Nepal et al., (2011) in their work, also stressed on the significance of integration between teams as a critical aspect for the success of Lean NPI processes.

Furthermore, an extended research programme, the UK Lean Aerospace Initiative (UK LAI) has previously researched the implementation of Lean in NPD within the aerospace industry as a means to increase productivity and competitiveness of the UK aerospace sector. Under this initiative, experts conducted studies for a period of about eight years and observed the workings of 45 UK-based aerospace companies (Parry et al., 2008). In this context, numerous researchers have identified that Lean concepts are immensely essential for the efficient implementation of NPD processes especially in the aerospace industry leading to high-quality products being introduced in a short span of time with minimal resources.

A more recent research conducted by Salgado and Dekkers (2018) deduced that Lean NPD practices were a combination of standard NPD processes coupled with principles of Lean thinking and relevant tools selected by managers based on their previous knowledge and intuition to allow for a Lean Product Development process to take place. Furthermore, Marodin et al. (2018), observe a link between Lean Manufacturing and Lean Product Development, where the former had a positive effect on the latter as well as on the operational performance, hence suggesting that in order to realize many Lean implementation benefits, businesses should implement both Lean Manufacturing and Lean NPD methodologies simultaneously. Furthermore, various authors such as Ward and Sobek II (2007) and Khan et al. (2013) in their respective works attempted to define a clear framework for Lean Product Development, however none of these have been considered as the generally accepted approach (Van Der Braak et al., 2018), though they possess overlapping features such as set-based concurrent engineering and leadership within teams.

A quantitative survey was also conducted to calculate and compare the volume of research conducted in the field of Lean manufacturing versus the application of Lean

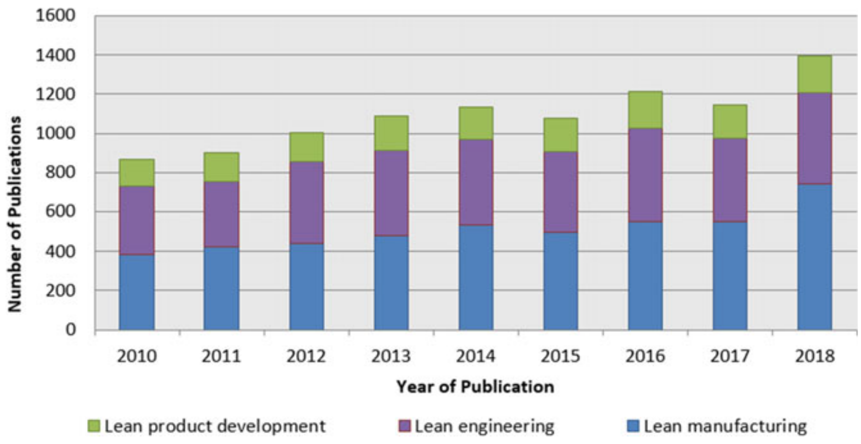

Fig. 2 Overview of retrieved publications by year

thinking in New Product Development (NPD) through the years in order to gain a better understanding of the need for more research in the latter field as described above. For the purpose of data collection as part of this quantitative survey, data related to a number of publications in the form of journal articles, reviews, book chapters and conference papers available on Scopus were used. As illustrated in Fig. 2, the horizontal axis displays the years beginning from 2010 until 2018 while the vertical axis represents the total volume of research material published during each corresponding year in the past eight years commencing from the year 2010. The lines in the graph represent the topic of Lean in manufacturing versus studies related to Lean in Product Development processes. For the purpose of this survey, keywords—Lean manufacturing, Lean engineering and Lean product development were used. The graph reveals that although the number of ’Lean manufacturing’ and ’Lean engineering’ publications substantially increased annually, research related to Lean product development has remained limited throughout the years. A similar study by Jasti and Kodali (2015) identified that limited research was conducted in the field of Lean Product Development and also called for an important requirement of further research in this field.

In addition, an analysis related to the frequency of industries across publications was conducted by Salgado and Dekkers (2018), in which the authors observed that the automotive and the aerospace industries were the most dominant industries in research related to Lean Product Development/Introduction. Baines et al. (2007) also support that the automotive sector is the most successful in implementing lean NPD compared to other industries. Thereby, it is important to conduct further studies in this area as well as assess the importance of Lean Development practices in Product Development Processes (PDP) in a high-performance quality-assured competitive industry like that of the metrology industry.

3 Methodology

The following research methodology (refer Fig. 3) was followed during the course of this study. To begin with, the authors conducted a brainstorming session in order to identify a relevant problem statement related to the field of Lean Engineering. Once an effective problem was identified, a literature review which covered various aspects of Lean thinking, New Product Development and the significance of the metrology industry was undertaken. Furthermore, a quantitative survey to analyse numerous papers was also completed as part of the literature review. Next, a case study to study the various phases of the NPD process was conducted at the selected case study company in United Kingdom (further details are provided in the next section), where data was collected and analyzed to understand how key KPIs were impacted by a Lean NPD process. Using the results obtained, the authors formulated a Lean Manufacturing framework for use in NPD processes and recorded their conclusions in addition to evaluating future steps in Lean NPD practices.

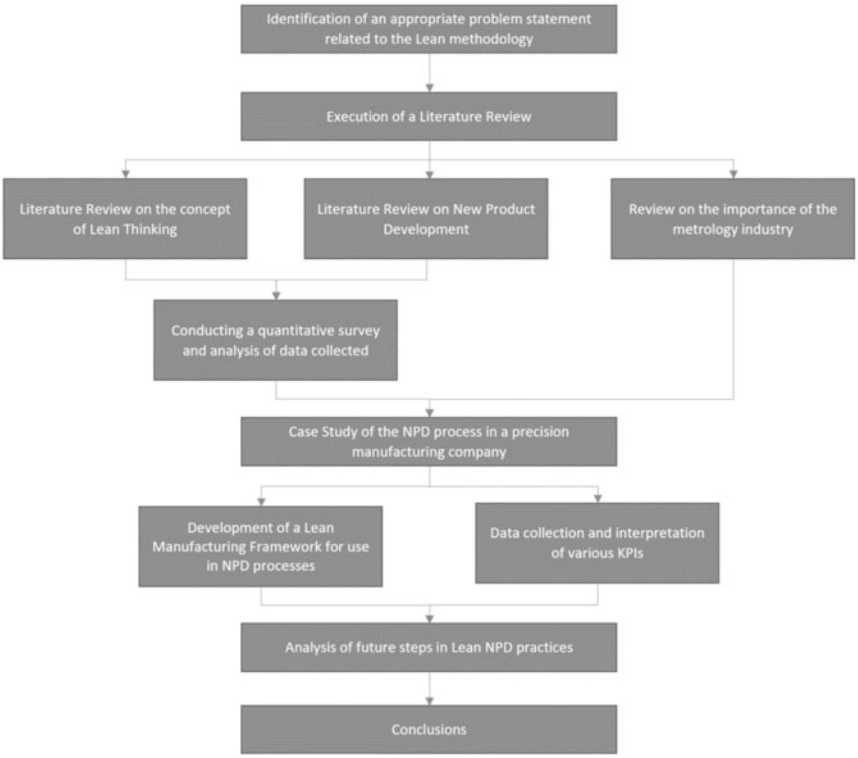

Fig. 3 Research methodology

4 Case Study

The metrology industry has a competitive advantage over others since instruments supplied by this market are vital for the proper functioning of other industries, hence, the demand for metrology instrument solutions is huge.

A case study was conducted at one of the UK's leading manufacturer and supplier of precision metrology instruments, best known for conducting robust and reliable measurements of roundness, cylindricity, surface form, surface finish, angle and straightness amongst others. The case company is in the metrology industry for over 100 years and supplies high standard instrument solutions customized to the needs of each critical market such as aerospace, optics, automotive and defense industries. At present, the company is working on technology related to non-contact measurement solutions as part of its strategy to expand its market reach. Based in central England, the head office houses an assembly unit for the assembly and testing of instruments as well as a machine shop for parts manufactured in-house in addition to the main office and the goods store. This main office is made up of departments such as Information Technology, Human Resources, Finance, Business Development, R&D and Operations (Purchasing, Materials Planning, Service and Manufacturing). The use of an effective and efficient MRP (Manufacturing Resource Planning) system is crucial to the growth of the business in addition to allowing for efficient communication between departments, and it is for this reason that the case company makes use of a rather Lean MRP system in the form of Microsoft Dynamics Navision (NAV) to aid in increased productivity. This MRP software is useful in integrating various processes within the business, especially related to operations such as Manufacturing, Purchasing, Assembly, Inventory, Finance, Sales and Planning. Moreover, it is through this planning software that the overall process from order intake until when the order is packed, shipped and invoiced to the customer takes place.

Key stakeholders in the NPD process include representatives from the Business Development, R&D as well as Manufacturing Engineering departments. The structure of the Product Development team involving key stakeholders is illustrated below in Fig. 4 in the form of a matrix organizational structure. The significance of this type of a matrix management lies in the specialty that employees report to more than one head for every individual project, which is quite common in Product Development processes that are usually cross-functional in nature.

A single Business Development Manager is usually assigned to a particular range of instruments and is responsible for all products within this range. In addition to growing a business in line with the strategies of an organization, an additional major role of the Business Development Manager and his team usually resides in the field of Product Development, i.e., in the awareness of current market needs and trends as well as the identification of new opportunities to tap into various markets. Following the address of a perceived market need and the suggestion of a new product, the Business Development Manager is assisted by his team in the development and release of a price list on various sellable configurations for the particular new product.

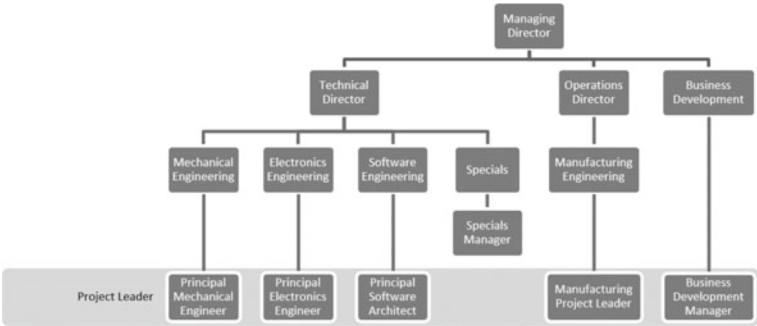

Fig. 4 Product development organization structure

For these reasons, the Business Development team forms a crucial part of the Product Development process. It is then the task of the Engineering/R&D team to research and innovate relevant technology in order to develop a robust reliable product through effective design reviews and systematic testing. Moreover, the R&D department is also responsible for the patenting of novel techniques and original designs, if any at the case company.

In addition to managing NPD projects under their leadership, it is the responsibility of the Project Leader to supervise projects as per the company's Product Development Strategy to respective project timescale, cost and quality as well as to report relevant progress to the Technical Director. On the other hand, the role of the Principal Engineers (Mechanical, Electronics and Software) involves overseeing design issues of all products linked to their specific discipline besides overlooking training of personnel within his department. Further, playing a critical role in the Product Development process is the Specials team overlooked by the Specials Manager and it is this team that is responsible for the development of products customized for various clients according to their specific requirements.

An individual Manufacturing Engineer is selected as a Manufacturing Project Leader to champion the project from an Operations perspective. It is the role of this Manufacturing Project Leader to streamline the particular Product Development project in terms of setting up a Lean manufacturing as well as a Lean supply chain process for the new product. A detailed description of the role of the Manufacturing department at different stages of the Product Development process is explained in further sections within this report.

The case company's NPD process is structured to be in line with relevant ISO (International Organization for Standardization) standards in order to facilitate and ensure a high quality as well as standardized process for all projects undergoing the Product Development process. In general, any project as part of NPD, undergoes a four-phase gated process from when the project is kicked-off until the new product is signed off and released into the market. Ideally, a gated process is a project management technique that allows for efficient management of a process with gates/decisions

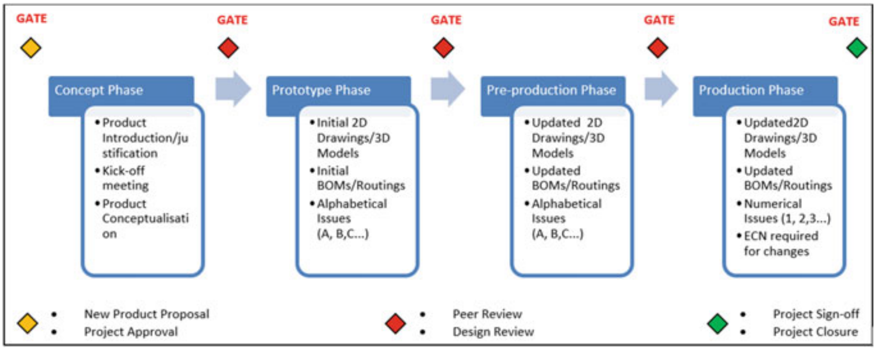

Fig. 5 Process of new product development undertaken at the case company

to make between each phase of a process. An outline of the NPD process undertaken by the company is illustrated below in Fig. 5.

Demand for an instrument such as Product A which provides additional functionality in precision measurement compared to existing metrology solutions was noticed in the market. Hence the idea of developing an advanced system with brand new software as well as latest capabilities for contour, surface finish and 3D measurement was identified and undertaken. In addition, this new product instrument solution would be fitted with new electronics in addition to new technology and modular furniture, thus giving clients the latest world-leading metrology instrument capable of high-precision measurement solutions. Product A consists of five modules, required to be assembled onto the instrument while Optional Accessories such as Modular Furniture are non-compulsory to the instrument's operation and are supplied or not, depending on the customer's choice. It is important to note here that each Required Module is structured to contain sub-assemblies that are then brought together to form that individual module, so as to ease the assembly process of the instrument.

The entire process of Product Development of Product A was observed by the authors. This included all stages from the concept phase of the project until its subsequent sign-off and release into the market. In addition to understanding the process, the authors also played a significant role in assisting the company's Operations personnel in making use of appropriate tools and techniques at various stages in the Product Development process in order to set up a Lean manufacturing approach as well as a Lean supply chain environment. Following the completion of the Product Development process and the implementation of suitable techniques for Lean manufacture, results from NAV, the company's MRP system, were compared in order to assess the impact of Lean in Product Development processes.

Since the purpose of this work deals with the manufacturing environment to develop a Lean Product Development process, subsequent sections outline various stages in the Product Development process followed by a description of relevant Lean tools and techniques utilized by the Manufacturing team at the case company to facilitate a smooth release of the new product into the market.

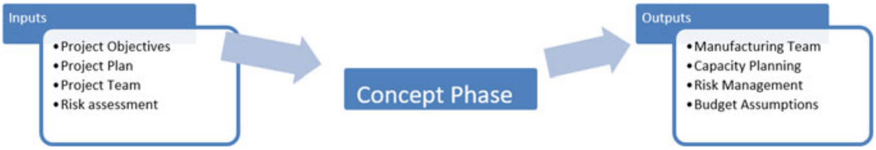

Fig. 6 Concept phase

(a) Concept Phase

Prior to the first phase of a Product Development project, a proposal for a new instrument in addition to its return on investment is presented in the midst of the Directors which once justified is approved, thus initiating the project. The Concept phase, also known as the Feasibility phase, is a crucial stage where the new product is conceptualized and target costs, as well as project requirements comprising instrument specifications, are developed and defined to the relevant stakeholders.

Appropriate inputs and outputs are present at every phase of the NPD process from a Manufacturing perspective. Inputs represent the volume of material/data available to the Manufacturing team while the outputs constitute tasks to be completed under the leadership of the Manufacturing project leader. As shown below in Fig. 6, the relevant inputs and outputs that are made available to the Manufacturing team during the Concept phase include the project objectives, analyzing project plans and budgets; which are crucial since they give an insight into the project. Moreover, risk management is crucial to the entire process of Product Development, especially in this initial phase. Hence, it is necessary that valid risk plans are specifically developed for each project and passed onto all stakeholders since every project is unique to another. Risks are detrimental to the efficiency of the process and overall project timescales, resources, project costs and plans should be accounted for in the risk assessments.

(b) Prototype Phase

It is during the Prototype phase that initial design documentation in the form of 2D drawings, 3D models, Bills of Materials (BOMs), routings (for parts machined/assembled in-house) and purchase specifications (for purchased parts) which meet the project requirements and the project concept are released and issued. Routings are usually an ordered sequence of processes (including finishing processes) required to produce a completed part or finished assembly which gives additional information in relation to the breakdown of hours and cost per process thus giving Engineers a perspective to manage their processes efficiently and effectively.

Figure 7 represents the inputs and outputs in the Prototype stage during which crucial inputs include skeleton/initial Bills of Materials (BOMs) which are made available by R&D to the Manufacturing team and a list of possible long-lead components as well as new processes or techniques used, if any, while key outputs expected to be fulfilled from a Manufacturing point of view at this stage comprise a prototype delivered to the expectations of the R&D team, identification of families of parts as well as setting up appropriate training for relevant assembly and service personnel.

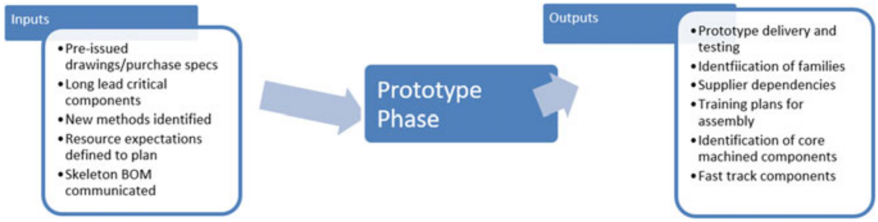

Fig. 7 Prototype phase

Generally, as part of NPD, companies develop various Bills of Materials (BOMs), most importantly eBOMs and pBOMs. While eBOMs (Engineering BOMs) which form the input to an NPD process are usually created by the Engineering team directly exported from the CAD system and are a list of parts or components that make up an assembly or sub-assembly as designed, pBOMs (Production BOMs) are specifically developed to represent a product from the point of view of its manufacture. These pBOMs which are derived from eBOMs are generally developed by the Manufacturing team as outputs of the NPD process for the purpose of ease of Manufacture and Assembly and are entered into the MRP system as well as used by various departments within Operations to manage manufacturing processes. Coming to supply chain dependencies, Original Equipment Manufacturers (OEMs) have been exposed to competitive suppliers on a global stage to procure relevant components from. Suppliers/vendors supply parts to manufacturers who integrate these into their finished products. Having multiple suppliers for a particular part decreases the dependency on a single source. Thereby, during the NPD process, it is important to understand vendor sourcing for high priority items and identify supplier dependencies as well as consider possible risks during assessment.

Regarding the crucial outputs to the Prototype phase in the NPD process as illustrated above, a family of parts or a product family is a collection of similar parts whose similarity in process Routings (if machined in-house), design or procurement (for purchased parts) facilitates structured planning and Lean BOMs. Product families can be added onto the MRP system as a single line item onto BOMs instead of multiple line items. It is the duty of the Manufacturing Engineer to keep crucial points in terms of stability of design, demand per week among others before creating a family of parts.

(c) **Pre-Production Phase**

Figure 8 illustrates the Pre-Production phase where drawings at Pre-Production issue in addition to a defined testing plan form a crucial input while outputs at this stage comprise the completion of all planning documentation as well as the completion of the manufacture, assembly and testing of a Pre-Production batch of instruments. During this stage, it is advisable for Manufacturing Engineers to work towards setting up of Kanbans either for families of parts, or sub-assemblies.

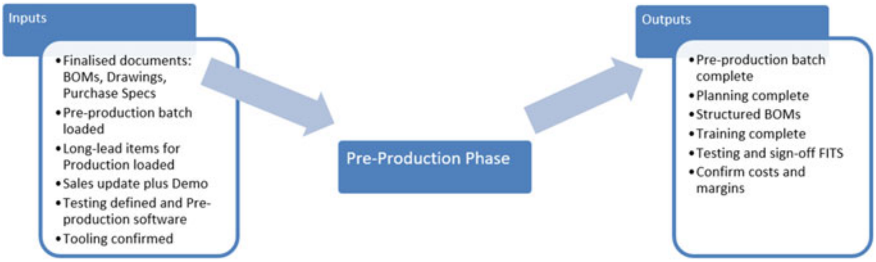

Fig. 8 Pre-production phase

Standardized work, a crucial Lean tool successfully utilized at the Toyota Plant is commonly used especially by various manufacturers as part of Product Documentation processes to document the best practice in order to complete a task. This tool ensures a high-quality process and provides a sequence of work instructions to the operator required to allow a task to run smoothly. Subsequently, at the case company, standardized work in the form of planning documents (created by a Manufacturing Engineer) is commonly made use of to carry out the assembly and packing of instruments, and in turn minimize common Lean wastes such as excessive motion or waiting time. These documents which streamline processes, provide a baseline and reduce variability contain work instructions for the Assembly Technician on how to put together sub-assemblies, modules and lastly the final instrument. It is important to note here that the format of these planning documents is uniform throughout. In addition, visual management through the means of 3D animations is made use of as part of the assembly process to allow personnel to better understand the assembly process sequence and waste less energy, time and resources. Once standardized work documents are in place and training of relevant Assembly staff has been completed, the cycle time taken to assemble a particular module, or the final instrument is recorded by a representative from Manufacturing Engineering. Training of staff is vital since it has been observed to result in the basic elimination of waste (Lewis & Cooke, 2013). Poka-yoke also known as 'mistake proofing' is a Lean technique commonly made use of as part of Standardized Work to make mistakes impossible and get processes right the first time itself (Saurin et al., 2012). Completion of all relevant planning documentation by the end of this phase is crucial to the success of the entire NPD process.

It is very important to meet the target cost of the new product initially set up at the beginning of the NPD process. The Engineering team can control costs by conducting a Cost–Benefit Analysis to ensure a Lean design while the Manufacturing team can aid Engineering in the design process by providing expertise in the form of benchmarking on choosing the right processes in order to bring together the final instrument. Additionally, Manufacturing Engineers can aid in meeting costs of the new product by working with cost-saving strategies. One such strategy which can be applied for purchased parts involves working closely with the Purchasing Team and suppliers to obtain volume quotes on a contractual basis for a minimum

Fig. 9 Production phase

quantity/minimum period. In addition, strategic sourcing in the form of identification and the development of supplier dependencies for purchased parts can also have an effect on the total cost of the instrument. For machined parts, increasing lot sizes in a single batch of parts while simultaneously maintaining efficient output is crucial to cost reduction since a cost saving would immediately be reflected due to reduction in the set-up time per part. All in all, it is essential that relevant stakeholders in the Product Development process discuss crucial cost implications at every Peer/Design Review.

(d) **Production Phase**

Finally, Fig. 9 representing the Production phase demonstrates principal inputs such as the necessity of all drawings to be at Production issue by this stage while outputs represent Production of instruments to take place on time to the necessary specifications. In addition to meeting target costs of a new product, it is the responsibility of the Manufacturing Project Leader to obtain a selling forecast of the instrument from the Sales Team in order to aid in the setup of a highly efficient and Lean manufacturing and Lean supply environment for the new product. It is important to note that once drawings and models enter the Production phase, an Engineering Change Note (ECN) is required to make and record changes in the future.

All in all, key deliverables in a NPD process from a manufacturing point of view are the finalized testing schedules, production Bills of Materials (BOMs), planning documentation, confirmed costings, spares policy and finalization of service requirements. The achievement of these deliverables is crucial to the success of this project or new product and for its successful release into the market. Following a successful release of the new product into the market, as well as once deliverables have been achieved by all relevant stakeholders, the new product is reviewed and signed off, thus completing the NPD process and closing off the project.

Pull-based Kanbans which safeguard the continuous supply of components when needed are an efficient Lean tool capable to improve operational performance (Rahman et al., 2013). Kanbans provide the benefit of zero lead time of the component within the system. In the case of the metrology manufacturer, Kanbans were used as a pull-through system for machined parts and families as well as for the assembly of various modules of the new instrument. A Kanban system was also put into place for machined families to ensure a continuous flow of parts and components so that demand is fulfilled at all times.

Furthermore, in order to encourage workers and increase their satisfaction towards their jobs, the case company introduced a Suggestion Scheme wherein employees put in their ideas to help the business improve its operational practices by eliminating waste. An internal team reviewed the suggestions on a monthly basis to decide if they are worth pursuing and accordingly award a cash reward to the ‘Best Suggestion’. In addition, visual signs as well as cellular manufacturing were used for the manufacture of all parts machined in-house and instruments assembled within the Assembly bays. These Lean tools facilitated high-quality processes and increased performance as well.

5 Proposed Framework and Results

Lean Product Development is quite experimental, encompasses a combination of tools and techniques and it is entirely up to managers to choose appropriate methods relying on their experience and their company’s competitive practices (Salgado & Dekkers, 2018). Hence, based on the information and knowledge gained related to Product Development during the case study, a framework of Lean tools was developed for businesses to consider towards effectively implementing Lean manufacturing operations in NPD process (Fig. 10). In the initial phases of NPD, i.e. during Product Introduction, risk management is quite important since the risk of a new project is quite high and therefore it is essential to accordingly manage and minimize the chances of a risk in the product concept and feasibility phases. Checking for supplier quality and dependencies can be performed during the Prototype (Prelimnary Design) phase of a new product. In addition, creation of Lean skeleton pBOMs can also start to take place in this phase. Usage of appropriate methods such as product families and flattened structures to create Lean pBOMs is quite essential to the process of NPD in order to eliminate waste and indirectly save money for the business. The Pre-Production (Detailed Design) phase is the most crucial when it comes to making use of Lean techniques in NPD, in the sense that it is during this phase that the planned product is very close to meeting its system requirements, hence tools such as Kanbans, Standardized work and Cellular layout can be put into place to achieve zero-lead time on all machined components and assemblies, where possible. The approach of JIDOKA is quite helpful for quality control in the NPD process as well since it stops a process once a defect has been detected and doesn’t allow it to resume until it has been resolved. Furthermore, rather than following decisions made by the top management of an organization, recommendations implemented from suggestions made by workers have a positive impact on the company as a whole in addition to encouraging a Lean environment. The Suggestion Scheme as covered in the case study was an excellent opportunity for workers to express their ideas and encourage them to deliver their best towards creating value for the company.

In general, the Lean philosophy in Product Development optimizes resources and effort put towards creating and delivering more value for customers and other stakeholders of the new product. Without streamlined processes in Product Development

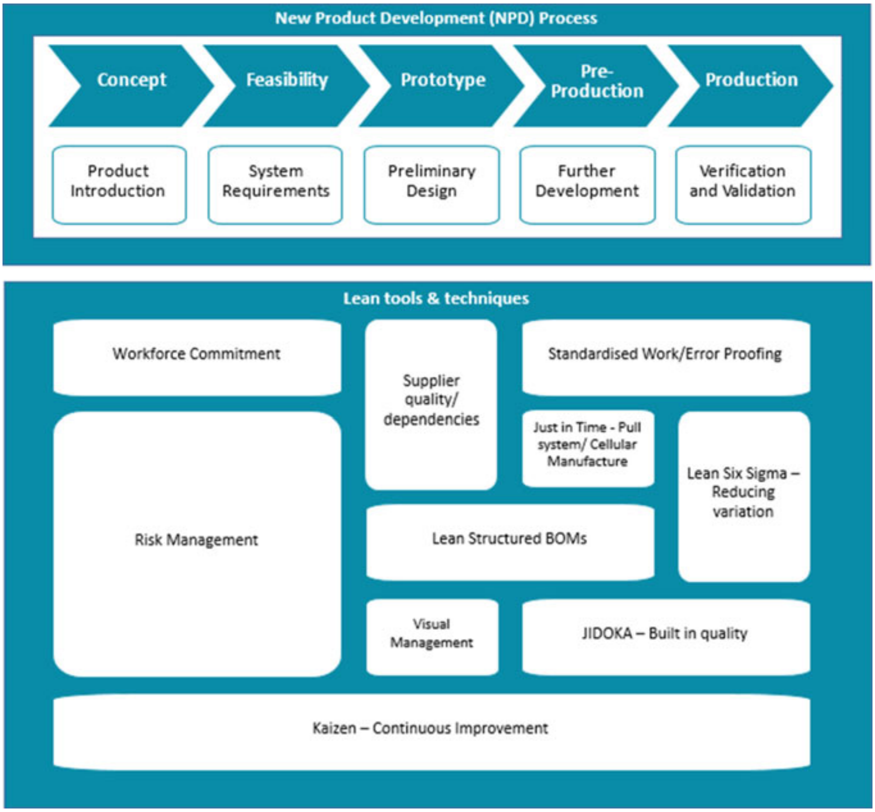

Fig. 10 A lean manufacturing framework for use in NPD processes

aimed towards creating value and achieving perfection, companies would simply end up wasting unnecessary resources, money, time and energy. It has been determined that almost 50% manufacturers across various industries around the world prioritize innovation and commonly make use of Lean as an improvement tool to integrate into their existing manufacturing processes. Nevertheless, they do not focus on creating value during the Product Development processes and reaping the benefits of Lean during NPD (Kronos Incorporated, 2016). Key Performance Indicators (KPIs), crucial to a NPD process monitoring and assessment, are the total cost of the new product, time-to-market, lead time, cycle time, on-time delivery, etc. Therefore, it is essential that businesses look into implementing Lean strategies in Product Development, especially through the Lean Development approach, where appropriate tools and techniques are made use of, in order to improve their performance in various KPIs.

The implementation of the Lean tools and techniques in various phases of the NPD process, as previously presented, led to significant improvements in various

KPIs. Initial data was collected during the Prototype phase for Product A while final figures were obtained at the production phase just before sign-off of the NPD process.

- Lead Time: Lead time was presumed to be the time taken to machine a component/family in-house from the time the MRP system releases an MO till when the resulting part is delivered into inventory. A 100% reduction was achieved due to the setup of Kanbans which resulted in zero-lead time for each and every machined component as well as family of parts within various modules of the new instrument. In addition, the setup of Kanbans aided in getting rid of unnecessary inventory by ensuring that excess products aren't present, while enough inventory being available at all times according to the sales forecasts.
- Cycle Time: Generally assumed to be the time taken to perform a particular task. In this particular case, cycle time was presumed to be the time taken to assemble various modules of the instrument, Product A, as well as the time taken to bring together the entire instrument. It is to be noted that a reduction of about 50% was obtained in the cycle time by means of standardization tasks as well as setting up of Kanbans for various Modules A-E of the instrument. In this way, when a customer order for the instrument comes in, Assembly personnel consume pre-built Modules from the Kanban stock to build the entire instrument, thus resulting in almost half the amount of time saved.
- Total Cost of the instrument: The total cost of an instrument assembly consists of four major categories—Material, Sub-contract, Labour and Overhead costs. Firstly, a material cost reduction of about 3% was obtained on purchased fabrications within the new instrument just by exploring opportunities with low-cost suppliers for supply on a contractual basis. By means of standardization, wastes such as unnecessary motion and waiting time were reduced leading to a cost reduction of 15% in terms of labour and overhead.

6 Conclusion

This research presented a case study which highlights the incorporation of lean tools in NPD and evaluates the benefits resulting from their use. The case selected has been based on a precision metrology instrument manufacturer and enabled the identification of Lean tools and techniques making a significant contribution towards the improvement of various efficiency KPIs in the context of NPD. Specifically, lead time, cycle time and total cost were significantly reduced as a result of the use of lean tools including standardization, Kanban, visual management, cellular layout and improvement suggestions scheme, marking the achievement of a highly efficient, lean-based NPD process.

As we move towards Industry 4.0, a new generation of industrial revolution, and as more and more data and information become available, it is increasingly important that smart metrology is used to ensure reliability of the data sources (Lazzari et al., 2017). Future research in the field of Lean NPD comprises finding ways to integrate the proposed Lean framework with Industry 4.0, as well as implementing an even more detailed framework for the setup of a Lean supply chain in the Product Development process.

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Assessing Application of Lean and Green Practices in Indian Hotel Industry Using Thematic Analysis

Snigdha Malhotra, Tilottama Singh, and Deepali Ratra

Abstract Accommodation industry has been accepted as one of the most profitable industry across the globe. The contribution of this industry to the growth of the economy is widely accepted by many countries and India is not an exception to this. Opportunity and participation of organizations in adoption of Lean and Green management strategies are increasing but it remains a challenge in hospitality industry. Over a period of time various steps have been undertaken to increase the application of green technology in Indian Hotels. Recognizing this very fact, the current paper aims at exploring the Lean & Green practices prevailing in the Indian hotel industry. A structured questionnaire was developed to collect the information from hoteliers, who are contributing to the industry for more than 8 years. Usable responses were ($N = 6$) analysed by thematic analysis using Nvivo software. The analysis of data revealed that Indian Hotel Industry is already in practice of applying the lean and green practices but still there are certain practices which are not being given much importance like energy conservation, stakeholder involvement, employee trainings and innovative sustainable practices though these practice are currently neglected stage but these can contribute to the future growth of the organization. This paper is an attempt to shift the focus of hotel industry from water and waste management to other important factors as well. The results of this study may not depict the entire picture of lean green practices at Indian hotel industry, as the sample was restricted to few hotels in India. Researchers may undertake further studies with larger hotel samples. Future researches can be done to investigate smaller, lower-ranked hotels, which may experience greater challenges in implementing lean green practices than those considered in this paper.

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1 Introduction

The hotel industry is a booming sector, which has been developing and coping with changing scenarios. A survey conducted by Trip Advisor.com in 2019, highlights that the growing needs of travelers have been shifting from economy and luxurious hotels to Green and Lean hotel avenues. As per 62% of the respondents, the environment remains the primary factor while looking for the hotel, meals and transport, which reflects that people are becoming more environmentally conscious and prefer environment-friendly hotels. The tourism sector is quite dynamic, and now they need to become more sensitive to the environment and social needs due to the changing perspective of their clients (Fernández-Robin et al., 2019). Since last few years, conscious efforts have been taken by hotels to become ecofriendly and minimizing waste via adoption of effective Green and lean practices. It is not a new concept; many hotels are there which have been following lean and green practices from more than three decades. While many are there, which have been just presenting themselves to be environment friendly to attract the customers as implementing lean and green practices involves investment. However, it is always in the best interest of the hotels to adopt these strategies for their long-term growth (Pizam, 2009). For example, in the restaurant industry, the installation of energy-saving equipment do involve massive initial investment. However, it results in the tremendous saving of energy and money over a long period. (Bentley, 2007). Thus by employing the Lean and Green practices, the industry can not only attract the environment-friendly clients by providing them with the quality trip but can also save its resources and environment.

Though lots of Literature available on examining the lean and green practices in hotels and how this is the future of hotel industry in forthcoming years, yet there is a research gap with respect to practical application of such strategies in hotels, which have been addressed in the present study.

The objective of the present study is to investigate the application of Lean and green Management practices followed in the hospitality sector and to make the statement about their suitability and the possible potential for optimization (Choudhary et al., 2019) Thus, it studies the lean and green practices prevalent in Indian hotel industry with specific reference to five-star properties and answer questions like What are the critical areas implementing lean green techniques and how effectively these strategies are adopted by the hotels, critical focus areas of implementation. To accomplish the underlying objectives, thematic analysis has been applied, by interviewing the experts in this industry on NVIVO. In this study, a qualitative analysis using thematic technique has been deployed to understand the current state of green lean methods implementation in hotels. Though many hotels are a part of the green lean league, yet there is a gap in exploring the strategies implemented by these properties at various levels and varied areas. Hence, the study uses the thematic technique, which is a family of qualitative social research methods that formalize, to varying degrees, the process of developing themes, which give detailed insight into the qualitative data. The themes represent a pattern of responses within the data.

Further, the results are interpreted understanding the degree of implementation of lean and green practices in the five-star properties. Several researchers presented applications of lean principles to supply chains. For example (Zarei et al., 2011), developed an integrated approach that links Lean Attributes (LAs) and Lean Enablers (LEs) to increase the leanness of a food supply chain. It is found that the application of Lean and Green practice are having significant impact on sustainable performance of the supply chain of the hotel industry (Hussain et al., 2019). It is required for the hotel's sustainability framework to include environment standards, safety standards, reduction, recycling, reuse, take back, energy efficiency, water conservation, green technology, clean transport, hazardous material treatment, etc., for the conservation of resources, reduction of energy and emissions and efficient recycling.

The qualitative study arrives at five major themes depicting the areas of implementation and has made a conscious effort to highlight the current state and ways to adopt green lean methods in hotel industry.

The study provides a platform for future research in hospitality sector with reference to green lean strategies implementation. With changing scenarios and future of work the hotel industry is also striving hard to achieve competitive advantage in the segment of green hotels. For gaining such advantage the hotels need to strive for being environment friendly and rigorously implement such practices (Gustin & Weaver, 1996).

1.1 Objectives

This paper gauges the elements and practices that lead hotels to become environmentally sound. This study is an attempt to gauge whether management and employees are keen in hotels that indulge in lean management and green technology. The in-depth interviews with the executives of hotel industry aim to study the current status of practices adopted as these practices culminate in the hotel's cost-saving, but the lack of rigor may be demonstrated at different levels of implementation. Moreover, the study also illuminates on the future roadmap and suggestions for executives to employ better lean and green practices in the Indian Hospitality Industry.

2 Literature Review

Recent era has witnessed that in order to enter the marketplace, to sustain in the market place and to grow in the volatile hospitality market environment a business has no choice other than adoption of lean and green practices in Hospitality Industry. During last decade, a numerous studies have been conducted in the field of lean and green management in general and specifically in Hotel Industry. The firms need to maintain a balance between the economic and environmental performance because of regulatory, competitive and community pressure (Zhan et al., 2018).

Laing and Frost (2010) investigated a number of the problems encompassing the management and staging of a green event. It examines the importance of stakeholder participation and considers numerous ways in which events are greening their operations. Hotel Association of India (HAI), (2012) The key problems that the Indian cordial reception trade has got to address are known and summarized by HAI's president by the form "HITES", that effectively denotes the efforts of the HAI team to make sure that HAI continues, as within the past, scale new "HITES". The letter E within the form stands for "environmental concerns".

In their study examined that hotels that voluntarily plan to green policies acquire higher results than alternative hotels. The conclusion is that governments should not solely regulate, however additionally promote awareness actions in little and medium-sized (SME) tourism corporations to boost the setting. SME tourism corporations should perceive that each setting and they themselves can profit.

Babita Krishnan (2016) found in her study that India is not behind in the application of sustainable practices in different industries, and the aim of these policies is to reduce carbon footprint of the country. It is discussed in the study that the major focus of hotel industry in India is on energy and water conservation, and linen reuse. The study also involved an assessment of responses from guests regarding their participation or likeliness of hotel, if the property is involved in green practices. It was concluded that since the evidence of environmental involvement of hotel and customer satisfaction was weak, the hotels need to involve these strategies into their daily practices for better results and acceptability.

Alameeri et al. (2018) stated that lean and green practices are the key components of sustainable management which aim at reducing wastage, increasing efficiency and achieving the sustainability.

Mbasera et al. (2016) mentioned that green practices adopted by hotel industry are defined as the environmentally friendly activities undertaken to become more sustainable. There can be eight environmental or green wastes namely greenhouse gases, eutrophication, excessive resource usage, excessive power usage, pollution, waste, excessive water usage and poor health and safety. The aim of the green practices is to reduce the environmental footprint, i.e. to reduce the hazardous emission, eliminate consumption of wasteful resources and minimizing the health risk during the whole cycle of production or supply (Marhani et al., 2013). It includes all the activities ranging from the monitoring to general environmental programme to proactive practices implementation through various R's. The various R's are reduced, reuse, recycle, refurbish, rework, reclaim, remanufacture, reverse logistics, etc. (Keller & Daugherty, 2001).

According to Farish (2009), the lean strategy was originated by the Toyota, to achieve zero wastage in their production process. The main objective was to cut the wastage and speed up the production or services without compromising quality and cost. It focuses on the seven factors: overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary movement (Womack et al., 1991). Lean management is a five-stage process, which involves value, value stream, flow, pull and perfection. The customer specifies the value, value stream specifies all the activities required bringing the product to the customers, third stage is to create the flow, in the final stage let the customer pull the product and the last one is the perfection. These steps are cyclical and aimed at continuous improvement (Archibald et al., 2011).

Both the techniques focus on the waste reduction, whether tangible or intangible. Both practices are complementary to each other (Dües et al., 2013). The lean practices are perceived to reduce the wastage, improve productivity and quality, to optimize the utilization of resources so as to deliver value to customers (Pakdil & Leonard, 2014) on the other hand green practices are perceived to lower the environmental risk and improving the ecological efficiency (Tseng & Bui, 2017). Due to the similarities on "cutting waste" between lean and green, lean manufacturing could be a pre-requisite step for implementing green. The concept of waste and waste reduction techniques are well complementing lean and green. (Dües et al., 2013) and the integration of both the techniques are having synergetic effect on the improvement of both the environment performance and operational efficiency (Choudhary et al., 2019). The above discussion indicates that the current study has been undertaken to explore less researched area, i.e. adoption of lean and green practices in Indian hotel industry.

2.1 Research Gaps

Researches discussions show that there is an apparent shift in Indian Hotel Industry towards implementation of Lean and Green practices and there has been a sudden adoption of plethora of sustainable practices at different levels and processes. (Hussain et al., 2019) Implementation of these practices has helped hotels to move towards productivity easily. More attention is paid to Hotel industry for adaption of lean and green practices as they have high usage of water and energy. The environmental negligence in this industry is causing alarming situations around us.

Sue to the changing climatic conditions and increasing Global warming, the customers are insisting organizations to be involved in practices that support environment protection, waste reduction and energy conservation. The study by (Dües et al., 2013) identified that Lean and Green practices are interlinked with each other and implication of Lean practices itself paves a way for faster implementation of Green practices. Lean and Green practices have been helping organizations since long to produce manifold profits and conserve environment simultaneously.

Hillary (2004) and Tzschentke et al., (2008) stated that there is a huge cost involved in implementation of green practices in hotel industry. The costs might include auditing, accreditation, training and development of employees, equipment installation cost, and green or eco-friendly certification fees, etc., which become a burden on any hotel which is not minting reasonable profits. Solar Panels, Low Flow Showers, Linen Reuse, Paperless Check-in and Check-out are a few strategies that are largely implemented in Indian Hotel Industry.

According to Choudhary et al. (2019) numerous researchers and practitioners have recommended value stream mapping as a basis for implementation of lean practices; but very less research is done to understand the lean and green paradigms to reap maximum benefits for organizations.

Thus, the three important contributions of the study are:

- The development of an insight on practical implementation of Green Practices by famous 5-star Hotels in India with the help of interviews conducted.
- The identification of barriers if any in implementation of Green Practices.
- The interview statements are analysed in Nvivo Software to identify the trend of Green Practices and to lead to identification challenges faced in Hotel Industry to adapt these practices efficiently.

3 Methodology

The methodology is divided into subsections explaining the design of research, nature of participants in the beginning and findings in the later part.

3.1 Research Design

Experts (n) were requested to share their response according to a semi-structured interview. The interviews helped the authors to identify issues and challenges faced by Indian Hotels in implementation of green lean strategies. In addition, it helped the authors to gauge the gaps in implementation of Lean and Green strategies. Hotel representatives working in Delhi NCR, Pune and Goa were interviewed. Thematic analysis was employed to analyse all interview responses. A list of codes was generated and organized according to categories and themes (Table 1).

3.2 Participants

Ten managerial level hotel employees were approached for conducting the interview, out of which seven managers agreed for it. 5 male employees and 2 females employees having an association with five start properties like Leela Palace Chanakyapuri, ITC Hotels, Leela Udaipur, Crowne Plaza Pune, Hyatt Delhi for more than eight years were interviewed for this study. The respondents fall in the age bracket of 32–40 years old. The academic background of these respondents is diverse as we had four employees with Master's degree, one with a diploma and two employees with Hotel Management specialization with MBA. Since the objective was to interview more experienced professionals of Hotel Industry, four employees had more than ten

Table 1 Themes or codes generated

	Themes	Description	References
1	Waste management	Waste from the hospitality industry consists of both wet and dry waste. The wet waste consists primarily of food waste which can account for more than 50% of the hospitality waste and up to one-third of all the food served within the hospitality sector	Mohan et al. (2017)
2	Water management	Hotels apply 4Rs: Reducing, Reusing, Reaching and Recycling strategies to manage their water resources efficiently	Kasim et al. (2014)
3	Sustainable practices	Green or eco-friendly practices in the accommodation sector are growing around the world. Conscious customers demand these services	Jones and Lockwood (1998)
4	Energy management	Energy efficiency and conservation at hotels is an essential practice. Hotels can benefit from using renewable energies for example water-heating, space heating and air-conditioning. Using renewable energy can reduce local air pollution, maintain destination quality and enhance the guest experience	Londoño and Hernandez-Maskivker (2016)
5	Stakeholders participation	There is a dominance of supply-chain stakeholder interests, which in turn outline the CSR orientation of hotels, whereas stakeholder influence, largely shaped by the interdependent, multi-faceted nature of the tourism industry, conditions the implementation of CSR in hotels	Farmaki (2019)

years of experience in hotel industry while rest had more than eight years experience (Table 2).

Instrument

We developed a focus group protocol with five open-ended questions and used clarifying enquiries as required during interviews. Questions were designed by using scale

Table 2 Participants summary

Participants	Organization	Designation
1	Hyatt group	Manager HR
2	Indian Hotels Company Limited	Manager HR
3	Oberoi group	Manager HR
4	InterContinental hotels	Director, sales
5	Leela hotels	Manager HR
6	ITC hotels	Manger HR

developed by Chan (2013a, 2013b), the questions were designed to assess intention of implementation of the lean green practices and hiring behaviours of participating organizations.

How does your Hotel try to align itself in each of the following areas:

Please list as many activities as you can.

1. Are water conservation measures given priority at your hotel? How is water management done?
2. Efficient Energy Management can result profitable to hotels. Is your Hotel involved in energy management?
3. Waste is waste no matter the shape or size and it all goes in the dumpster. However, for the smart hotel owner, that is not always the case. Waste Management is done innovatively by the hotel industry. Kindly elaborate.
4. It is imperative that stakeholders be involved in all stages of planning. With stakeholder support, sustainable tourism plans are more likely to succeed. How are you involving your Stakeholders in implementing lean and green supply chain of your Hotel?
5. Any other Sustainable Initiatives (if any) taken by your Hotel.

3.3 Results and Discussions

During the interview, the respondents shared various areas in green lean strategies in hotels and its relations to various aspects like customer dealing, operations and waste management. However, the paper presents the themes emerging out of the interviews and suggests strategies for effective implementation (Table 3).

3.4 Suggestions to Increase Green Lean Practices in Hotels

Respondents were invited to share their views on present adoption of green lean practices in these various five-star properties and the ways to increase such practices. Many themes tend to emerge through these interactive discussions; however, the following major themes were considered for the study (Fig. 1).

Table 3 Summary of respondents' feedback on green lean practices adopted in hotels

	Suggestions to increase green lean practices	Number of feedback	Percentage
1	Waste management	4	52.15
2	Water management	6	62.75
3	Sustainable practices	5	56.7
4	Energy management	4	34.3
5	Stakeholders participation	4	28.3

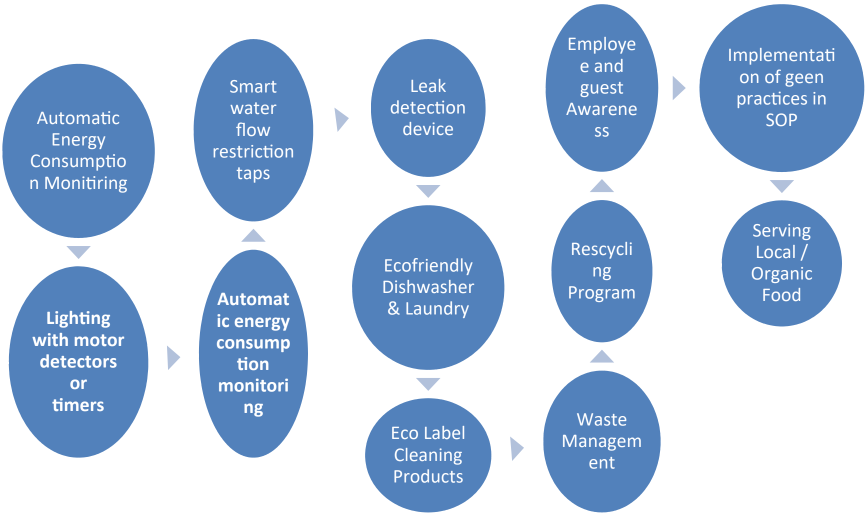

Fig. 1 Themes emerging in thematic analysis. *Source* The authors

Majority of respondents (62.75%) have stated that majority of the properties work on water conservation both at operational level and by incorporating various infrastructure measures to save water. In addition, 56.7% of the respondents have also showcased how implementation on ground level through operations is helpful in effective implementation of green lean methods. Third major area highlighted by 52.15% of responses was waste management and recycling followed by the infrastructure layout of the hotels matching the sustainability requirement supported by 34.3% of responses. Then the other critical areas like effective laying of Hotel SOP's and employee awareness with respect to such sustainable measures act as key tools for implementing such practices.

Thus, the findings revealed that "water conservation" is considered as a very important agenda, and themes emerging out of it are "effective use of water", "supply and efficient use of energy", and "use of renewable energies". It was observed while "water" remains the focus area for all five-star properties and given most importance, other important issues like Energy & Waste Management, Using Biodegradable Material and Paperless Check—in and Checkouts, etc., still need attention. The results of this study can encourage managers/practitioners in hotel accommodation to concentrate on the indicators that could promote the implementation of green and lean practices effectively either through stakeholders or by adopting them as a part of Hotel's SOPs. It would further help the Hotel to attract both national and (inter)national tourists and moving towards sustainability, which is the need of hour.

The results also show that hoteliers are focusing and adapting Water Conservation and Waste Management very efficiently and with great focus, while there is very less attention given to other measures like Stakeholder involvement, Energy management and other Sustainable practices. Energy management remains weakest amongst all, as the hotels who are using biogas and other natural resources are efficiently managing it, while others adopt only contemporary practices like LED lights, solar panels, etc.

4 Limitation and Directions for Future Research

The study only captured the managers and above employees working in five-star properties for more than eight years. Perhaps, in the future, it may be worth investigating perspectives and experiences of hotel employees at various levels and globally providing a vast area of scope and research. Further study should also be conducted using mix methods in order to capture broader and more insightful data. In spite of some limitations associated in this study, the results of this research provide meaningful findings that should be of interest to both researchers and hotel professionals especially in India.

5 Conclusion

Researchers have identified that lean environment is integrated with green implementation. This integration has been stated very significant to companies and presenting Green as the new Lean is no longer a surprising statement (Mollenkopf et al., 2010).

As the awareness regarding climate change is increasing, there is a relevant pressure on Hotel Industry from the customer's end drive their business towards Lean and Green Practices and state themselves as environmentally responsible properties (Simons and Mason, 2003).

Gary G. Bergmiller, University of South Florida (2009) in his research has told us how leading Lean manufacturers are benefited from Green manufacturing. He has stated the need to produce Zero Waste systems, as they would be most efficient to achieve Economic success as well as move towards sustainable development activities. The objective of economic and environmental success have to go hand in hand, they cannot move in different directions for any hotel/ company. And to achieve this,

Fig. 2 Word cloud obtained from Nvivo

he has stated that Lean Management and Green Technology are the two efficient strategies. His findings are relevant and applicable to Indian Hotel Industry.

The paper demonstrates the parameters for the implementation of lean green practices in Indian Hotel Industry. Feedback from six hoteliers on their identification of application of practices at their workplace was done. Five parameters were finalized for the study after the review session with authors and past researches. Semi-structured interviews were conducted and transcripts were recorded by the authors. The transcripts were run in Nvivo to analyse the themes and major focus areas of Indian Hotels. The results demonstrate the barriers faced by the industry. Particularly, this method successfully obtains the areas we need to give more attention to. The results from word cloud as represented in Fig. 2 and truncated report Table 4 shows that Water Conservation and Waste Management are largely highlighted and are paid more attention to. Stakeholder Involvement, Sustainable practices and Energy Management are less highlighted and thus need to be improved. Amongst these, stakeholder involvement and energy management would be taken into deeper consideration. This study contains certain limitations. Firstly, the shortage and complexity to reach respondents to ensure the validity of the research, future researchers can design a more detailed questionnaire to achieve better exploration. Secondly, future studies should try to involve empirical analysis to increase the implementation of lean and green practices in hotel industry. This would pave way for new trends in future.

Table 4 Truncated report from the coding in NVivo

	IHG	LEELA	IHCL	OBEROI	HYATT	ITC
Energy	**14.29%**	**4%**	**7.14%**	**0%**	**7.14%**	**12.82%**
Carbon footprint	0%	0%	3.57%	0%	0%	2.56%
Reducing carbon Footprint	0%	0%	0%	0%	0%	2.56%
Electricity	0%	4%	0%	0%	7.14%	0%
Cut electricity	0%	4%	0%	0%	0%	0%
Electricity usage	0%	0%	0%	0%	7.14%	0%
Energy audits	0%	0%	0%	0%	0%	2.56%
Energy consumption	14.29%	0%	0%	0%	0%	0%
Low-power systems	0%	0%	0%	0%	0%	2.56%
Greenhouse gas emission	0%	0%	0%	0%	7.14%	0%
Solar energy	0%	4%	3.57%	0%	0%	5.13%
Stakeholders initiative	0%	4%	7.14%	0%	7.14%	2.56%
Plan	0%	0%	3.57%	0%	7.14%	0%
Incentive plan	0%	0%	3.57%	0%	0%	0%
Prevention plans	0%	0%	0%	0%	7.14%	0%
Program	0%	0%	3.57%	0%	0%	0%
Loyalty programs	0%	0%	3.57%	0%	0%	0%
Supply	0%	4%	0%	0%	0%	2.56%
Organic products supply	0%	4%	0%	0%	0%	0%
Organic suppliers	0%	0%	0%	0%	0%	2.56%
Sustainable	**28.57%**	**0%**	**3.57%**	**10%**	**0%**	**5.13%**
Cost-efficient business practices	0%	0%	3.57%	0%	0%	0%
Local employment opportunities	0%	0%	0%	10%	0%	0%
Responsible	14.29%	0%	0%	0%	0%	2.56%
Corporate responsibility	0%	0%	0%	0%	0%	2.56%
Environmentally responsible	14.29%	0%	0%	0%	0%	0%
Sustainability program	14.29%	0%	0%	0%	0%	0%
Sustainable initiatives	0%	0%	0%	0%	0%	2.56%
Sustainable wines	0%	0%	0%	0%	0%	2.56%
Waste	**0%**	**16%**	**7.14%**	**10%**	**14.29%**	**12.82%**
Bottling	0%	0%	3.57%	0%	0%	0%
Bottling plant	0%	0%	3.57%	0%	0%	0%
Plastic bottles	0%	0%	3.57%	0%	0%	0%
Composting	0%	4%	0%	10%	0%	0%
Composting machine	0%	4%	0%	0%	0%	0%
Making compost	0%	0%	0%	10%	0%	0%
Food	0%	0%	0%	0%	14.29%	2.56%
Food donations	0%	0%	0%	0%	7.14%	0%
Food waste prevention training	0%	0%	0%	0%	7.14%	0%
Inedible food waste	0%	0%	0%	0%	7.14%	0%
Offering food	0%	0%	0%	0%	0%	2.56%
Organic waste	0%	0%	0%	0%	0%	2.56%
Recycling waste water	0%	4%	0%	0%	0%	0%

(continued)

Table 4 (continued)

Reusing waste chemical	0%	4%	0%	0%	0%	0%
Sanitation treatment plant	0%	0%	3.57%	0%	0%	0%
Single use plastics	0%	0%	3.57%	0%	0%	0%
Soap recycling	0%	0%	0%	0%	0%	2.56%
Straws	0%	4%	0%	0%	0%	2.56%
Biodegradable straws	0%	0%	0%	0%	0%	2.56%
Paper straws	0%	4%	0%	0%	0%	0%
Replacing straws	0%	4%	0%	0%	0%	0%
Using carts	0%	4%	0%	0%	0%	0%
Using fertilizers	0%	0%	0%	0%	0%	2.56%
Vegetation waste	0%	0%	0%	10%	0%	0%
Waste disposal system	0%	0%	3.57%	0%	0%	0%
Wet waste	0%	0%	3.57%	0%	0%	0%
Water	**0%**	**4%**	**10.71%**	**20%**	**0%**	**7.69%**
Efficient water	0%	4%	0%	0%	0%	0%
Greywater systems	0%	0%	0%	10%	0%	0%
Hybrid water	0%	4%	0%	0%	0%	0%
Recycling waste water	0%	4%	0%	0%	0%	0%
Regional water risks	0%	0%	0%	0%	0%	2.56%
Reusing water	0%	0%	0%	10%	0%	0%
Using water conservators	0%	0%	0%	0%	0%	2.56%
Waste disposal system	0%	0%	3.57%	0%	0%	0%
Water harvesting	0%	4%	0%	0%	0%	2.56%
Rain water harvesting	0%	4%	0%	0%	0%	0%
Water harvest	0%	0%	0%	0%	0%	2.56%
Water usage audit	0%	0%	3.57%	0%	0%	0%
Water-saving practices	0%	0%	3.57%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%

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Analysing Green Aspects in Lean Manufacturing for Textile Industry Using Grey DEMATEL Approach

Shivam Goyal, Sanskriti Goel, and Vernika Agarwal

Abstract The increasing stakeholder's demands towards lean and green products are driving the organizations to redesign their operational strategies. Textile Industry being one of the fundamental industries in our daily lives is becoming a major environmental issue as it is the major factor for environment deterioration. In order to minimise the various environment issues like water pollution due to discharge of chemicals in processing the raw materials and to manufacture the finished products with minimal wastage of resources, Lean in Green manufacturing is a major concern. The present study aims at understanding the motivational factors which can direct in achievement of Green in Lean manufacturing in Indian Textile industry, so as the manufacturing has the least impact on the environment. The aim of the present chapter is to understand the relationship between the motivational factors in achieving economic, social and environmental aspect. The focus is to identify the motivational factors which can help in attainment of Green in Lean manufacturing. Grey Decision trial and evaluation laboratory (DEMATEL) methodology in employed for understanding the contextual relationship between motivation factors. The present study is being validated using the case of Indian Textile sector.

Keywords Textile industry · Green · Lean manufacturing · Grey DEMATEL · Stakeholders

1 Introduction

The outline and liability of the business industry in today's era lies with the interest of organizational as well as social welfare (Prasad et al., 2020). The textile industry generates a lot of waste while dyeing and bleaching in which various chemicals are used to process the apparel or raw material, which in return discharges wastewater containing toxic substances and heavy colour that pollutes the environment

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(Gonçalves et al., 2019). Lean manufacturing is an ongoing effort on waste reduction whereas the main focus of green manufacturing is to reduce the dependence on environmental sources(Nallusamy et al., 2015). Lean manufacturing mainly focuses on waste reduction, based on reducing the wastes discharged from various processes like dyeing and bleaching. Green manufacturing focuses on avoidance of discharge of toxic wastes generated from bleaching and dyeing in the water bodies, pollution control as well as using renewable sources for electricity generation (Prasad et al., 2020). Due to absence of green resources and their increased prices, there is an ardent need to focus on green in lean manufacturing practices which will lead to effective and efficient utilization of green resources along with minimal wastage.

Thus, the requirement of investigating green in lean manufacturing by scrutinizing the main focus areas is increasingly in demand by the businesses. Further, working manufacturing processes in order to inculcate green manufacturing practices as well as to do least possible wastage by using the resources in best possible efficient way (Nallusamy et al., 2015). The ideology of green in lean manufacturing not only would save the environment but would also lead to run effective business globally for long-term value creation. Effectiveness in the following manufacturing strategies is the need of the hour in every organization in today's era especially where the manufacturing operations are machine-oriented, so the manufactured products are made out of minimal wastage and through environment-friendly ways to often gain a streaming valuing in the textile industry. The motivational factors like ergonomic value stream mapping and product stewardship, etc., lay the emphasis on the requisite focus areas, i.e., green as along with lean manufacturing in the textile industry.

The Objective of the study:

- To deliberate over the motivational factors leading to lean-green manufacturing in the Textile Industry.
- To understand the interrelationships between the motivational factors
- To group these motivational factors into cause and effect in order to provide the decision makers with clear picture.

In order to meet these research objectives, the present study utilises Grey DEMATEL approach that will not only help us in analysing and knowing the relationships among the motivational factors, also further assist in prioritizing these motivational factors according to their level of influence. The use of grey systems theory in combination with DEMATEL method seems an effective and victorious way in order to deal with the obscurity and uncertainty of data.

The chapters are classified into the following sections, Sect. 2 elaborates the review of the literature. Section 3 discusses the numerical illustration. Section 4 discusses the result and analysis. Section 5 discusses the conclusion and limitation.

2 Review of Literature

The following section provides the literature review of the existing studies and researches conducted on textile industry. It discusses about how each one of the motivational factors lead in achieving the very goal of green as well as lean manufacturing in the textile industry in this dynamic environment in between 2007 and 2020. The present study aims at understanding the motivational factors which can direct in achievement of Green in Lean manufacturing in Indian Textile industry, so as the manufacturing has the least impact on the environment.

A case study-based paper by Saleeshya et al. (2012) states that techniques like value stream mapping, Kanban and agile manufacturing are the motivational factors resulting fairer returns in the continuous processing industry to gain the very objective of lean manufacturing in textile industry. A research study (Tsai, 2018) lays emphasis on adoption of practices like activity-based manufacturing along with the theory of constraints and technical aids like mathematical modelling as well as Industry 4.0 techniques for environment conservation by maintaining green supply chain management. Whereas TPM aims at proper maintenance of plant and machinery by following the concept of agile manufacturing for productive and smooth flow of functions in the industry as stated in the paper by Sakti et al. (2019) whereas OEE (Overall Equipment Effectiveness) is the gold standard for measuring manufacturing productivity as well as complying to the environment protection norms for pollution prevention leading to achieve green as well as lean textile manufacturing industry. The compliance of SMED principle (Silva & Godinho Filho, 2019) is to reduce the time required to set up and adapt the changed sewing style from time to time to carry out operation effectively and efficiently. Paper by Desore and Narula (2018) states the role of product stewardship in the industry. Product stewardship in textile industry is an approach to look upon all the possible green practices at different stages in their production, use and disposal to take every possible bit of material and resources into use for achieving the goal of green manufacturing. Whereas the research by Ajmera et al. (2017) discusses the importance of lean six sigma is a combination of lean manufacturing and six sigma. In order to achieve lean manufacturing Lean Six sigma makes a combination leading to waste elimination and process improvement. The concept of circular design in the paper by Maia et al. (2013) in textile industry promotes the objective of green manufacturing.

The papers published on the prevailing topic have classified their research on various research methodology. The papers collected for literature review have their basic focus on DEMATEL, Grey, Best Worst Method. All the listed papers have used one of the above methodologies in their papers to see the importance of motivational factors in Lean or Green manufacturing. In our research, we have used a combination of both Grey and DEMATEL approach to understand the motivational factors in textile industry. The usage of Grey DEMATEL methodology resulted in removal of vagueness and uncertainty of data. The review of literature (given in Table 1) reveals that earlier no work is done in context of Green in Lean Manufacturing in Textile industry and even no author has elucidated a combination of Grey DEMATEL

Table 1 Identification of factors from literature

Agile manufacturing	Activity based costing	Theories of constraints	Value Stream mapping (VSM)	Product stewardship	Pollution prevention	Single-minute exchange (SMED)	Kanban
M1	M2	M3	M4	M5	M6	M7	M8
–	–	–	–	✓	–	–	–
–	–	–	✓	–	–	–	–
–	–	–	–	–	–	✓	–
–	–	–	✓	–	–	–	✓
–	–	–	–	–	–	–	–
–	–	–	–	–	✓	–	–
–	–	–	–	–	✓	–	–
–	–	–	–	–	✓	–	–
–	–	–	–	–	✓	–	–
–	–	–	–	–	✓	–	–
–	–	–	✓	–	–	–	–
–	–	–	–	–	✓	–	–
✓	–	–	✓	–	–	–	–
–	–	–	✓	–	✓	–	–
–	✓	✓	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–

(continued)

Table 1 (continued)

Total productive maintenance (TPM)	Green supply chain management (GSCM)	Circular/regenerative design	Additive manufacturing	5's OEE	Lean six sigma	References	Sector
M9	M10	M11	M12	M13	M14		
–	–	–	–	–	–	da Silva et al. (2019)	Textile industry
–	–	–	–	–	–	Ahmed et al. (2018b)	Textile industry
–	–	–	–	–	–	Desore and Narula (2018)	Textile industry
–	–	–	–	–	–	Ahmad (2018a)	Textile industry
✓	–	–	–	–	–	Goforth (2008)	Textile industry
–	✓	–	–	–	–	Gonçalves et al. (2019)	Textile industry
–	–	✓	–	–	–	Maia al. (2013)	Textile industry
–	–	–	✓	–	–	Nallusamy et al. (2015)	Footwear/apparel industry
–	–	–	✓	–	–	Prasad et al. (2020)	Textile industry
✓	–	–	✓	✓	–	Rusinko (2007)	Textile industry
–	✓	–	–	–	–	Ajmera et al. (2017)	MSME

(continued)

Table 1 (continued)

Total productive maintenance (TPM)	Green supply chain management (GSCM)	Circular/regenerative design	Additive manufacturing	5's OEE	Lean six sigma	References	Sector
M9	M10	M11	M12	M13	M14		
–	✓	–	–	–	–	Sakti et al. (2019)	Carpet industry
–	–	–	–	–	–	Saleeshya et al. (2012)	Textile industry
–	–	–	–	–	–	SChMIDT and Fang (2016)	Textile industry
–	✓	–	–	–	–	Tsai (2018)	Textile industry
–	✓	–	–	–	–	Tseng (2009)	Textile industry
–	–	–	–	–	✓	Weerasinghe et al. (2019)	Textile industry

methodology as we have done for our paper. The present study is conducted to identify the green approaches which lead to lean manufacturing by scrutinizing various motivational factors and applying the approach of Grey DEMATEL methodology.

3 Numerical Illustration

3.1 Research Design

The main aim behind the research design is to identify the motivational factors which can fulfil the stakeholder requirement of the textile industry leading to lean in green manufacturing. An extensive survey on the literature as well as varied discussions with various stakeholders was done in return to find out the list of motivational factors. Seven stakeholders were identified for the interpretation of the data. The team of stakeholder comprises of 3 customers, 4 textile industrialists. This assorted team of stakeholders were selected to incorporate various perspectives into the decision-making process. Based on the consensus of these stakeholder, the following motivation factors were shortlisted:

- **Agile Manufacturing (M1)**: Agile manufacturing deals with the dynamic environment. This manufacturing style deals with everchanging consumer needs and changes in the market trends to keep up with the dynamic environment (Saleeshya et al., 2012).
- **Activity-based costing (M2)**: Activity-based costing is a cost reliable style of manufacturing. It mainly focuses on optimum segregation of costs as per costs incurred in every activity undertaken while manufacturing (Tsai, 2018).
- **Theories of Constraints (M3)**: Theories of constraints is the most constructive approach. It underlines all the hindrances that stand on the path of achieving the organizational goals in any way (Tsai, 2018).
- **Value Stream Mapping (VSM) (M4)**: The implementation of VSM is an effort for acknowledging and realizing the best possible results out of the people and processes by observing the previous activities and accordingly deciding the future implementations for lean manufacturing (Gonçalves et al., 2019; Nallusamy et al., 2015).
- **Product stewardship (M5)**: Product stewardship in textile industry is an approach to look upon all the possible green practices at different stages in their production, use and disposal to take every possible bit of material and resources into use (Desore & Narula, 2018).
- **Pollution prevention (M6)**: The effluents resulting from the textile industry generate numerous pollution problems. Through R&D, use of conventional technologies, ecological technologies can bring a change (Goforth, 2008).
- **Single-minute exchange (SMED) (M7)**: The purpose of SMED principle is to reduce the time required to set up and adapt the changed sewing style from time

to time to carry out operation effectively and efficiently (Silva & Godinho Filho, 2019).

- **Kanban (M8)**: The principle of Kanban system is implemented to gain the objective of lean method of manufacturing in the textile industry. The main objective is to gain maximum possible productivity in lea than the ideal processing time (Prasad et al., 2020).
- **Total productive maintenance (TPM) (M9)**: TPM aims at proper maintenance of machinery for productive and smooth flow of functions (Ahmad et al., 2018).
- **Green supply chain management (GSCM) (M10)**: Green supply chain includes green as well as sustainable policies and practices throughout production process of the industry that would not harm the environment in any way. It implies to inculcate environment-friendly practices throughout the cycle of supply chain management in order to gain the very objective of green manufacturing (Ahmed et al., 2018; Maia et al., 2013).
- **Circular/regenerative design (M11)**: The concept of circular design in textile industry promotes the objective of green manufacturing. Making a new product out of the waste would sustain our resources and environment (Franco, 2017; Weerasinghe et al., 2019).
- **Additive manufacturing (M12)**: One of the trending and in-expensive techniques is additive manufacturing (excluding the initial expenses in setup of machinery). This is one of the most eco-friendly methods of production as it eliminates all sorts of environmental degradation caused by dyeing by doing 3D printing (SChMIDT et al., 2016).
- **5's OEE (M13)**: OEE (Overall equipment effectiveness) identifies the manufacturing effectiveness in the mean-time with utmost effectiveness and efficiency as per the bars and offset by the industry taking upon all the 5's factors of OEE into consideration in the textile industry (Sakti et al., 2019).
- **Lean six sigma (M14)**: One of the reliable and frequently applied techniques for lean manufacturing is six sigma. This technique aims at overall organization's process improvement. Six sigma aims at improvement of all possible areas whether it be related to ecological or it be related to costs or process effectiveness (Ajmera et al., 2017).

The present study is conducted to identify the green approaches which lead to lean manufacturing using Grey DEMATEL methodology. To conduct the study motivational factors were shortlisted which will lead to the achievement of the objectives. DEMATEL methodology is extensively used in several business applications nowadays. The use of classical or crisp resultant from DEMATEL is very effective methodology in demonstrating the cause and effect relationships among the factors and by further prioritizing them, it may at times have some difficulties in deducing uncertainty and vagueness of data. In order to get over this and to increase its capabilities, the extensions of DEMATEL method is included which is not limited to fuzzy, grey DEMATEL.

In real-world applications, there are chances of increased vagueness and uncertainty because of human errors in verdicts and imprecise information. In order to overcome the chances of ineffectiveness in classical or crisp DEMATEL methodology, the adoption of grey systems theory-based DEMATEL method appears to be an effective and important approach as an option. The Grey systems theory which was developed by Tseng (2009) is a methodology that enables the authors or researchers to work upon the chances of uncertainty and ambiguity in the evaluation process. It presents a beneficial methodology for the analysis of systems with imprecise information in order to handle uncertainty and vagueness successfully.

3.2 Application of Grey DEMATEL Approach

The proposed decision-making methodology is used to analyse the industrial motivators. The methodology is used as per the steps illustrated above. After finalizing the list of motivational factors with the help of previous research papers and discussion with stakeholders, the data was analysed. The present study is conducted to identify the green approaches which lead to lean manufacturing by scrutinizing various motivational factors and applying the approach of Grey DEMATEL methodology.

Step 1: Identification of the evaluation criteria and the grey linguistic scale: In this step, we have identified the evaluation criteria and the grey linguistic scale. The linguistic scale and the corresponding grey numbers used in the present work are "No Influence (NI)" is represented as [0, 0], "Very Low Influence (VL)" as [0, 0.25], "Low Influence (L)" as [0.25, 0.5], "High Influence (H)" as [0.5, 0.75] and "Very High Influence (VH)" as [0.75, 1]. Following the steps of research methodology which includes evaluation of the motivational factors was done and linguistic scale was assigned to the motivational factors. Table 2 represent the evaluation of motivational factors by decision maker.

In a similar way, the data was taken from the rest of the decision makers for the research study regarding the linguistic term.

Step 2: Determining the direct relation matrix: In this step, the measurement of relationship between the criteria is illustrated which is shown as $C = \{C_i | i = 1, 2,\ldots,n\}$, the relationship is established by asking a group of experts to make pairwise comparisons in terms of linguistic scale given in Table 1. The comparison done by experts, led to constructing of the initial direct relation grey matrix A.

$$A^k = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} 0 & \otimes a_{12}^k & \cdots & \otimes a_{1n}^k \\ \otimes a_{21}^k & 0 & \cdots & \otimes a_{2n}^k \\ \vdots & \vdots & \cdots & \vdots \\ \otimes a_{n1}^k & \otimes a_{n2}^k & \cdots & 0 \end{bmatrix} \tag{1}$$

Table 2 Linguistic term matrix for decision maker

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14
M1	N	L	VL	VL	L	L	VL	VL	L	H	VH	L	H	L
M2	N	N	L	L	H	VL	N	VL	VL	VL	L	H	H	H
M3	N	N	N	H	L	L	H	L	VL	L	H	N	VH	VH
M4	L	VL	N	N	VL	H	L	L	L	VL	N	VL	H	L
M5	H	L	N	N	N	H	VL	H	VL	H	L	L	VL	H
M6	VL	H	VL	L	L	N	L	VH	VL	VH	VH	L	VH	VH
M7	VH	L	H	L	VL	VL	N	L	L	VL	H	N	N	VH
M8	L	H	L	VH	H	L	H	N	N	N	VL	VL	L	L
M9	VL	H	VL	L	L	VH	H	VH	N	L	L	N	VL	H
M10	L	L	H	L	VH	VH	VH	L	L	N	VL	L	H	VH
M11	H	VL	H	VL	VL	VH	VL	H	L	VL	N	VH	L	VL
M12	N	N	N	VL	N	VL	L	L	H	N	L	N	L	VH
M13	VL	L	VH	H	L	H	H	H	VH	L	H	VL	N	H
M14	L	VL	L	L	H	VH	H	VH	VL	H	H	N	H	N

where k represents the number of experts, $\otimes a_{ij}^{k} = \left[\underline{a}_{ij}, a_{ij}\right]$ are grey numbers and for $\otimes a_{ii}^{k} = [0, 0]$ for $i = 1, 2, \ldots, n$.

Step 3: Combination of all grey direct relation matrices: All the grey direct relation matrices obtained are averaged by using Eq. (2) and we get the aggregate matrix Z.

$$Z = \left(\sum_{i=1}^{k} A^{k}\right)/k \tag{2}$$

Step 4: Establishing and analysing the structural model: In this step the transformation of criteria scales into comparable scales is carried out, the linear scale transformation is changed to a normalization formula. Let

$$\sum_{j=1}^{n} \otimes z_{ij} = [\sum_{j=1}^{n} \underline{z_{\mathrm{ij}}}, \sum_{j=1}^{n} \overline{z_{ij}}] \tag{3}$$

And

$$r = \max_{1<i<n}\left(\sum_{j=1}^{n} \overline{z_{ij}}\right)$$

Then, the normalized direct-relation grey matrix, G, is equal to $G = r^{-1} \times Z$.

And

$$G = \begin{bmatrix} 0 & \otimes g_{12} & \cdots & \otimes g_{1n} \\ \otimes g_{21} & 0 & \cdots & \otimes g_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ \otimes g_{n1} & \otimes g_{n2} & \cdots & 0 \end{bmatrix}$$

where

$$\otimes g_{ij} = \frac{\otimes z_{ij}}{r} = \left[\frac{\underline{z_{ij}}}{r}, \frac{\overline{z_{ij}}}{r} \right] \quad (4)$$

After all the direct relation grey matrix are obtained and averaged. The average aggregate matrix Z is obtained. To convert the criteria scales into a comparable scale, the linear scale is transformed into a normalized formula using step 4. In Table 3, the Normalized direct relation matrix G is illustrated. After the Normalized Direct Relation Grey matrix is obtained, now using step 5 we obtain the Grey Total Relation Matrix T.

Step 5: Establishing the total relation matrix: As the grey normalized direct relation matrix G is obtained, the evaluation of grey total relation matrix T cab be done using the following equations:

$$\begin{aligned} T &= G + G^2 + ... + G^k \\ T &= G(I - G)^{-1}, \text{when } \lim_{k\to\infty} G^k = [0]_{n\times n} \end{aligned} \quad (5)$$

$$T = \begin{bmatrix} \otimes t_{11} & \otimes t_{12} & \cdots & \otimes t_{1n} \\ \otimes t_{21} & \otimes t_{21} & \cdots & \otimes t_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ \otimes t_{m1} & \otimes t_{m2} & \cdots & \otimes t_{mn} \end{bmatrix}$$

And

$$\otimes t_{ij} = \left[\underline{t_{ij}}, \overline{t_{ij}} \right] \quad (6)$$

Table 4 represents the Grey Total Relation Matrix.

After the grey total relation matrix T is obtained, the matrix T is whitened to get the crisp values using the CFCS (Converting Fuzzy data into Crisp Scores) method. The whitening of Matrix T is done using step 6 of the methodology. After the values are converted to crisp values the cause and Effect relationship is obtained between the motivational factors by (D + R) and (D – R) in Table 5 given below. The values of D-R more than zero indicate that the motivational factor is a cause and the value D-R less than zero indicates that the motivational factor is an effect.

Table 3 Normalized direct relation grey matrix G

	M1	M2	M3	M4	M5	M6	M7
M1	[0,0]	[0.026,0.013]	[0.013,0]	[0.013,0]	[0.026,0.013]	[0.026,0.013]	[0.013,0]
M2	[0,0]	[0,0]	[0.039,0.013]	[0.039,0.013]	[0.065,0.039]	[0.013,0]	[0,0]
M3	[0,0]	[0,0]	[0,0]	[0.065,0.039]	[0.039,0.013]	[0.052,0.026]	[0.065,0.039]
M4	[0.026,0.013]	[0.013,0]	[0.013,0]	[0,0]	[0.026,0]	[0.052,0.026]	[0.065,0.169]
M5	[0.052,0.026]	[0.052,0.026]	[0,0]	[0.013,0]	[0,0]	[0.078,0.182]	[0.026,0]
M6	[0.039,0.013]	[0.078,0.052]	[0.039,0.013]	[0.052,0.026]	[0.052,0.026]	[0,0]	[0.052,0.026]
M7	[0.091,0.065]	[0.039,0.013]	[0.078,0.052]	[0.052,0.026]	[0.039,0.013]	[0.026,0]	[0,0]
M8	[0.052,0.026]	[0.052,0.026]	[0.026,0.013]	[0.091,0.065]	[0.078,0.052]	[0.065,0.039]	[0.052,0.026]
M9	[0.026,0]	[0.065,0.039]	[0.039,0]	[0.039,0.013]	[0.052,0.026]	[0.091,0.065]	[0.078,0.052]
M10	[0.065,0.039]	[0.065,0.039]	[0.039,0.026]	[0.026,0.013]	[0.091,0.065]	[0.104,0.078]	[0.104,0.078]
M11	[0.039,0.026]	[0.013,0]	[0.013,0.026]	[0.013,0]	[0.013,0]	[0.091,0.065]	[0.013,0]
M12	[0.013,0]	[0,0]	[0.013,0]	[0.013,0]	[0,0]	[0.013,0]	[0.039,0.013]
M13	[0.013,0]	[0.039,0.013]	[0.065,0.039]	[0.039,0.026]	[0.039,0.013]	[0.052,0.026]	[0.065,0.039]
M14	[0.065,0.039]	[0.039,0.013]	[0.039,0.013]	[0.065,0.039]	[0.078,0.052]	[0.091,0.065]	[0.078,0.052]

M8	M9	M10	M11	M12	M13	M14
[0.013,0]	[0.026,0.013]	[0.078,0.052]	[0.065,0.039]	[0.039,0.013]	[0.052,0.026]	[0.065,0.039]
[0.026,0]	[0.026,0]	[0.026,0.013]	[0.039,0.013]	[0.052,0.026]	[0.078,0.052]	[0.065,0.039]
[0.052,0.026]	[0.039,0.013]	[0.052,0.026]	[0.039,0.026]	[0.052,0.013]	[0.091,0.065]	[0.104,0.078]
[0.039,0.013]	[0.039,0.013]	[0.026,0]	[0.026,0.013]	[0.026,0]	[0.065,0.039]	[0.065,0.039]
[0.052,0.026]	[0.026,0]	[0.078,0.052]	[0.065,0.039]	[0.065,0.039]	[0.052,0.026]	[0.091,0.065]
[0.091,0.065]	[0.052,0.013]	[0.104,0.078]	[0.104,0.078]	[0.052,0.026]	[0.104,0.078]	[0.091,0.065]
[0.039,0.013]	[0.039,0.013]	[0.026,0]	[0.039,0.026]	[0.026,0]	[0.026,0]	[0.104,0.078]
[0,0]	[0,0]	[0,0]	[0.013,0]	[0.039,0.013]	[0.065,0.039]	[0.052,0.026]
[0.091,0.065]	[0,0]	[0.052,0.026]	[0.039,0.013]	[0,0]	[0.039,0.013]	[0.078,0.052]
[0.052,0.026]	[0.039,0.013]	[0,0]	[0.052,0.026]	[0.039,0.013]	[0.065,0.039]	[0.104,0.078]
[0.052,0.026]	[0.026,0.013]	[0.052,0.026]	[0,0]	[0.052,0.039]	[0.026,0.013]	[0.013,0]
[0.039,0.013]	[0.052,0.026]	[0,0]	[0.026,0.013]	[0,0]	[0.039,0.013]	[0.091,0.065]
[0.065,0.039]	[0.091,0.065]	[0.052,0.026]	[0.039,0.026]	[0.026,0]	[0,0]	[0.078,0.052]
[0.091,0.065]	[0.026,0]	[0.052,0.026]	[0.065,0.039]	[0.026,0]	[0.052,0.026]	[0,0]

Figure 1 represents the relationship of the 14 motivational barriers based on the linguistic scale values, provided by the decision maker. The values above 0 indicate the causes and values below 0 indicate the effect due to the causes.

4 Result and Analysis

As seen from the above discussion the factors which constitute cause are M3, M4, M5, M9 and M10. Over the past few years, the degree of uncertainty and complexity in the general environment has impacted all areas of business. Irrespective of the nature of the business, the key differentiator is how seamlessly the supply chain operates. One-day delivery in e-tail, getting the specific product you want in the

Table 4 Grey total relation matrix T

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14
M1	0.019	0.017	0.015	0.017	0.022	0.029	0.026	0.026	0.016	0.015	0.017	0.014	0.019	0.024
M2	0.017	0.016	0.013	0.015	0.016	0.026	0.024	0.024	0.017	0.019	0.017	0.013	0.016	0.024
M3	0.044	0.041	0.038	0.034	0.042	0.048	0.041	0.047	0.035	0.037	0.042	0.029	0.035	0.042
M4	0.041	0.046	0.042	0.048	0.047	0.046	0.300	0.049	0.041	0.047	0.047	0.041	0.042	0.043
M5	0.063	0.060	0.070	0.072	0.084	1.037	0.076	0.068	0.066	0.055	0.059	0.057	0.064	0.062
M6	0.063	0.051	0.056	0.060	0.069	0.109	0.071	0.060	0.054	0.047	0.049	0.054	0.054	0.072
M7	0.023	0.026	0.020	0.029	0.033	0.043	0.041	0.038	0.024	0.035	0.034	0.027	0.040	0.031
M8	0.024	0.024	0.025	0.021	0.023	0.026	0.024	0.040	0.030	0.038	0.036	0.025	0.031	0.043
M9	0.043	0.036	0.034	0.042	0.044	0.039	0.038	0.040	0.039	0.041	0.046	0.041	0.053	0.053
M10	0.057	0.055	0.057	0.067	0.053	0.052	0.050	0.074	0.056	0.086	0.068	0.057	0.067	0.068
M11	0.016	0.021	0.016	0.019	0.022	0.016	0.023	0.022	0.017	0.020	0.025	0.016	0.027	0.034
M12	0.014	0.012	0.011	0.015	0.017	0.020	0.016	0.018	0.009	0.014	0.014	0.010	0.013	0.012
M13	0.038	0.033	0.026	0.036	0.040	0.045	0.037	0.040	0.022	0.033	0.038	0.030	0.052	0.046
M14	0.039	0.043	0.037	0.039	0.039	0.039	0.038	0.040	0.041	0.046	0.044	0.043	0.053	0.092

Table 5 Values of D + R and D − R for Motivational factors

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14
D	0.278	0.258	0.555	0.880	1.893	0.869	0.444	0.410	0.588	0.865	0.293	0.194	0.515	0.633
R	0.499	0.482	0.461	0.513	0.551	1.572	0.805	0.587	0.469	0.533	0.535	0.456	0.564	0.646
D + R	0.777	0.740	1.016	1.394	2.444	2.441	1.248	0.997	1.057	1.397	0.827	0.650	1.079	1.279
D-R	−0.222	−0.224	0.094	0.367	1.342	−0.70	−0.361	−0.178	0.119	0.332	−0.242	−0.262	−0.050	−0.012
Cause/effect	Effect	Effect	Cause	Cause	Cause	Effect	Effect	Effect	Cause	Cause	Effect	Effect	Effect	Effect

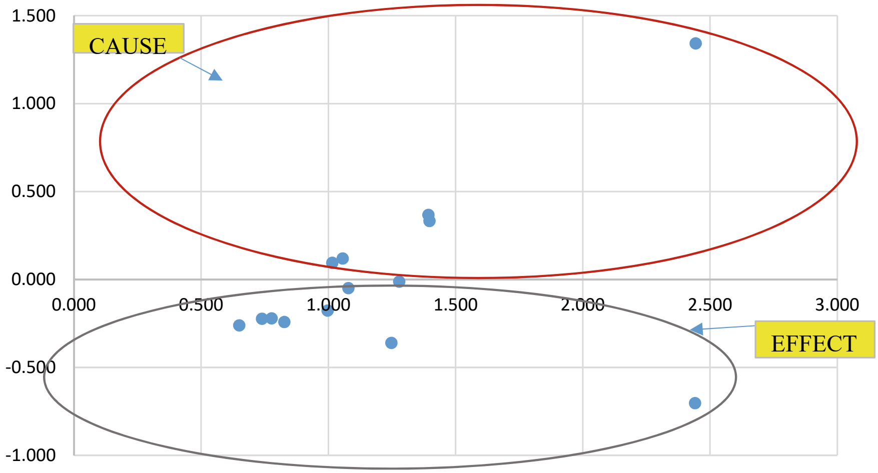

Fig. 1 IRD diagram for motivational factors

store you choose to go to or an infrastructure project being completed in time, it all links back to an effective supply chain. Thus, Theories of Constraints (M3) has evolved as an essential approach in overcoming the hindrances that stand on the path of achieving the organizational goals in any way. VSM helps in implementation of implementations for lean manufacturing. Firms are also collaborating with upstream and downstream supply chain partners to design eco-efficient products, and promoting their transformation toward sustainability with effective marketing and advertising campaigns. Thus, product stewardship (M5) in textile industry is an essential motivation factor to take every possible bit of material and resources into use. TPM (M9) aims at proper maintenance of plant and machinery for productive and smooth flow of functions in the industry. GSCM (M10) aids in inclusion of eco-efficiency in textile manufacturers.

Figures 2, 3, 4, 5 and 6 represent the cause and effect relationship of each motivational barrier on the other barriers. The relationship is established and calculated

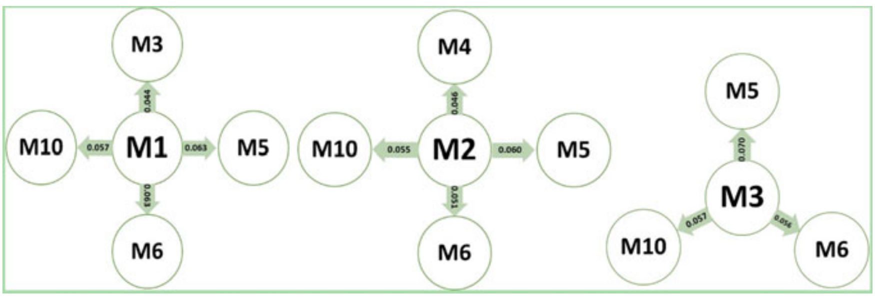

Fig. 2 Cause-effect relationship diagram

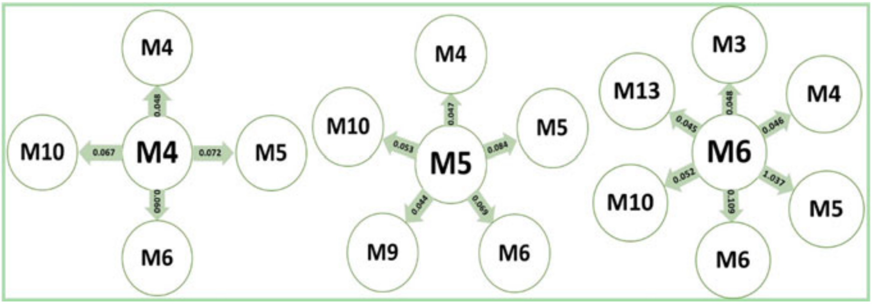

Fig. 3 Cause-effect relationship diagram

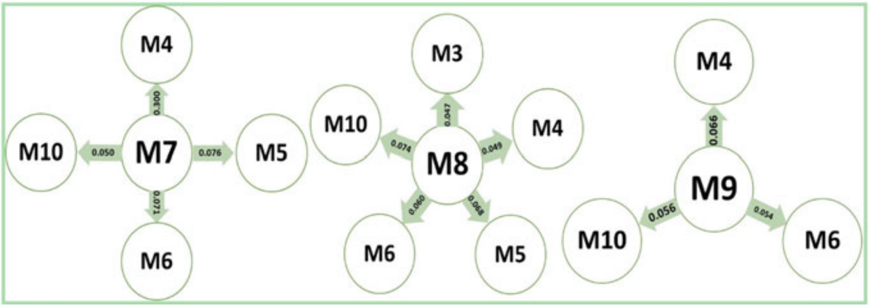

Fig. 4 Cause-effect relationship diagram

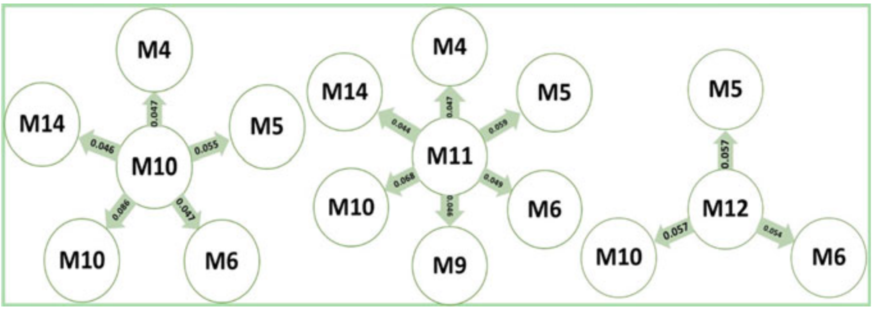

Fig. 5 Cause-effect relationship diagram

by taking out the threshold value and then comparing the values which are greater than the threshold value in each motivational factor listed. The highlighted values are represented in Table 5 in the Grey Relation Total Matrix T. As in Fig. 2 we can state that M1 has a direct effect to M3, M5, M10, M6. This illustrates the relationship between the given factors. The same concept is used to establish cause and effect relationship between the other motivational factors. The results from the relationship

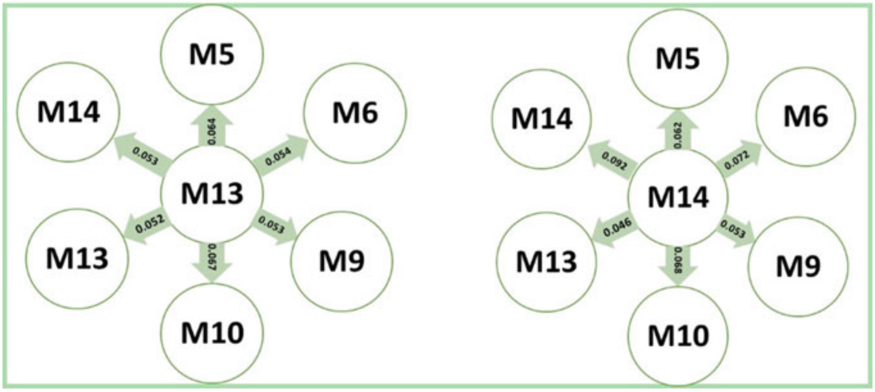

Fig. 6 Cause-effect relationship diagram

that can be established are that every motivational factor represents a chain effect relationship with each other. In every case, every motivational factor has a rippling effect relationship with at least one of the other motivational factors.

The conclusions drawn from the research analysis that were conducted in recent years lay an increased focus on lean and green manufacturing in the textile industry. In the research analysis, there has been use of motivational factors to either establish lean manufacturing or green manufacturing.

5 Conclusion

The study provides an analytical framework to the stakeholders and decision makers in the textile industry. The research focused on scrutinizing the motivational factors for a textile industry with the help of research papers and decision makers. In the literature review, it was analysed that all the authors used a limited number of motivational factors for their research and combination of all the motivational factors extensively used for our research. The problem that we came across is that all the papers identified have focused their research on either green manufacturing or lean manufacturing and so our research did the combination of the same to analyse the cause and effect of Green on Lean manufacturing in a textile industry using the motivational factors. The study adopts methodology based on Grey DEMATEL to evaluate the cause and effect relationship among the motivational factors and to avoid the uncertainty and ambiguity of data. The aim of the paper was to identify the motivational factors for the textile industry and to establish the cause and effect relationship for the factors. To study the relationship grey linguistic terms were used to avoid uncertainty of data. The decision makers have different perspectives for the data as per our research. All the factors are very important for the achievement of Green in Lean Manufacturing for a textile industry. But what we concluded from our findings is that M3, M4, M5, M9, M10 factors are the causes which effect the other M1, M2, M6, M7, M8, M11, M12, M13, M14 directly. So, the textile industry aiming in achieving Green in Lean manufacturing can focus on the factors which are the causes and the effect of the same will be visible on rest of the factors. It can also be concluded that cause from any factor very much affects the other factor.

The future scope and research include the validation of cause-effect model. Moreover, the results of the current study can be validated for other sectors of the economy. Future work can be done by including some mathematical models.

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Lean and Green in Supply Chain Management: Push and Pull Mechanism

Loveleen Gaur and Aayush Tyagi

Abstract Today business enterprises have enormous competition in terms of brand, value, sustainability, efficiency and price. Companies also take advantage by reducing the cost incurred in manufacturing without degrading the quality or reducing the price of the product. It introduces lean to green management in Supply Chain Management (SCM). The above approach eliminates waste products and reduces unwanted resources. Moreover, this also helps in corporate branding of going green, because everyone is becoming environment conscious and everyone like to buy from industries which practices lean and green thinking. The idea of lean SCM refers to the elimination of waste and reducing non-valuable activities associated with spare time, labor, equipment, space and inventory. The key is to identify non-adding value items and eliminate these to reduce cost. There are few items for which clients are not willing to pay. The green paradigm raises the efforts to minimize the negative effect of firms and industries on environment. It includes climatic changes, pollution and non-renewable resources. The green approach requires working with dealers and clients to improve efficiency and sustainability for lean and green environment. The objective of this research is to analyse and examine relation between lean and green Supply Chain strategies. This chapter aims to analyse the role and impact of Push and Pull system in Lean Green and Sustainable Supply Chain Management. The chapter further focuses on the methods to implement the same in Industry.

Keywords Lean · Green · Push · Pull · Sustainability · Globalization · GSCM and supply chain management

1 Introduction

Earlier, SCM practices mainly focus on the fulfillment of required needs. But, nowadays, cultural changes in organizations are leading to goal-oriented and sustainable product management. The lean concept introduced in Japan for an automobile

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firm to reduce waste in manufacturing (Ting, 2008). In the 21st century, Companies' uses lean manufacturing to increase their competitiveness usually depends upon increasing value to customers concerning quality, efficiency, productivity and customer satisfaction. The primarily focus of lean manufacturing is on waste reduction. Lean production help firms to discard non-profit-related activities concerning extra time, workers, tools and inventories throughout the supply chain process (Malihe Manzouri, 2014). Although these strategies allow organizations to reduce cost and improve product value simultaneously. GSCM has emerged from traditional SCM in the last few decades (Mathu, 2019). GSCM technique is to minimize the harmful effects of industries and their supply chain on the environment. A Green supply chain manufacturing necessitates working with dealers and clients, analyse processes, networks and extended stewardship throughout the product life cycle (Qinghua Zhu, 2004). By integrating eco-friendly concept to SCM to improve environmental sustainability comprises of green purchasing, efficient distribution as well as a well-organized warehousing and distribution techniques with biofuel transportation (Khan, 2018). It is an essential oversight because most of the industries lack synergies due to misunderstanding or irregularity. When lean initiative enables required volume to flow through the supply chain, a minimum amount of inventory needs to be source, produce, transport which may minimize the negative impact on resources. However, the lean synergies that deploy Just-In-Time delivery of the product may contradict the green paradigm (Diane Mollenkopf, 2010). To overcome the harmful effects of the JIT approach, firms may opt for re-useable packaging.

2 Literature Review

Foremost techniques of Lean production include Six Sigma, Just in Time and Push-Pull mechanism. Green production involves sustainability, environmental issues and ecological.

Diana Mollenkopf, Hannah Stolze, Wandy L. Tate and Monique Ueltschy conducted a research on "Lean Green and Global Supply Chain" to identify the relationship among green, lean and global supply chain strategies. The literature emphasis on implementing these strategies simultaneously (Diana Mollenkopf, 2010).

Ni Zheng, LU Xiaochun analyse push and pull production system in Supply Chain. The paper compares push and pull method based on order completion time and inventory level (Ni Zheng, 2009).

Sicco C. Santema research on how can we redesign SCM in order to create faster, cheaper and better flow in SCM (Santema, 2011).

G.Maeques, J.Lamothe, C.Thierry performs analysis on Pull inspired Supply with respect to demand uncertainty (Marques, 2009).

Naga Vamsi Krishna Jasti, Aditya Sharma and Rambabu Kodali build a case study. The research concludes that Lean SCM also leads to green Supply Chain by collaborating suppliers and distributers with the objective of delivering right item at right place at right time (Naga Vamsi, 2012).

Susana Duarte, Virgilio Cruz-Machado determines whether lean, green, agile and resilient strategies can be applied and combine in Supply Chain Management (Susana Durate, 2013).

Susana Duarte, Cruz-Machado predicts that lean and green will easily fulfill the requirements of industry 4.0. Industries that are based on lean green SCM concept are already focused (Susana Duarte, 2017).

Daniel Spina, Luiz Carlos Di Speiro, Luiz Artur, André Luís de Castro Moura Duarte perform an empirical research to identify whether SCM practices should be adopted by managers to enhance performance or not (Daniel Spina).

Helena Carvalho, Susana G. Azevedo, V. Cruz-Machado concludes SCM should be resilient to failures and unexpected events. Helena proposed a conceptual model in support of SCM resilient (Helena Carvalho, 2014).

Pedro L. González-R, Jose M. Framinan and Rafael Ruiz-Usano propose a methodology for operation and design of JIT mechanism in Supply Chain (González-R et al., 2012).

Singh Sarbjit aims to find out whether industries should follow pull strategies or push strategies. The paper concludes that Pull system is pushing the push system in last few years (Sarbjit, 2017).

J. Ashayeri, R.P. Kampstra conclude that distribution logistics operations synchronization with purchasing and sales represents a substantial opportunity for industries and supply chain improvement (Ashayeri).

David F. Pyke, Morris A. Cohen study the concept of push and pull in distributed systems, the author also develops a framework for push and pull system (Pyke, 1990).

Dagne Birhanu (2014) Classify the boundary between lean and agile, push and pull-based strategy in SCM. The author classifies SCM into responsive vs. effective with the help of functional mapping.

Corniani (21) Describes push and pull in market-driven management. The author identifies the solution to bridge the gap between business and its demand.

3 Methodology

An extensive literature review is conducted to examine research and practice with respect to concurrent application of lean, green and Global Supply Chain Management. Today, numerous literature try to address the issue in lean, green and global SCM but unfortunately most theories have neglected the intersection of these three strategies practiced by multinational organizations. This chapter tries to synthesize the available literature on lean, green and global SCM and their implementation strategies.

4 Lean Green and Global Implementation

4.1 Conventional SCM and Global Supply Chain Management

The SCM is the mechanism of waste of goods and services that transforms raw materials into processed goods. GSCM is integrating related environmental issues into SCM which includes product design, cloth sourcing, production processing, product delivery and cease of existing control of product after its beneficial existence (Ali). In a sustain SCM, a level of flow is maintained in an effective and ecological efficient manner to sustain the effect of value goods through SCM. GSCM is economical as well as environmental friendly while SCM is only economical. However, Green SCM is slow as compared with SCM, price is also very high for GSCM (Thoo Ai Chin, 2015). GSCM is preferred moderately due to high pricing.

4.2 The Interface of Lean and Global Supply chain Strategies

Many researchers have taken into consideration the combination of lean production and green supply chain to apprehend whether they are contradicting or complementary. There is conflict among lean and global production techniques because creating a smooth flow of production in SCM requires collaboration in all departments. There are also numerous regions of conflict among lean and global supply chain strategies that lean production also expedite globalization (Rai Waqas Azfar, 2014). The elements that pressure firms to pursue lean supply chain are customer demand, increased transparency, volatile demand and IT technology. Successful implementation of lean and global manufacturing yields to a better buyer–supplier relationship. Several studies proved that lean SCM is not compatible with GSCM because lean production requires low inventory and fast delivery of good while on the other hand, GSCM also requires extensive stocks which leads to longer transit time. Lean SCM additionally involves collaboration and communication among all departments in organization and it is hard to achieve in GSCM (Everton Drohomeretski) (Table 1).

4.3 Implementing Lean Green SCM Strategies

The available literature on lean production is already well organized. However, the increased awareness of sustainable environment issues has emerged with synergies among lean and green manufacturing practice in the professional business world (Wadhah Abulafaraa, 2019). There is an unpremeditated bond of lean and current environmental issues. The existing theory is argued with the fact that all lean and green practices are not concerned with pollution reduction. Lack of environmental

Table 1 Traditional SCM versus green SCM

Characteristics	Traditional SCM	Green SCM
Ecological optimization	High ecological impact	Low ecological impact
Values	Economical	Economic and ecological
Speed & flexibility	High	Low
Price	Low price	High price
Cost pressure	High cost pressure	High cost pressure
Relationship type	Short term relationship	Long term relationship
Channel leadership	Not required	Required for coordination

awareness is one of the drawbacks of implementing lean and green SCM production. However, implementing green production is very costly and even time-consuming. Recycling and improvement in waste reduction can play a significant role in implementing lean-green supply chain strategies. There are several common strategies for integrating lean and green SCM. Moreover, corporations that follow ISO 9000 standard requirements are willing to adopt ISO 14000 standards. It will result in better performance, robustness and will also help to create a healthy environment all around.

5 Lean Green Manufacturing Approach

Today, every organization has understood the value of sustainability and identified the importance of lean and green production. If companies want to retain themselves and compete in the market, they have to be sustainable and environmental friendly. Current trends predict that many steps are taken in this regard to achieve the desired result in sustainability either from lean or green initiatives. Although, these steps don't seem to be very promising. Researchers do agree that it is challenging to integrate lean green and global SCM. To follow a systematic strategy industries need to work in synergies environment. Therefore, reducing their weakness and strengthening their strengths. Study of similarities and variations among lean and inexperience (green) production may assist in the implementation of lean and inexperience manufacturing approach. There are three pillars of lean manufacturing and sustainability which can also be called as 'Triple-Bottom-Line' sustainability conceptualization which are as follow:

i. *Economical*
ii. *Social*
iii. *Environmental*.

To fulfil today's sustainable demand of the market, companies urge for sustainable solutions. Therefore, companies are updating and modifying lean strategies to go green. It helps them to minimize cost, increase profits and optimize resource usage. The impact of lean contribution towards sustainability are:

i. *Reduce costs*
ii. *Increase in profit*
iii. *Optimize resource usage*
iv. *Eliminate waste*
v. *Improve the work environment*
vi. *Health benefits.*

6 PUSH and PULL Strategy

The lean green and global integration are hardly practiced in general. Although it debatably exists in practice but is restricted in day-to-day life. The available literature on Lean-Green, Green-Global and Sustainable supply chain management is very limited and the integrated model of lean, green and global SCM is also yet to develop (Alena Puchkova, 2016).

Push is a controlled flow of information in the same direction when a successive node order request for the preceding node, including all internal operations leads to pull mechanism. Push approach allows product through the channels from the production side to the retailer. Push-based supply chain is time-consuming, and the major drawback is it takes time to respond to change in demand, which further results in overstock, delays and obsolesce. Push type manufacturing means production on demand.

In a pull-based SCM, production and distribution are demand-driven irrespective of the forecast (Hunt, 2019). Toyota Manufacturing completely works on the pull mechanism. This approach is known as the supermarket model. However, the supply chain works on the combination of push and pull strategy, and the interface between the pull stages concerning push scene is called push–pull boundary. In a pull mechanism, production is made based on demand.

Today Information Industries are allowing the shift of production and sales from push kind to pull type. Pull type SCM is based totally on the call for facet including JIT. Therefore, inventories are stored at a minimum, and products may be supplied at a brief lead time and at exceeding speed. Besides that push SCM corresponds for train, buses and aeroplanes for which delivery is based totally on call for a forecast by term and route. There could be a diverse type between push and pull approach based on a variety of materials, WIP and how to deal with actual demand in the supply chain. Figures 1 and 2 represent push and pull model in SCM.

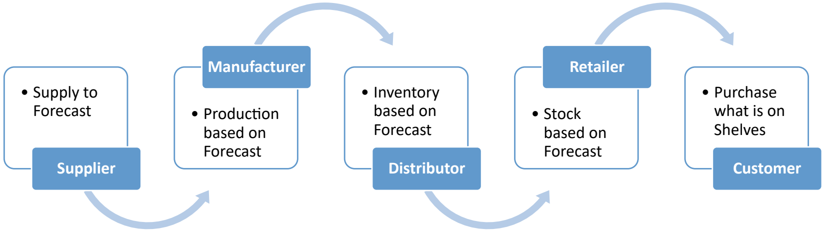

Fig. 1 Push-based strategy

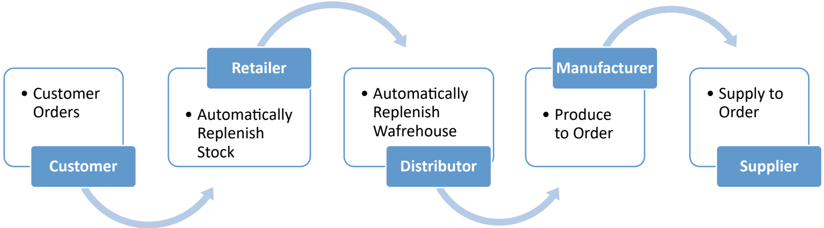

Fig. 2 Pull-based strategy

6.1 Factors Affecting Decision in Push–Pull

The important factors which determine whether the industry opts for pull system or push system are given below:

i. *Demand*—Demand is an important factor in deciding push–pull strategy. Pull strategy is more feasible if the demand is certain. Whereas, with the increase in uncertainty organizations use push strategy for better forecasting.
ii. *Cost of Goods*—Pull system is advisable for the high-cost products, e.g. Luxury cars whereas push system is recommended for affordable products, e.g. Daily used products, FMGC products.
iii. *Variety*—if the product has multiple varieties then it will be better to go for pull system, e.g. Automobile industry and if the product has minimum variety then push system will be more suitable, e.g. Manufacturing industries.
iv. *Risk*—Another important factor which can make or break any industry. If the risk associated with the product is very high then one must always use pull strategy and vice-versa.

7 Conclusion

The research in push–pull system have several contributions to the SCM mechanism. The focus of the study was to synergies the available research on lean green production in Supply Chain Management. Till now, it has not been proven yet how firms and organizations can implement lean and green strategies. This chapter focuses on reducing the gap between conventional SCM and lean green SCM. Several companies are emphasized on lean green optimization technique, but in reality these approaches do not seem naturally implemented. It is a concern for every industry because nowadays every organization seeks sustainable development goals. Research also suggest that lean and green strategy alone will not be enough to reach sustainability. It is utmost required to integrate all the pillars of sustainability, i.e. economic, environmental and social. In today's scenario, IT companies depend not only upon green purchasing, manufacturing and green distribution but also focuses on green reverse logistics. Reverse logistics is an ideal solution to reduce environment pollution (Rui Ren, 2019). The primary reasons for implementing lean-green supply chain in practices are Ethical leadership, Customer and Supplier management, societal factors and recycling before EOL.

Moreover, Supply Chain and logistics are undoubly very much dependent upon biofuels. Logistics activities depend highly upon biofuels to accomplish tasks. Therefore, renewable energy becomes more critical because biofuels not only increase economic growth for the country but also reduces carbon emission.

This chapter concludes that pull strategy is taking over push system as pull system eliminates Planning complexities and overproduction. Organizations are slowly moving on from ISO9001 standards to ISO 14001 because ISO14001 promises voluntary international environment standards. This chapter will inspire scholars, practitioners and IT officials to accept push–pull system in SCM to improve the sustainability in their businesses.

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