Analysing the interdependency relationships among drivers for lean and green manufacturing using ISM approach

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Abstract

Customer awareness towards sustainability, environmental performance and government policies have enforced the manufacturing firms to implement best techniques and practices to fulfil customer expectations. In this study, the drivers for lean and green manufacturing have analyzed which will help the organizations to reduce waste emissions, improve environmental performance and increase profit. A total of sixteen drivers are identified from the literature and consulted with the experts' team for further study. These drivers are further analyzed with interpretive structural modelling (ISM) approach to see the relationship among drivers. The study shows that cost reduction, increase in market share, government support and adequate technology development are the key drivers for lean and green manufacturing. Finally, the paper draws some conclusions and implications from the study. These implications will guide the management and policymakers to focus on the main drivers for lean and green implementation in the manufacturing industry.

Keywords: Lean manufacturing; Green manufacturing; Drivers; Interpretive structure modelling; MICMAC analysis.

1. Introduction

Competition in the global and local market has encouraged manufacturing organizations to use new advanced green techniques and achieve economic profits [1]. Due to the increase in awareness of environmental impact among customers, many firms are trying to achieve sustainability in the supply chain [2]. Global markets are focusing on standard norms, rules and regulations to reduce the environmental effect. These rules and regulations encouraging managers to adopt new advanced techniques in their firms which will reduce the environmental effect [3]. Lean and green manufacturing is an integrated approach that helps firms to achieve economic profits with the application of environmentally friendly practices and techniques [4, 5]. The lean and green integrated approach will guide the management in firms to implement new techniques and achieve sustainability in the supply chain. The connection between lean and green manufacturing has been discussed by various researchers in the past few years. The integrated approach of lean and green manufacturing will help the organizations to achieve social, economic and environmental sustainability [4, 6, 7]. Micheli [8] analyzed the effect of drivers such as firm size, ISO 14001 certification, past performance etc. on green drivers in Chinese manufacturing companies. Luo [9] investigated the connections between lean manufacturing and green manufacturing and factors which can affect the implementation process in Malaysian manufacturing firms. Various factors can motivate and encourage the firms to implement lean and green practices in their firms. These factors are also known as 'drivers'.

The main aim of this study is the identification and modelling of drivers for lean and green manufacturing. This will guide the management of various firms to implement the lean and green strategy in Indian industries. In the first phase, with the help of expert's suggestions and literature review, a total of sixteen drivers have identified for further study. These drivers have analyzed

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with the help of interpretive structure modelling (ISM) approach and categorized with MICMAC (Matrice d' Impacts croises multiplication applique' an classment) approach.

In summary, the modelling of lean and green manufacturing drivers for Indian industries will help the organizations to achieve economic, social and environmental sustainability. The paper has arranged into six sections which include an introduction. Section 2 covers the literature review for the drivers of lean and green manufacturing. The methodology used in this analysis is shown in Section 3. Section 4 covers the results and discussion of the study. Section 5 and 6 present the managerial implications and conclusion of the study with future scope and limitations.

2. Literature Review

Many researchers have shown the integrated approach of lean and green manufacturing implemented in various firms to achieve economic and environmental efficiency [6, 11, 12, 13]. Song [14] analysed the impact of various factors on the adoption of the lean and sustainable manufacturing system in automotive industries. The study [15] analysed the synergies between lean and green manufacturing practices. Compos [15] developed a model for an integrated lean and green approach to implementing a hybrid lean sustainable system in firms. Previous researchers have analyzed the relationship between lean and green manufacturing for various manufacturing industries. However, the studies related to drivers for lean and green manufacturing implementation in industries are less. Researchers have focused on the application of lean and green manufacturing in operational and economic activities. This study will help the management to analyze the drivers for lean and green manufacturing in the Indian industries scenario. The drivers selected from the literature survey and expert's opinions have shown in table 1.

Table 1. Drivers for lean and green manufacturing

Drivers	Description	References
Cost reduction	Lean and green manufacturing can help to reduce the consumption of resources, reduces energy and water consumption in the organization. The reduction in consumption of resources results in the overall cost reduction of products and helps to achieve economic profits.	[6], [18], [21]
Competitiveness	Competition in global and local markets forced the organizations to implement new techniques and strategies. The competitiveness in the market helps to create new opportunities for improvement in the production process and helps to adopt new advanced green and lean techniques.	[8], [10], [20], [21]
To increase market share	Green techniques help the firms to acquire more market share via competition over prices and cost which is achieved through these techniques. Green techniques help the firms to achieve cost reduction and qualify the products as per customer requirements.	[17], [19], [21]
Government Support	Governments can provide supports to manufacturing organization through allocating funds, conducting awareness programs, providing assistance in skill development. Government can also help the industries through collaboration work and provide incentive schemes to industries.	[2], [8], [10], [11], [15], [17], [18], [21]
Public pressure	Pressure from various social communities such as local communities, politicians, NGOs, media and community groups can force the organization to reduce its industrial emissions such as gas emissions, solid waste and	[6], [8], [10], [20]

	wastewater. These waste emissions are harmful to the environment and can be reduced with the adaption of green techniques.	
Green brand / Company image	The company image in view of society can help the firm to maintain a reputation of producing environmental friendly products. This can play a significant role in any company's growth.	[6], [8], [10], [11], [18], [20], [21]
Environmental awareness of customers	Awareness among customer towards the environment can create pressure on firms to manufacture environmentally-friendly products.	[2], [8], [10], [11], [16], [17], [18], [21]
ISO 14001 certification	The ISO 14001 certification will mandate the organization to implement an environmental management system in the firm. This will also mandate the firms to adopt such manufacturing strategies which help to reduce the negative effect on the environment.	[16], [18], [20]
Potential use of energy resources	Organization's willingness to optimize the resource consumption and energy consumption in the firm can encourage the management to adopt lean and green techniques in the system.	[2], [11], [18], [20], [21]
Reusing and recycling materials and packaging	Reusing and recycling of materials will help the organization to reduce its product cost. The recycling of waste packaging materials can also help the firm to reduce its overall cost. This recycling helps the firms to implement new green techniques in the manufacturing process.	[16], [20], [21]
Reverse logistics	Reverse logistics focuses on the product design in such a way that the product dismantling will be easy at the end of the life of products.	[20], [21]
Green design/green purchasing/green innovation	Adaption of green techniques from the beginning phase of production to the end of life of the product will be beneficial for the firm to produce environmentally friendly products.	[11], [16], [20]
Top management commitment	Commitment and support from top management can help the firms to improve environmental performance. Initiatives from top management will help the firms to adopt new lean and green techniques.	[2], [6], [10], [11], [15], [17], [21]
Stakeholders Pressure	Pressures from stakeholder can force the manufacturer to adopt new green practices.	[2], [11], [18], [20], [21]
Environmental collaboration with suppliers	Suppliers concern over environmental performance will help the organizations to produce environmental friendly products.	[16], [17], [18], [21]
Adequate technology development	Adaption of the latest energy-efficient and resource-efficient technology in the organization to increase operational and environmental performance.	[2], [8], [10], [17]

3 Methodology

3.1 Interpretive Structural Modelling

ISM approach is generally used to develop a comprehensive model which is used to define the relationship among a set of factors. ISM method is primarily based on the data collected from the experts' opinions and suggestions. A total of the eight-member team was selected for this study.

The experts who participated in the study belongs to manufacturing industries and academic institutes. The steps followed in the ISM approach are explained below:

- Identification of the set of driving factors for lean and green manufacturing.
- Structural Self Interaction matrix (SSIM) development with the help of experts' opinions and suggestions.
- Development of Initial reachability matrix (IRM).
- Checking for transitivity in IRM and conversion to the final reachability matrix.
- Level partitioning for factors.
- MICMAC analysis for the driving factors.

3.2 Questionnaire and Data Collection

ISM methods primarily based on the data collected from the experts' opinions and suggestions. In this study, twelve members team from the industrial background were approached for the modelling purpose. After the frequent mails and calls, six experts show their interest to participate in the study. Besides these industry experts, two academic professional also shown their interest to participate in the study. In this way, a total of the eight-member team was selected for this study. The experts who participated in the study belongs to manufacturing industries and having experience more than ten years in the industry. The data for SSIM has collected from the experts' team to establish a relationship among drivers.

3.3 Development of SSIM

SSIM is developed with the help of 'lead to' type relationship among drivers. The relationships among drivers are shown by four symbols to show the dominance relationship among drivers. The symbols used in the study are 'V', 'A', 'X' and 'O'. Symbol 'V' shows that driver 'a' leads to achieving driver 'b'. Symbol 'A' shows that driver 'b' leads to achieving driver 'a'. Symbol 'X' shows that driver 'a' and 'b' are helping to each other. Symbol 'O' shows that driver 'a' and driver 'b' are not related to each other. SSIM is shown in table 2.

3.4 Initial Reachability Matrix

SSIM matrix is transformed into an initial reachability matrix after the conversion of symbols into binary values. IRM matrix can be seen in Table 3. The rule of conversion of all symbols 'V', 'A', 'X' and 'O' are explained below:

In SSIM matrix if value (x,y) is V, then value of (x,y) coordinate will 1 and (y,x) coordinate will 0. Similarly, if in SSIM matrix value (x,y) is A, then then value of (x,y) coordinate will 0 and (y,x) coordinate will 1. If in SSIM matrix value (x,y) is X, then value of coordinate (x,y) and coordinate (y,x) will be 1. In SSIM matrix value (x,y) is O, then value of coordinate (x,y) and coordinate (y,x) will be 0.

Table 2. SSIM matrix

S.No.	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	V	V	V	V	V	V	V	V	V	V	V	V	V	X	V	
2	A	X	A	V	V	V	V	O	V	O	X	A	A	A		
3	V	V	V	V	V	V	V	V	V	V	V	V	X			
4	V	V	V	V	V	O	V	V	V	V	V	V				
5	A	V	X	V	V	V	V	V	V	O	O					
6	A	X	A	V	V	V	V	V	V	O						
7	A	O	O	X	O	O	A	A	O							
8	A	A	A	V	X	X	V	V								
9	A	A	A	V	A	A	A									
10	A	A	A	V	X	X										
11	A	A	A	V	X											
12	A	A	A	V												
13	A	A	A													
14	A	V														
15	A															
16																

Table 3. Initial Reachability Matrix

S.NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	0	0	0	1	0	1	0	1	1	1	1	0	1	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
5	0	*1*	0	0	1	1	0	1	1	1	1	1	1	1	1	0
6	0	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0
7	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
9	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0
10	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0
11	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
12	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
13	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
14	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0
15	0	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0
16	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1

3.5 Final Reachability Matrix and level Partitions

In the initial reachability matrix, rule of transitivity is applied to remove the transitivity in the matrix. The rule of transitivity can be explained as if a variable 'X' is having relation with variable 'Y' and variable 'Y' is having relation with variable 'Z', then Variable 'X' will definitely have a relation with variable 'Z'. After applying transitivity rules in the IRM, the final reachability matrix is formed. The FRM can be seen in table 4. These drivers are further levelled through level partitioning (Table 5). The reachability and antecedent set of each driver is used to create level partitioning.

Table 4. Final Reachability Matrix

S.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Driving Power
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
2	0	1	0	0	0	1	0	1	0	1	1	1	1	0	1	0	8
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
4	1*	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	15
5	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	11
6	0	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0	9
7	0	0	0	0	0	0	1	0	1*	0	0	0	1	0	0	0	3
8	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	6
9	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	3
10	0	0	0	0	0	0	1	1*	1	1	1	1	1	0	0	0	7
11	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	6
12	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	6
13	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
14	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	11
15	0	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0	9
16	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	13
Dependence Power	3	9	3	3	6	9	8	13	14	13	12	13	16	6	9	4	141

Table 5. Level Partitioning

S.No.	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,3,4	1,3,4	VII
2	2,6,8,10,11,12,13,15	1,2,3,4,5,6,14,15,16	2,6,15	IV
3	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,3,4	1,3,4	VII
4	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16	1,3,4	1,3,4	VII
5	2,5,6,8,9,10,11,12,13,14,15	1,3,4,5,14,16	5,14	V
6	2,6,8,9,10,11,12,13,15	1,2,3,4,5,6,14,15,16	2,6,15	IV
7	7,9,13	1,3,4,7,9,10,13	7,9,13	II
8	8,9,10,11,12,13	1,2,3,4,5,6,8,10,11,12,14,15,16	8,10,11,12	III
9	7,9,13	1,3,4,5,6,7,8,9,10,11,12,14,15,16	7,9	II
10	7,8,9,10,11,12,13	1,2,3,4,5,6,8,10,11,12,14,15,16	8,10,11,12	III
11	8,9,10,11,12,13	1,2,3,5,6,7,8,10,11,12,14,15,16	8,10,11,12	III
12	8,9,10,11,12,13	1,2,3,4,5,6,7,8,10,11,12,14,15,16	8,10,11,12	III
13	13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	13	I
14	2,5,6,8,9,10,11,12,13,14,15	1,3,4,5,14,16	5,14	V
15	2,6,8,9,10,11,12,13,15	1,2,3,4,5,6,14,15,16	2,6,15	IV
16	2,5,6,7,8,9,10,11,12,13,14,15,16	1,3,4,16	16	VI

3.6 Formation of ISM Model

Based on FRM, a diagraph is developed which includes transitivity links. These transitivity links have removed and drivers have replaced with the corresponding drivers' numbers. The final model is known as the ISM model for drivers. The model can be seen in figure 1.

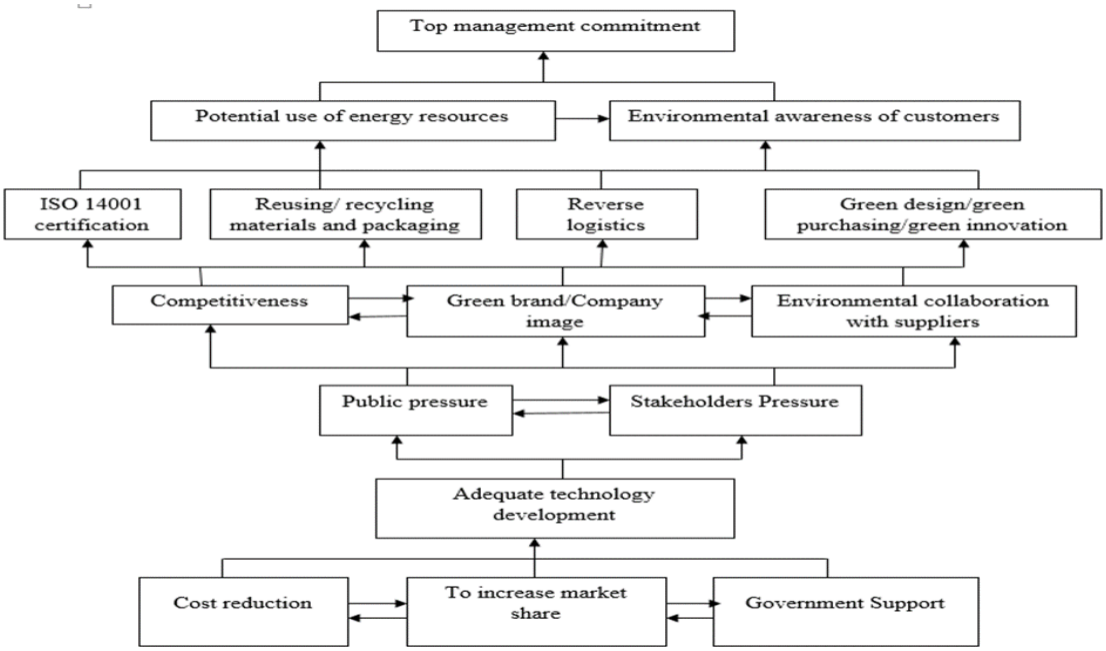

Fig. 1. ISM Model

3.7 MICMAC analysis

MICMAC analysis is used to analyze the relationship between dependency and driving power of drivers. The values of driver power and dependency power were calculated in the final reachability matrix. Figure 2 depicts the MICMAC analysis. In MICMAC analysis, drivers are divided into 4 parts or quadrants. These quadrants are autonomous, dependent, independent and linkage drivers. Autonomous drivers are those that have a low value for driving and a low value for dependency power. Drivers with a high value of dependence power and a low value of driving power come under the dependent driver's category. Drivers with high value of dependence power and high value of driving power come under the linkage driver's category. Drivers with high value of driving power and low value of dependence power come under the independent driver's category. The division of these drivers into four categories is important for firms, as it will help to define the role of each driver. The MICMAC analysis will define the effect of each driver on the other category drivers. Drivers belong to an independent category will support the linkage drivers. Similar way, independent drivers and linkage drivers will support the dependent drivers.

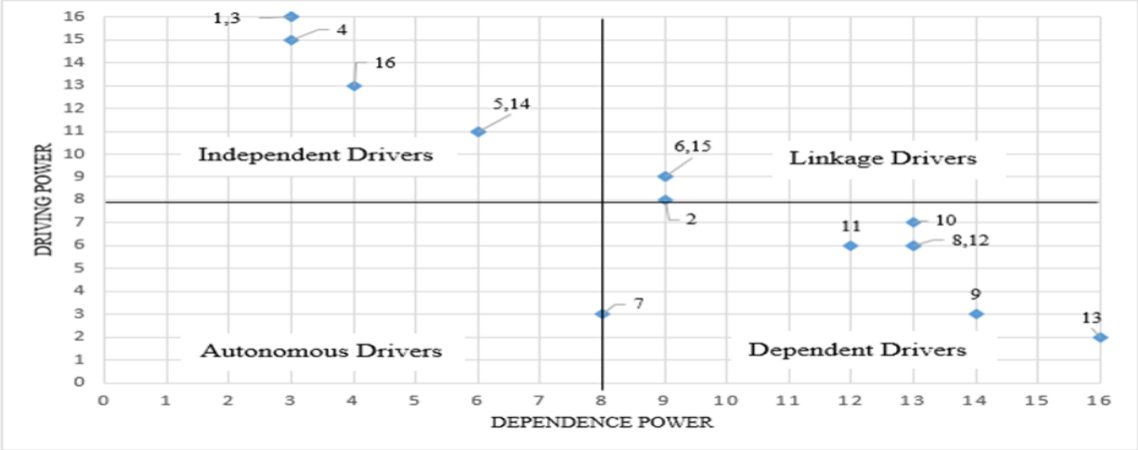

Fig. 2. MICMAC analysis

4. Results and Discussion

Drivers for lean and green manufacturing are defined in this study based on a literature review and expert opinions. In this way, a total of sixteen drivers are identified and further considered for modelling. ISM approach has used to develop a hierarchical structure model for drivers. This approach helps to develop a contextual relationship among drivers. With a better understanding of these drivers, the organization can effectively implement lean and green practices in the organization. The outcomes of this study are explained below:

- 'Cost reduction', 'to increase market share' and 'Government support' found as primary drivers for lean and green manufacturing implementation. For any manufacturing firm, the cost of the product is an important point of concern for the manufacturer and customer as well. Price strategy plays an important parameter in the global and local market for any organization. Lean and green practices help the firm to focus on the overall cost of manufacturing which includes administrative cost, capital cost, sales and cost associated with environmental-related techniques. Researchers [18, 22] have identified cost reduction as the most important driver for lean and green manufacturing. Manufacturing organizations generate a large amount of waste in terms of wastewater, gas emission and solid waste. Government can encourage the organization through various incentive schemes and assistance to adopt new advanced green techniques. Government can also implement strict rules, laws and regulations which strongly encourage firms to adopt new green and lean techniques in the manufacturing system. Study [9,6] shows that regulatory compliance from the government can help and guide the manufacturing firm to be sustainable.
- 'Adequate technology development', 'Public pressure', 'Stakeholder pressure' found as important drivers for lean and green manufacturing. Manufacturing organizations need to upgrade the system with advanced and highly energy-efficient technology. The adaption of these advanced technologies encourages the firms to achieve economic, environmental and operational efficiency. Study [8] suggested that adequate technology development can help the various firms to reduce waste emissions and utilize the resources efficiently. Public pressure by various organizations such as NGOs, local authorities, social activities and media can play an important role in the adaption of green practice by the firms. Public

pressure and opinions will help to maintain a reputation by organizations [22].

- Competitiveness', 'Green brand/Company image', 'Environmental collaboration with supplier' are also important drivers as concerned with lean and green manufacturing. In the global market, the demand for green products is increasing day by day. The global market becomes more competitive towards the adaption of green techniques and encouraging other companies to adopt the same techniques. The study [17] found competitiveness as an important driver for the organization to improve the operational and economic performance of the system. Company image considered as an indirect driver for firm performance as it requires the organization to take responsibility towards the environmental management system [8]. Researcher [22] found in the study that environmental collaboration with the supplier will help the firm to transform the whole supply chain into sustainable.
- 'ISO 14001', 'Reusing/ Recycling materials and packaging', 'Reverse logistics', 'Green design/green purchasing/green innovation' are found as essential drivers for lean and green manufacturing. Study [20] analyzed that green purchasing, green designs and green innovations are very crucial strategies for green manufacturing. It will help to evaluate the company performance for sustainability. ISO 14001 certification helps and influences the companies to adopt green practices in the manufacturing process.
- MICMAC analysis suggests that no drivers were found as an autonomous category. This means that the study confirms that all drivers selected for the study are playing an important role in lean and green manufacturing. All the drivers analyzed in the study are essential factors towards the implementation of lean and green in the manufacturing process.

5. Managerial Implications

The management from the organization can take this model as a road map for understanding and assessing the firm's performance and activities for greenness and leanness. This modelling approach provides flexibility to decision-makers towards the implementation of lean and green manufacturing. The study will guide the management to analyze the most influential drivers for lean and green manufacturing in the early stage of strategy adaption. The study can help the researchers to compare the results of the study with other modelling techniques and expand the results. The study can also help the practitioners to analyze the implementation benefits of lean and green manufacturing.

6. Conclusions

Environmental performance of a manufacturing firm plays a significant role in the decision making process [21]. Environmental awareness among customer and supplier will help to reduce the consumption of natural resources and help the manufacturing process activities to be sustainable. The adaption and implementation process of lean and green activities in the firm are challenging task for management as it needs a high level of responsibility, skill and financial support. This can be achieved with the help and support from government agencies by providing funds, incentive schemes, conducting assistance programs for skill development etc. The study develops a hierarchical level ISM based model for lean and green manufacturing drivers. This study provides a brief view of drivers for lean and green manufacturing. Sixteen drivers have identified from literature review and expert's opinions. These drivers are cost reduction, competitor green strategies, to increase market share, government support, public pressure, green brand/company image, environmental awareness of customers, ISO 14001 certification, the potential use of energy

resources, reusing and recycling materials and packaging, reverse logistics, green design/green purchasing/green innovation, top management commitment, stakeholders pressure, environmental collaboration with suppliers and adequate technology development. The contextual relationships among the drivers are analyzed by the ISM modelling approach to determine the most important driver for lean and green manufacturing. ISM model is used in this study, as it helps to know and analyze the dependency among drivers with the help of expert's opinions and suggestions. According to the finding of the study, cost reduction, increase market share and government support are the most important drivers for the lean and green implementation process. Cost reduction is always a primary important driver for an organization. The adaption of lean and green techniques require adequate funding and guidance from highly skilled management.

The modelling approach of drivers helps industrial practitioners to implement lean and green strategies in their firms. This study will provide valuable input to the researcher to expand the results with more structured techniques and real data. This study is having some limitations, the drivers are primarily identified from the literature and expert opinions in the study. A survey approach can be used to identify more realistic drivers which are not reported in the literature.

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