

Research Article

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Evaluating Lean Performance of Indian Small and Medium Sized Enterprises in Automotive Sector

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Abstract: Under new “make in India policy” India has started to become global manufacturing hub and many Indian organizations are looking to implement lean philosophy to gain sustainable strategic benefits over others. Therefore, a need was felt to develop comprehensive lean evaluation system for Indian automotive small & medium sized enterprises in order to measure its present lean status and potential improvements to gain significant strategic advantages. Research started with the identification of various lean factors and associated sub factors through literature survey. Fuzzy analytic hierarchy process was applied to assign weight to various extracted lean factors and sub factors because of its evident merits. Fuzzy comprehensive analysis was applied to assess present status of Indian automotive small and medium sized enterprises, where lean does not practice. Lean performance of Indian automotive small & medium sized enterprises was ascertained as poor. The proposed model could be useful to guiding the Indian automotive small and medium sized enterprises in judicious selection of lean practices to gain significant sustainable strategic advantage over its competitors. Novelty of this research is to emerge from the development of comprehensive lean measurement model for Indian small and medium sized enterprises in automotive sector.

Keywords: Sustainable strategic advantage, Lean factors & sub factors, Fuzzy AHP (Analytic hierarchy process), Fuzzy comprehensive analysis

1 Introduction

The concept of lean manufacturing has been implemented successfully in all kinds of manufacturing environment worldwide, ever since its inception in 1990. It has become panacea for all types of manufacturing problems and brought about dramatic improvements in achieving manufacturing excellence. However, primarily all missions did not succeed because of non-judicious use of different lean practices and absence of proper measurement system in place.

According to the recent research undertaken, manufacturing leanness was feasible in Finnish SMEs environment. Manufacturing leanness was achieved using lean practices of continuous improvements and reduction of all kinds of waste in the system. But many SMEs failed miserably in their lean voyage because of the inadequate customized lean deployment methodology. The early identification of potential weaknesses could make companies more aware of their own competencies and weaknesses. Findings suggested, having adequate customized lean deployment methodology could make SMEs more rationale in their voyage of lean implementation and chances of failure can be minimized (Majava & Ojanperä, 2017 [1]). A comprehensive six phased lean implementation model was also suggested. According to the model the lean implementation program should start with strategic analysis of market driven by customer requirement, followed by formation of cross functional team, judicious selection of lean tools, value stream mapping, and others (Chakravorty, 2010 [2]).

Current research focused on measuring the lean performance of Indian automotive SMEs using fuzzy AHP. Indian SMEs are prime driver of Indian economy and providing employment to millions of people. A valid lean performance measurement system could provide with vital clues about their weaknesses in lean tools selection and subsequent implementation, so that they can take suitable corrective measures to improve leanness and gain sustainable strategic advantages over their competitors.

The research started with the exploration of various lean factors and associated sub factors, those explain lean-

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ness of system being evaluated through literature survey. Literature survey resulted in framing the hierarchical structure of the system. Next step was the selection of suitable weighing methodology to obtain weight of those extracted factors and sub factors to ascertain their relative importance.

The direct ratio methodology is often applied for the determination of the various factors and their associated sub factors. The direct ratio procedure starts with defining the factors and associated sub factors. Pair wise comparison is done to find out their relative importance. Lastly the defined weight must be verified for inconsistency if any. But in real world scenario it is extremely challenging to obtain consistence preference of decision makers for the subjective evaluation and expect them to act 100% rationally all the times. Therefore, direct ratio procedure will have some inconsistencies (Rommelfanger & Eickemeie, 2013 [3]). Now, it becomes imperative to find out some other methods, which can tolerate certain degree of inconsistency and provide fool proof measures of finding inconsistencies. Analytical hierarchy process (AHP) was one of the better choices available. AHP was first put forth by Thomas L. Satty. AHP allows weight determination by disintegration of the problem into various hierarchical stages, known as sub problems. Though the AHP provide a process to check inconsistencies and assign the weight in logical and structured manner but AHP has often been criticized for not taking care of inaccuracies and uncertainties in decision making (Tsvetinov & Mi khailov, 2004; Yang & Chen, 2004 [4, 5]). During the process of pair wise comparison, AHP represents relative importance with the exact number. However, in practical situation, it is extremely tough for the evaluator to measure the importance exactly using crisp values. The assessment should be in predefined range having minimum, mean, and maximum value configuration. The fuzzy set theory, considers this configuration. Extended version of AHP that is fuzzy set AHP procedure works on a nine-point scale with triangular fuzzy number to evaluate the various lean factors those explain sustainable strategic advantages within Indian automotive SMEs environment (Rommelfanger & Eickemeie, 2013 [3]). After developing the weight index for entire measurement system, fuzzy comprehensive analysis was applied to assess level of leanness of Indian automotive SMEs.

2 Literature survey

2.1 History

Toyota production system is the foundation of lean production system. The term lean was first put forth by MIT in 1990 to redefine Toyota production system as lean manufacturing system (Yadav *et al.*, 2010 [6]).

Lean was the strategy to reduced cost, while continuously improving the quality of all kind of product and services you delivered, resulting in enhanced customer satisfaction (Womack & Jones, 2010 [7]).

The term leanness gives the measure of lean and also defined in variety of ways by the different researchers across the globe. Leanness was defined as effects of various lean tools and practices implemented on lean performance of the organizations (Vimal & Vinodh, 2012 [8]). Leanness was also defined as level of commitment to lean manufacturing (Soriano & Forrester, 2002 [9]). Leanness is a broader is broader in scope and transcend beyond the use of lean tools and practices to almost all operational features of the organization including design, development, quality, maintenance, and safety (Singh *et al.*, 2010 [10]). Leanness defined as level of perfection in value stream mapping (Wan & Chen, 2008 [11]). Leanness was the measure of extent of waste elimination activities, continuous improvements, and achieving zero defect. Leanness defined as extent of waste elimination generating from redundant processes, inefficient operations, and excessive build-up of inventory (Hallgren & Olhager, 2009 [12]).

Lean philosophy was initially started as an operational stage in auto sector in 1980s. Toyota has become number one auto maker after successful implementation of lean philosophy, surpassing auto giant General motors, Ford motors, and Chrysler. Now lean production system started to gain acceptance worldwide in variety of industries including services, in quest of same benefits as Toyota enjoys (Piercy & Rich, 2009 [13]). It has been argued lean production system is more suitable for discrete manufacturing in comparison to continuous production found in process industry. But there are evidences of lean manufacturing system being successfully implemented in process industries like chemicals and pharmaceuticals with fair amount of success (Abdulmalek & Raj Gopal, 2007 [14]).

2.2 Identification of lean tools and practices

Commonly, the effects of five most vital lean practices were analysed in the literature such as, pull production system, heijunka, continuous improvement, total productive maintenance (TPM) and value stream mapping (VSM) on contemporary measures lean performances. Findings indicated that heijunka was having the strongest impact on operational performance, followed by continuous improvement, total productive maintenance, and value stream mapping. Research offered statistically proven evidence of linkage between lean practices and operational performance. Research would be helpful in better lean planning and lean tool selection (Belekoukias, 2014 [15]). Yadav and associates defined lean practices as total elimination of waste from the system, wherever it exists. Stream lined flow of information, material, and continuous improvement in all parts of the system were cited as key lean practices to achieve perfection (Yadav *et al.*, 2010 [6]). Kaizen, cellular manufacturing, and poka-yoke were cited as key lean practices towards attaining the targeted level of leanness (Womack & Jones, 2010 [7]). According to a recent study conducted in 2014, lean root map was developed for describing the details of framework of lean implementation (Sundar *et al.*, 2014 [16]). Continuous improvement was also suggested as one of the key lean practices. The goal of continuous improvement can be achieved by proper training, early detection of process problems, proper development of idea management, and adequate reward & recognition system (Holtskog, 2013 [17]). Various practices of lean implementation such as VSM, 5S, Poka-yoke, Kanban, JIT etc. were analysed for gear shaft manufacturing company. VSM was identified as key lean practices in variety of industrial environment (Nallusamy, 2016 [18]). Importance of takt time was emphasized through value stream mapping in order to synchronize the production with demand in order to achieve manufacturing superiority and dramatic improvements in the productivity of machine tool sector SMEs (Ricondo *et al.*, 2016 [19]). Value stream mapping, 5S, and Kanban have been successfully applied to reduce lead time and in process inventory in Indian bearing industry, resulting in significant enhancement in the productivity (Saraswat *et al.*, 2015 [20]). Value stream mapping combined with other lean tools such as 5 why and Ishikawa diagram were successfully applied in health care products to reduce lead time and in process inventory in the system (Tomas & Martin, 2015 [21]). Method time measurement & line balancing were successfully applied in truck body assembly line to reduce bottleneck and cycle time in the system (Kumar & Kumar, 2014 [22]). Value

stream mapping, Kaizen, and single piece flow were applied to reduce cycle time, inventory and to increase visibility in crank shaft assembly line system (Venkataraman, 2014 [23]). Total productive maintenance was implemented in machine shop to enhance machine availability, performance of and to improve the quality yield (Singh *et al.*, 2013 [24]). Lean practices such as waste elimination, kaizen, just in time, pull, cross functional team, decentralized responsibilities, integrated functions and vertical information systems were implemented in kitchenware industry to achieve considerable improvement in all contemporary performance parameters (Subashini & Kumar, 2014 [25]). Combination of lean practices and tools such as Total Productive Maintenance, Total Quality Management, Failure Mode and Effect Analysis, 5S, Quality Function Deployment, Kaizen, Kanban and Value Stream Mapping were used as inputs to structural equation modelling to determine various dimension of lean manufacturing (Vinodh & Joy, 2012 [26]). Simulation along with value stream mapping was used to design lean production system for doors and windows manufacturer following job shop production system (Gurumurthy & Kodali, 2011 [27]). Seventeen lean practices and lean tools namely: cross functional employee, quality circle, set up time reduction, 5S, Kanban, continuous flow, preventive maintenance, small lot size, total quality control (TQC), Kaizen, cellular layout, standard operational Training, focused factory, Supplier management, Visual control, Teamwork were suggested with varying degree of importance for successful lean implementation in SMEs environment (Rose *et al.*, 2011 [28]). According to research conducted in Malaysia, Kanban system was the key lean practice for the successful lean implementation in Malaysian SMEs (Rahman *et al.*, 2013 [29]). Value stream mapping, Kanban, 5S, Total productive maintenance, and single minute exchange of die, and Poka-yoke can be applied in Indian SMEs to reduce waste in the system and productivity improvements (Marasini *et al.*, 2014 [30]). Questionnaire administered survey and subsequent statistical analysis suggested the most important and extensively used lean practices were continuous improvement, organization at work place, and standardization in Malaysian automotive SMEs (Rose *et al.*, 2013 [31]). Exploratory factor analysis was also conducted for Malaysian manufacturers to identify the most important lean factors. Lean factors identified were process optimization, layout, and work organization (Yusup *et al.*, 2016 [32]). A set of basic nine lean practices were suggested as starting point of the lean implementation affecting overall performance of the firm regardless of its size. These practices were focused on waste identification and

Table 1: Lean tools & their objectives

Lean Practice	Objective	Reference
Pull production system	Produce according to demand	[15]
Heijunka	Production levelling according to both volume & variety	[15]
Kaizen	Continuous improvement of the process to attain small & incremental changes in efficiency & effectiveness of all operations.	[6, 7, 15, 17, 23, 25, 26, 28, 31]
Total productive maintenance	To increase productivity of organization.	[15, 24, 26, 28, 30]
Value stream mapping	Stream line flow of information & material to increase visibility & responsiveness of the system	[6, 15, 19–21, 23, 26, 27, 30]
JIT (Just in time)	Removal of all kind of waste from the system	[6, 18, 25, 30, 33]
Cellular Layout	Increased flexibility in production without compromising volume of production.	[7, 28]
Poka-yoke	Mistake proofing to prevent defect propagating deep into the system	[7, 18, 30]
Takt time	Synchronise production with demand	[19]
5S	Organization at work place	[18, 20, 26, 28, 30]
KANBAN	Visual control	[18, 20, 26, 28–30]
Line balancing	Removal of bottleneck operation	[22]
SMED	Single minute exchange of dies to reduce set up time	[30, 35]

elimination (Yusup *et al.*, 2015 [33]). In Table 1 describes the objectives of various key lean tools.

Improper lean tool selection and lack of lean implementation methodology were cited as major hindrance in implementing lean philosophy in SMEs. It is quite evident from the literature survey; different lean practices were suggested and also feasible in different kinds of manufacturing environment but most of lean practices cited were overlapping and confusing in nature. Recently a comprehensive study was done in India to identify various lean factors and their associated lean variables feasible in Indian SMEs automotive industry environment. The following table (Table 2) describes various lean factors and associated lean variables for Indian SMEs in automotive sector, which provided the basis for comprehensive evaluation of leanness of Indian automotive SMEs (Tiwari & Tiwari, 2018 [34]).

2.3 Lean Measurement System

Slack based lean measurement system based on linear programming was developed with bench marking to quantify the degree of leanness, commonly known as lean score. Lean score determine the impact of various lean

practices by quantifying the extent of value addition and waste elimination (Wan & Chen, 2008 [11]). Lean evaluation model was developed using fuzzy set theory, based on five vital lean parameters for Indian auto component industry (Singh *et al.*, 2010 [10]). Fuzzy logic based theoretical lean measurement system was proposed comprises of three levels namely: lean enabler, lean criteria, and lean attribute followed by gap analysis. By identify the weak lean criteria which help to take corrective measures to improve the leanness organization (Vimal & Vinodh, 2012 [8]). Mathematical lean measurement model was developed to assess the effectiveness of various lean strategies on waste reduction in manufacturing organization. This model helped in identification of suitable lean strategy for manufacturing organization (Soriano & Forrester, 2002 [9]). Survey based method was used to evaluate the operational performance of variety of manufacturing firms spread in all four geographic regions in India, who have implemented lean philosophy. About 80% of the firms implemented the lean practices such as: customer focus, JIT, SMED, statistical process control, TPM, and cross functional problem solving. Implementation of these lean practices resulted in improvement of productivity and reduction in lead time, inventory & space requirement (Ghosh, 2012 [35]). Fuzzy logic based advisory system was formu-

Table 2: Lean factors and associated lean variables

Extracted factors & their labelling	Description of associated variables
F ₁ Problem identification & prevention	<ul style="list-style-type: none"> • f₁₁ (Continuously improve process to prevent the defect from occurring) • f₁₂ (Calculate the process capability index after the product design) • f₁₃ (Mistake proofing to arrest the problems before it could propagate deep into value chain) • f₁₄ (Use cause and effect diagram to find out root cause of problem) • f₁₅ (Standard operating procedure) • f₁₆ (Use statistical process control to reduce variance) • f₁₇ (Use visual signals to notify the problem)
F ₂ Strategic relationship with the suppliers	<ul style="list-style-type: none"> • f₂₁ (Maintain close relationship with our suppliers). • f₂₂ (Suppliers visit regularly to our plant) • f₂₃ (Plant managers visit suppliers' plants regularly) • f₂₄ (Maintaining long term relationship with our suppliers) • f₂₅ (Suppliers' managed inventory system.) • f₂₆ (Suppliers' participation in product and process design)
F ₃ Pull production system	<ul style="list-style-type: none"> • f₃₁ (Receive raw material on time by the suppliers) • f₃₂ (Production is pulled by demand in the immediately following station) • f₃₃ (Kanban control mechanism to manage inventory in the system) • f₃₄ (Do not build inventory in anticipation of demand) • f₃₅ (Customer pulls the product from the value chain)
F ₄ Flow production	<ul style="list-style-type: none"> • f₄₁ (Create family of parts having similar production requirement) • f₄₂ (Use production levelling to maintain the flow of production) • f₄₃ (Create family of parts having similar routing requirement) • f₄₄ (Equipment is grouped according to processing requirements of part family) • f₄₅ (Cellular layout to process part family)
F ₅ Quick change over	<ul style="list-style-type: none"> • f₅₁ (Employees practice regularly to reduce change over time) • f₅₂ (Continuously improve the design of our equipment to reduce set up time) • f₅₃ (Continuously try to reduce the suppliers lead time) • f₅₄ (Synchronise our production cycle time with the customer demand)
F ₆ Total productive maintenance	<ul style="list-style-type: none"> • f₆₁ (Use maintenance operation as a tool for productivity enhancement) • f₆₂ (Increase the availability of equipment by periodic maintenance) • f₆₃ (Provide proper training to bridge the gap between operators & maintenance staff) • f₆₄ (Use standard maintenance procedure to keep equipment in excellent condition)
F ₇ Customer involvement	<ul style="list-style-type: none"> • f₇₁ (Receive regular feedback regarding quality of the product) • f₇₂ (Customer involvement in product and process design) • f₇₃ (Maintain long term relationship with our customers)

lated to help out SMEs in decision making with regards to the lean implementation. The system intended to measure the lean readiness of the organization. The level of lean readiness determined the amount of resources needed and having a vital bearing over the success and failure of lean implementation program (Achanga *et al.*, 2012 [36]). Using attributes of both efficiency and effectiveness in manufacturing organization, lean evaluation system was developed to continuously assess lean implementation (Karim & Zaman, 2013 [37]). Lean model that takes into accounts the various lean principles was developed. The rationale

behind the development of the model was in depth understanding of the change process in lean implementation leading to alleviation of uncertainty and vagueness in lean implementation. The model also provided the vital clues about the effect of inclusion and removal of a particular lean tool on the leanness and subsequently on operational performance of the company (Karlsson & Åhlström, 1996 [38]). Framework for evaluation of cost effectiveness of various lean tool was developed, applying multi criteria decision making. The framework was developed with the help of Deming & Kaizen cycle. Quality function de-

ployment, value stream mapping and balanced score card were applied in order to measure the cost effectiveness of lean tools using in relation to the customer requirements and the issues related to implementation (Alsyof *et al.*, 2011 [39]).

2.4 Lean measurement model

Customized multi-level lean measurement model using fuzzy comprehensive analysis was proposed to develop comprehensive lean measurement system for Indian automotive SMEs. (Li *et al.*, 2009; Chang, 1996 [40, 41]). The basic assumption of model is that whole problem can be divided into three hierarchical level i.e. level 1 (Top level), level 2 & level 3. Assumption is also the limitation of the model allowing one-way communication that is top level to bottom level. Mean elements at each level of hierarchy particularly at lower level of hierarchy are independent in nature.

The following are step by step approach to model development: -

Step 1: Establish target and identify the subject

Target is to achieve sustainable strategic advantage to Indian SMEs in automotive sector by implementing lean philosophy.

Step 2: Find evaluation grade to assess leanness.

Evaluation grade set $V = (\text{Excellent } v_1, \text{Very good } v_2, \text{Good } v_3, \text{Moderate } v_4, \text{Poor } v_5)$

Step 3: Identification of various lean factors

Next important step to develop lean measurement model was to define various lean factors those explain lean performance of Indian SMEs in automotive sector.

$$F = \{F_1, F_2, F_3, F_4, F_5, F_6, F_7\}$$

Where F = Lean performance.

Step 4: Identification of various lean sub factors

Lean sub factors are basically associated lean variables to factors.

$$F_1 = \{f_{11}, f_{12}, f_{13}, f_{14}, f_{15}, f_{16}\}$$

$$F_2 = \{f_{21}, f_{22}, f_{23}, f_{24}, f_{25}, f_{26}\}$$

$$F_3 = \{f_{31}, f_{32}, f_{33}, f_{34}, f_{35}\}$$

$$F_4 = \{f_{41}, f_{42}, f_{43}, f_{44}, f_{45}\}$$

$$F_5 = \{f_{51}, f_{52}, f_{53}, f_{54}\}$$

$$F_6 = \{f_{61}, f_{62}, f_{63}, f_{64}\}$$

$$F_7 = \{f_{71}, f_{72}, f_{73}\}$$

Step 5: Assign weight to various factors and associated sub factors applying fuzzy AHP (Refer section 2).

AHP is extremely productive instrument in adjusting the fuzziness of the data. The linguistic level of evaluation by the experts are mapped to triangular fuzzy numbers (Table 4) to form fuzzy pair wise comparison matrix (Table 5). The model is having three level, level 1(Goal), level 2 (factors), & level 3 (Sub factors) (Refer table 5).

Step 6: Frame fuzzy membership matrix for each of the single factor

Establish fuzzy membership matrix of each of the single factor on f_n sub factors.

R_i is the fuzzy evaluation matrix of factor F_i and r_{ijk} signifies degree of k th kind of evaluation for factor F_i to evaluation level j that is associated sub factor f_{ij} .

Step 7: Frame fuzzy evaluation matrix (Judgment Vector) for each of the single factors

Synthesize fuzzy evaluation matrix for every single factor using weights of associated sub factors (level 2) obtained with the help of fuzzy AHP that is $w_i = (w_1, w_2, w_3, \dots, w_n)$.

$$B_i = (W_i \times R_i) = (b_{i1}, b_{i2}, \dots, b_{im})$$

Fuzzy membership vector B_i represent mapping of comment set to factor F_i .

Step 8: Perform fuzzy comprehensive analysis & obtain overall fuzzy membership matrix for the entire system.

$$R = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_i \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & \cdots & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & \cdots & b_{2m} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \cdots & \vdots & b_{nm} \end{bmatrix}$$

Suppose the weights obtained for all the factors set using fuzzy AHP is $W = (W_1, W_2, \dots, W_n)$.

The overall fuzzy evaluation matrix or synthesize fuzzy matrix vector for the entire index system can be represented as: $B = W \times R = (b_1, b_2, \dots, b_m)$

B represents the mapping of comment set to entire index system. Suppose $b_0 = \max(b_1, b_2, \dots, b_m)$ corresponds to comment set v_k then v_k represented the evaluation of entire system.

Table 3: Random Index

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.48	1.51

3 Proposed fuzzy AHP model

3.1 AHP procedure

Step 1: Frame pair wise comparison matrix using expert's opinions.

$$\begin{bmatrix} M_{11} & M_{12} & \cdots & \cdots & M_{1n} \\ M_{21} & M_{22} & \cdots & \cdots & M_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ M_{n1} & M_{n2} & \cdots & \cdots & M_{nn} \end{bmatrix} \quad (1)$$

Step 2: Consolidate the triangular fuzzy number with the help of following formula: -

$$M_{ij} = (M_{ij}^1 \otimes M_{ij}^2 \otimes \cdots \otimes M_{ij}^n)^{1/n} \quad (2)$$

Step 3: Perform consistency check for the decision making

Consistency value $CV(n) = \frac{CI(n)}{RI} \leq 0.1$, where consistency index $I(n) = \frac{\lambda_{\max} - n}{n-1}$, λ_{\max} is the greatest Eigen value of pair-wise comparison matrix and n is the order of the matrix. RI stands for random index and its value can be found with the help of following table (Table 3). RI is the average value of CI. Table was obtained using the Satty scale developed by Thomas L. Satty applying simulation with the help of 100 runs.

Step 4: calculate the consolidation grade using the following equation: -

$$C_i = \sum_{j=1}^m M_{ij} \left[\sum_{i=1}^n \sum_{j=1}^m M_{ij} \right]^{-1} \quad (3)$$

Step 5: Compare the consolidated triangular fuzzy number and calculate the consolidation grade using the following equation:

$$V(C_i \geq C_j) = \begin{cases} 1 & \text{if } m_i \geq m_j \\ 0 & \text{if } l_j \geq u_i \\ \langle l_j - u_i \rangle \div \langle m_i - u_i \rangle - \langle m_j - l_j \rangle & \text{Otherwise} \end{cases} \quad (4)$$

Step 6: Calculate the minimum consolidation grade

$$\text{Min} V(C \geq C_1, C_2 \cdots C_k) \quad (5)$$

$$\text{Min} V((C \geq C_1) \text{ and } (C \geq C_2) \cdots \text{ and } (C \geq C_k))$$

$$\text{Suppose } w_i = \text{Min} V(C_i \geq C_j) \text{ where } i \neq k.$$

The weight vector can be framed as $W = \text{Normalize the weight vector to get final priority vector.}$

3.2 Triangular membership function

Triangular membership function was framed using fuzzy set theory. These membership functions were used for pair-wise comparison. Team comprises of five lean experts was chosen for the current study to rate their preferences using following membership function. Subjective evaluation of experts expressed in linguistic terms mapped to their corresponding fuzzy values (Table 4).

$$M_x = (l, m, n) \Rightarrow 1/M_x = (1/l, 1/m, 1/n)$$

Table 4: Triangular Fuzzy conversion scale

Linguistic Term	Membership function (l,m,n)
Equally preferred	(1,1,1) (1,1,2)
Moderately preferred	(1,2,3) (2,3,4)
Strongly preferred	(3,4,5) (4,5,6)
Very strongly preferred	(5,6,7) (6,7,8)
Extremely preferred	(7,8,9)

M_{ij}^k represent subjective importance of i^{th} criterion in comparison to j^{th} criterion by the k^{th} expert using membership function. The following equation computes the value of M_{ij} .

$$M_{ij} = (M_{ij}^1 \otimes M_{ij}^2 \otimes \cdots \otimes M_{ij}^n)^{1/n}$$

Where n is the number of experts involved in decision making.

4 Data Analysis

4.1 Weight indexing

Weight assignment for $F = (F_1, F_2, F_3, F_4, F_5, F_6, F_7)$, Where F = Lean performance using fuzzy AHP method. A

Table 5: Pair wise comparison matrix

	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
F ₁	[1 1 1]	$\begin{bmatrix} 4 & 5 & 6 \\ 4 & 5 & 6 \\ 3 & 4 & 5 \\ 5 & 6 & 7 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \\ 1 & 2 & 3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \\ 1 & 1 & 1/2 \end{bmatrix}$
F ₂	$\begin{bmatrix} 1/4 & 1/5 & 1/6 \\ 1/4 & 1/5 & 1/6 \\ 1/4 & 1/5 & 1/6 \\ 1/3 & 1/4 & 1/5 \\ 1/5 & 1/6 & 1/7 \end{bmatrix}$	[1 1 1]	$\begin{bmatrix} 1/2 & 1/3 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \end{bmatrix}$	$\begin{bmatrix} 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 \\ 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 \end{bmatrix}$	$\begin{bmatrix} 1/5 & 1/6 & 1/7 \\ 1/5 & 1/6 & 1/7 \\ 1/3 & 1/4 & 1/5 \\ 1/3 & 1/4 & 1/5 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$	$\begin{bmatrix} 1/5 & 1/6 & 1/7 \\ 1/5 & 1/6 & 1/7 \\ 1/5 & 1/6 & 1/7 \\ 1/6 & 1/7 & 1/8 \\ 1/6 & 1/7 & 1/8 \end{bmatrix}$
F ₃	$\begin{bmatrix} 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \\ 1 & 1 & 1/2 \end{bmatrix}$	$\begin{bmatrix} 2 & 3 & 4 \\ 2 & 3 & 4 \\ 2 & 3 & 4 \\ 3 & 4 & 5 \\ 3 & 4 & 5 \end{bmatrix}$	[1 1 1]	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \end{bmatrix}$
F ₄	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 2 & 3 & 4 \\ 1 & 2 & 3 \\ 2 & 3 & 4 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	[1 1 1]	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \end{bmatrix}$	$\begin{bmatrix} 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \end{bmatrix}$
F ₅	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1/2 & 1/3 \end{bmatrix}$	$\begin{bmatrix} 2 & 3 & 4 \\ 2 & 3 & 4 \\ 1 & 2 & 3 \\ 2 & 3 & 4 \\ 2 & 3 & 4 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1/2 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 2 & 3 \\ 1 & 1 & 1 \end{bmatrix}$	[1 1 1]	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1/2 & 1/3 \\ 1 & 1 & 1/2 \end{bmatrix}$
F ₆	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1/2 \end{bmatrix}$	$\begin{bmatrix} 5 & 6 & 7 \\ 5 & 6 & 7 \\ 3 & 4 & 5 \\ 3 & 4 & 5 \\ 3 & 4 & 5 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 1 \end{bmatrix}$	[1 1 1]	$\begin{bmatrix} 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \end{bmatrix}$
F ₇	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 5 & 6 & 7 \\ 5 & 6 & 7 \\ 5 & 6 & 7 \\ 6 & 7 & 8 \\ 6 & 7 & 8 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 2 & 3 & 4 \\ 2 & 3 & 4 \\ 2 & 3 & 4 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix}$	[1 1 1]

panel of five lean experts was formed. Lean expert are consultants having hands on experience of at least four years of lean implementation in Indian SMEs.

Step 1: Perform pair-wise comparison and translate the opinion of the experts into triangular fuzzy numbers (Table 5).

Step 2: Perform consistency analysis of pair-wise comparison matrix.

The maximum Eigen value of pair-wise comparison matrix is 7.36.

$$CI(n) = \frac{\lambda_{\max} - n}{n - 1}, n = 7 \quad CI(n) = 0.06$$

Value of RI = 1.32

$$\text{Consistency value } CV(n) = \frac{CI(n)}{RI} \Rightarrow CV(n) = 0.045$$

Consistency value is less than 0.1, mean it can be safely assumed the decision taken by the expert in formulation of pair-wise comparison matrix is consistence in nature.

Step 3: Using equation (3), consolidation of triangular fuzzy numbers gives the following sets of values:

$$C_2 = (0.026, 0.04, 0.07), \quad C_1 = (0.11, 0.18, 0.31),$$

$$C_3 = (0.09, 0.14, 0.07), \quad C_4 = (0.05, 0.10, 0.10),$$

$$C_5 = (0.06, 0.12, 0.20), \quad C_6 = (0.10, 0.19, 0.30),$$

$$C_7 = (0.14, 0.23, 0.40)$$

Step 4: Using equation (4, 5) calculate the consolidation grade.

$$\text{MinV}(C_1 \geq C_2, C_3, C_4, C_5, C_6, C_7) = 0.77,$$

$$\text{MinV}(C_2 \geq C_1, C_3, C_4, C_5, C_6, C_7) = 0.11,$$

$$\text{MinV}(C_3 \geq C_1, C_2, C_4, C_5, C_6, C_7) = 0.47,$$

$$\text{MinV}(C_4 \geq C_1, C_2, C_3, C_5, C_6, C_7) = 0.20,$$

$$\text{MinV}(C_5 \geq C_1, C_2, C_3, C_4, C_6, C_7) = 0.35,$$

$$\text{MinV}(C_6 \geq C_1, C_2, C_3, C_4, C_5, C_7) = 0.78,$$

$$\text{MinV}(C_7 \geq C_1, C_2, C_3, C_4, C_5, C_6) = 1,$$

Resulting weight vector = (0.77, 0.11, 0.47, 0.20, 0.35, 0.78, 1) and the normalization of weight vector gives the priority vector depicting the relative importance of the factors in relation to the degree of leanness. $(F_1, F_2, F_3, F_4, F_5, F_6, F_7) = (0, 22, 0.03, 0.13, 0.054, 0.95, 0.21, 0.27)$. Similarly, the priority vectors for all the sub factors defined as level 3 factors can be calculated in relation to their factor at level 1 using the methodology as described above.

Table 6: Weight Indexing

Goal	Primary Factor (Level 1)	Weight	Secondary Factors (Level 2)	Weight
Measurement of leanness	F ₁ Problem identification & prevention	0.22	f ₁₁ (Continuously improve process)	0.13
			f ₁₂ (Calculate the process capability index)	0.15
			f ₁₃ (Mistake proofing)	0.20
			f ₁₄ (Use cause and effect diagram)	0.17
			f ₁₅ (Standard operating procedure)	0.11
			f ₁₆ (Use statistical process control to reduce variance)	0.19
			f ₁₇ (Use visual signals to notify the problem)	0.05
	F ₂ Strategic relationship with the suppliers	0.03	f ₂₁ (Maintain close relationship with our suppliers).	0.19
			f ₂₂ (Suppliers visit regularly to our plant)	0.08
			f ₂₃ (Plant managers visit suppliers' plants regularly)	0.05
			f ₂₄ (Maintaining long term relationship with our suppliers)	0.22
			f ₂₅ (Suppliers managed inventory system.)	0.20
			f ₂₆ (Suppliers participation in product and process design)	0.25
	F ₃ Pull production system	0.13	f ₃₁ (Receive raw material on time by the suppliers)	0.12
			f ₃₂ (Pull production system)	0.27
			f ₃₃ (Kanban control)	0.25
			f ₃₄ (Do not build inventory in anticipation of demand)	0.21
			f ₃₅ (Customer pulls the product from the value chain)	0.15
	F ₄ Flow production	0.054	f ₄₁ (Create family of parts having similar production requirement)	0.24
			f ₄₂ (Use production levelling to maintain the flow of production)	0.12
			f ₄₃ (Create family of parts having similar routing requirement)	0.20
			f ₄₄ (Group equipment according to processing requirements of part family)	0.16
			f ₄₅ (Cellular layout to process part family)	0.28
	F ₅ Quick change over	0.095	f ₅₁ (Employees practice regularly to reduce change over time)	0.38
			f ₅₂ (Continuously improve equipment design to reduce set up time)	0.25
			f ₅₃ (Continuously try to reduce the suppliers lead time)	0.17
			f ₅₄ (Synchronise production cycle time with the customer demand)	0.20
	F ₆ Total productive maintenance	0.21	f ₆₁ (Use maintenance operation as a tool for productivity enhancement)	0.32
			f ₆₂ (Periodic maintenance)	0.28
			f ₆₃ (Autonomous maintenance)	0.22
			f ₆₄ (Use standard maintenance procedure)	0.18
	F ₇ Customer involvement	0.27	f ₇₁ (Receive regular feedback regarding quality of the product)	0.27
			f ₇₂ (Customer involvement in product and process design)	0.39
			f ₇₃ (Maintain long term relationship with our customers)	0.37

Using fuzzy AHP methodology, the weight index for the entire measure system was developed. The following table describes the weight index for the measurement system (Table 6).

4.2 Fuzzy comprehensive analysis

A panel of 50 experts from 50 Indian automotive SMEs is selected to evaluate the status of leanness SMEs at automotive sector in India and further to determine the way of implementation of various lean practices. All experts are managers in their industry and responsible for the key production line. Fuzzy evaluation matrix for factors F1 to F7 are framed according to evaluation grade described in the model development section.

For example, f_{11} level 3 factor is concerned, 9 experts think it good, 16 experts think it moderate, and 25 experts think it poor. Fuzzy vector for f_{11} written as, $R_{11} = (0.0, 0.0, 0.18, 0.32, 0.50)$. Similarly, fuzzy vectors for others are as follows:

$$R_{12} = (0.0, 0.0, 0.15, 0.35, 0.50),$$

$$R_{13} = (0.0, 0.0, 0.12, 0.28, 0.60),$$

$$R_{14} = (0.0, 0.0, 0.16, 0.36, 0.48),$$

$$R_{15} = (0.0, 0.0, 0.22, 0.38, 0.40),$$

$$R_{16} = (0.0, 0.10, 0.14, 0.26, 0.50),$$

$$R_{17} = (0.0, 0.12, 0.15, 0.33, 0.30)$$

Fuzzy evaluation matrix for factor F_1 is: -

$$R_1 = \begin{bmatrix} 0.0 & 0.0 & 0.18 & 0.32 & 0.50 \\ 0.0 & 0.0 & 0.15 & 0.35 & 0.50 \\ 0.0 & 0.0 & 0.12 & 0.28 & 0.60 \\ 0.0 & 0.0 & 0.16 & 0.36 & 0.48 \\ 0.0 & 0.0 & 0.22 & 0.38 & 0.40 \\ 0.0 & 0.10 & 0.14 & 0.26 & 0.50 \\ 0.0 & 0.12 & 0.15 & 0.33 & 0.30 \end{bmatrix}$$

Similarly, the fuzzy evaluation matrix for other factors can be written as:

$$R_2 = \begin{bmatrix} 0.0 & 0.0 & 0.10 & 0.15 & 0.75 \\ 0.0 & 0.0 & 0.15 & 0.25 & 0.60 \\ 0.0 & 0.10 & 0.12 & 0.35 & 0.43 \\ 0.0 & 0.05 & 0.10 & 0.25 & 0.60 \\ 0.0 & 0.0 & 0.0 & 0.20 & 0.80 \\ 0.0 & 0.0 & 0.0 & 0.30 & 0.70 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.0 & 0.0 & 0.0 & 0.40 & 0.60 \\ 0.0 & 0.0 & 0.10 & 0.70 & 0.20 \\ 0.0 & 0.0 & 0.25 & 0.75 & 0.0 \\ 0.0 & 0.0 & 0.15 & 0.65 & 0.20 \\ 0.0 & 0.0 & 0.17 & 0.43 & 0.40 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 0.0 & 0.0 & 0.0 & 0.20 & 0.80 \\ 0.0 & 0.0 & 0.05 & 0.25 & 0.70 \\ 0.0 & 0.0 & 0.07 & 0.33 & 0.60 \\ 0.0 & 0.0 & 0.10 & 0.45 & 0.45 \\ 0.0 & 0.0 & 0.00 & 0.20 & 0.80 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} 0.0 & 0.0 & 0.10 & 0.80 & 0.10 \\ 0.0 & 0.0 & 0.0 & 0.20 & 0.80 \\ 0.0 & 0.0 & 0.0 & 0.10 & 0.90 \\ 0.0 & 0.0 & 0.20 & 0.60 & 0.20 \end{bmatrix}$$

$$R_6 = \begin{bmatrix} 0.0 & 0.20 & 0.25 & 0.35 & 0.20 \\ 0.0 & 0.25 & 0.25 & 0.45 & 0.05 \\ 0.0 & 0.18 & 0.32 & 0.35 & 0.15 \\ 0.0 & 0.0 & 0.10 & 0.45 & 0.45 \end{bmatrix}$$

$$R_7 = \begin{bmatrix} 0.0 & 0.10 & 0.25 & 0.22 & 0.43 \\ 0.0 & 0.0 & 0.0 & 0.05 & 0.95 \\ 0.0 & 0.10 & 0.60 & 0.30 & 0.0 \end{bmatrix}$$

Weight vectors for secondary factors (Level 3) are (Table 5):

$$W_1 = (0.13, 0.15, 0.20, 0.17, 0.11, 0.19, 0.05),$$

$$W_2 = (0.19, 0.08, 0.05, 0.22, 0.20, 0.25),$$

$$W_3 = (0.12, 0.27, 0.25, 0.21, 0.15),$$

$$W_4 = (0.24, 0.12, 0.20, 0.16, 0.28),$$

$$W_5 = (0.38, 0.25, 0.17, 0.20),$$

$$W_6 = (0.32, 0.28, 0.22, 0.18),$$

$$W_7 = (0.27, 0.39, 0.37).$$

Fuzzy vector for factor F_1 is $B_1 = W_1 \times R_1 = (0, 0.025, 0.155, 0.32, 0.50)$. Similarly, for other factors:

$$B_2 = (0, 0.016, 0.06, 0.236, 0.68),$$

$$B_3 = (0, 0, 0.12, 0.63, 0.23),$$

$$B_4 = (0, 0, 0.036, 0.272, 0.7),$$

$$B_5 = (0, 0, 0.08, 0.49, 0.43),$$

$$B_6 = (0, 0.17, 0.24, 0.40, 0.192),$$

$$B_7 = (0, 0.064, 0.28, 0.19, 0.05).$$

Fuzzy evaluation matrix for the entire measurement system can be framed as:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \end{bmatrix} = \begin{bmatrix} 0.0 & 0.025 & 0.155 & 0.32 & 0.50 \\ 0.0 & 0.016 & 0.06 & 0.236 & 0.68 \\ 0.0 & 0.0 & 0.11 & 0.63 & 0.23 \\ 0.0 & 0.0 & 0.036 & 0.272 & 0.70 \\ 0.0 & 0.0 & 0.08 & 0.49 & 0.43 \\ 0.0 & 0.17 & 0.24 & 0.40 & 0.19 \\ 0.0 & 0.064 & 0.28 & 0.19 & 0.48 \end{bmatrix}$$

The evaluation grade is translated into numerical score with the help of table 7.

Table 7: Classification of sustainable competitive advantage

Score for leanness	90-100	70-90	60-70	40-60	0-40
Evaluation grade	Excellent	Very good	Good	Moderate	Poor

Evaluation grade $V = \{\text{Excellent, Very good, Good, Moderate, Poor}\} = \{95, 80, 65, 50, 20\}$

Weight vector for the entire measurement system is $W = (0.22, 0.03, 0.13, 0.054, 0.095, 0.21, 0.27)$. Fuzzy vector for the entire measure system can be framed as:

$B = W \times R = (0.0, 0.06, 0.176, 0.31, 0.38)$. Maximum value of B is 0.38, which corresponds to poor (v5) in the comment set. Means the current status of leanness of Indian automotive industry is poor, which corresponds to numerical value of $B \times V = 39.34$. Similarly, numerical score of evaluation of factors F_1 to F_7 are $\{38.075, 30.58, 43.78, 29.94, 38.3, 53.04, 33.82\}$.

5 Discussion and conclusion

With the increasing globalization, organizations across the world are trying to formulate the manufacturing strategy which could give them sustainable strategic advantage. Therefore, it is become imperative to identify the

drivers of sustainable competitive advantages. Judicial implementation of various lean practices is the prime driver which optimizes the resource consumption and reduces the waste in the system. However, the detail study is required to find the influential lean factors, those could boost leanness or lean performance of Indian automotive SMEs. As a result, gains the significant sustainable strategic advantages over others. One of the outcomes of the present study was the development of framework describing the various lean factors and associated sub factors. These are the drivers of leanness automotive SMEs environment in India for further improvement. Fuzzy AHP methodology was applied to ascertain the importance of these factors. Finally, fuzzy comprehensive analysis was done to adjudge the current status of leanness of Indian automotive SMEs.

The proposed model measures the extent of leanness of Indian automotive SMEs by applying the fuzzy comprehensive analysis. The current status of leanness of Indian automotive SMEs was poor in terms of resource optimization, elimination of waste, and customers' involvement in product & process design. Although majority of SMEs in Indian automotive sector started to apply various lean practices but still they have lack of clear understanding of various lean practices and method, its benefits, and potential outcome in the form of sustainable strategic advantage. The proposed measurement model could be contributed among the various lean factors, their relative importance, potential opportunities and possible outcome. By visualizing the understandable scenario of lean practice, the Indian SMEs could implement various lean practices more judicially and objectively. They need to be focused more on certain key lean factors and associated sub factors to gain maximum benefits. As per numerical score of evaluation grade, it was found that the customer involvement, problem identification & prevention, and total productive maintenance are the top three most important factors. In addition, there numerical evaluation values were 33.82, 38.075, and 53.04 for customer involvement, problem identification & prevention, and total productive maintenance respectively. These scores indicated poor contribution of the most important factors in enhancing the leanness and could impart significant sustainable strategic advantage to Indian automotive SMEs. Improvement in these important factors and associated activities should be in top priority of the Indian automotive SMEs to achieve significant sustainable strategic advantage to stay ahead in intense global competition.

Fuzzy AHP assigns highest weight to factor customer involvement, followed by problem identification & prevention and total productive maintenance. The findings are in

consensus with the study conducted for Indian automotive industry to rank the various factors of lean manufacturing explaining sustainable competitive advantage (Tiwari & Tiwari, 2018 [34]).

Lean index system was developed for Indian auto component industry applying fuzzy set theory. Lean index was presented on the 100 points scale of the various lean parameters selected such as suppliers issue, priorities of investment, lean tools, waste management, and customer issue. The lean index suggested the current status of leanness is below average. Means, Indian auto component industry was deprived of vital lean benefits. The findings were in consensus to the findings of present study (Singh *et al.*, 2010 [10]).

According to a study conducted by applying different dimensions to measure leanness namely: manufacturing process and equipment, manufacturing planning and scheduling, visual information system, Supplier relationship, customer relationship, workforce and product development & technology. Most of them are in consensus to the present study. However, the model developed measured the degree of leanness according to the extent of waste reduction achieved applying these lean practices (Wahab *et al.*, 2013 [42]).

Susilavati and associates developed a similar model to assess leanness using eight key indicators and sixty-six sub indicators. Though the model provides substantial insight to measure leanness and can be applied for variety of organization, however the model is subjective in nature and lack objectivity (Susilawati *et al.*, 2013 [43]).

An attempt has been made, applying analytic hierarchy process to analyse and rank the important green lean practices having significant impact over firm's performance in Indian SMEs. TPM was found as most important lean practice, whereas ISO1400 was vital green practice. Synchronizing production with the demand was essential criteria for achieving significant leanness and reducing emission to environment was critical to achieve greenness. Model facilitated the implementation of lean and green manufacturing in Indian SME. The present study also suggested TPM as second most important factor to achieve leanness (Thanki *et al.*, 2016 [44]).

Though the proposed model comprehensively defined and measures the degree of leanness in relation to sustainable strategic advantage for Indian SMEs in automotive sector, the amount of subjectivity involved in the evaluation of real world objects cannot be ignored. Factors of agility should be incorporated in the model to measure the responsive of the organizations in an increasingly uncertain and challenging business environment. By incorporation measure of both leanness and agility we can develop

fool proof measure of sustainable strategic advantage of Indian automotive SMEs.

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Appendix

Kindly refer to the values in table 5, for an example cell F1:F2. The evaluator 1 rated F1 in comparison to F2 as (4,5,6) using the triangular membership function, evaluator 2 as (4,5,6) and so on.

Convert the pairwise comparison matrix shown as table 5 taking the mean of the ratings of all five evaluators. Calculate the value of M_{ij} using equation $M_{ij} = (M_{ij}^1 \otimes M_{ij}^2 \otimes \dots \otimes M_{ij}^n)^{1/n}$ equation 2 (Refer 2.2) and create matrix as shown in table 5. Use the matrix for the consistency check. Start with calculating the eigen value. Rest is self explanatory and very clear step by step process as illustrated in the case presented. Procedure illustrated is for the determination of weights for the factors that F1: F7. Same way the pair wise comparison matrix is formed for all the subfactors associated with particular factors. For an example for factor F1 the pair wise matrix of order (7* 7) is formed, because number of associated sub factors are 7. Experts evaluated the relative importance of the sub factors using pair wise comparison in relation to the factor. Evaluate the relative weights of the associated factor using the methodology described.

The following table describe the mean value of the ratings of the five experts:

	F1	F2	F3	F4	F5	F6	F7
F1	(1,1,1) M_{11}	(3.94,4.96,5.97) M_{12}	M_{13}	M_{14}	M_{15}	M_{16}	M_{17}
F2	M_{21}	M_{22}	And so on				
F3							
F4							
F5							
F6							
F7							

Convert the table using equation 2 to convert triangular values into single value to calculate the eigen value of the matrix for consistency check (Step 3). Follow the process as described in step 4,5,6 to get consolidation grade and normalize it to get the final weight for the factors F1:F7.

Step 5:

$$V(C_1 \succeq C_2) = 1, \quad V(C_1 \succeq C_3) = 1, \quad V(C_1 \succeq C_4) = 1, \quad V(C_1 \succeq C_5) = 1, \quad V(C_1 \succeq C_6) = 1, \quad V(C_1 \succeq C_7) = 0.77$$

Step 6:

$$\text{Min}V(C_1 \succeq C_2, C_3, C_4, C_5, C_6, C_7) = \text{Min}V(1, 1, 1, 1, 1, 0.77) = 0.77$$