

Green lean manufacturing: Way to sustainable productivity improvement

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ABSTRACT--The aim of this paper is to get insight into the concept of green lean manufacturing to precisely comprehend the idea of green lean manufacturing, and diverse practices in the course of extensive literature survey. This paper also gives the reasonable idea of associations between leanness and business agility, subsequently the effect of business agility on the productivity of the manufacturing organization in particular. Ever since 1990, the thought of lean manufacturing has been a catchphrase and many industries across the globe implemented the philosophy effectively. This gives me an opening to look at the various procedures of lean practices worldwide in detail. The foundation of lean philosophy is to deliver the product at a least possible cost on time as demanded by the customers, using effective waste removal process to maximize the value of the product and also make sure the quality of the product in accordance to the needs and wants of the customers. The leanness makes the production system agile, which is in turn, could become the appropriate long term strategy for the sustainable competitive advantages. Business agility is the organizations' capability to respond aptly to the fickle needs and wants of the consumers, which is endlessly becoming formidable in globalized world. Business agility has turned into a barometer of long term success for many organizations worldwide. Green lean manufacturing is the promising philosophy with intent of improving the productivity, by constantly enhancing the efficiency & effectiveness of the business. Finally the literature review helps in assessing the research gap and research problem. Consequently the preparation of research hypothesis and research design, with the objectives of addressing the core issue while conducting a study on it.

KEYWORDS--Lean Manufacturing, Business Agility; Productivity; Green Manufacturing, Interpretive Structural Modeling; Fuzzy Comprehensive Analysis; Analytical Hierarchical Programming.

INTRODUCTION

SMEs have been major contributory in transforming manufacturing sectors worldwide. The contribution of SMEs' to Indian GDP is more than 30% and providing employment to nearly 50% of employable population. Despite such major influence and tremendous potential to boost Indian economy, SMEs' are struggling for their existence after globalization in particular. Indian automotive SMEs' are no exception. Due to the short product life cycle, fast changing customers taste and technological advancement, Indian automotive SMEs' are facing stiff competition both in and out of the country. Due to long product development time, poor inventory and other waste management their product cost is escalating, profit margin is fast diminishing and they are on the doorstep of becoming uncompetitive. In other words we can say they are fat and inefficient organizations, consuming lots of resources without appreciable value addition. They must strive to become lean. For their own existence they must learn and implement green lean manufacturing to create maximum value of the products by consuming lesser amount of vital resources.

Lean manufacturing is a philosophy widely acknowledged by many organizations worldwide ever since the early 1990s. Lean manufacturing can be best described as waste elimination process from the system,[1]. Anything, process or product-services, which does not value to your product is waste,[2]. Value should be in the eyes of the customer. Customers will value more the end product if and only if it matches to their requirements, delivered on time at a least possible cost. The idea of lean manufacturing strives towards maximizing the value of your end product in the eyes of the customers by incessantly refining the quality of the end product and elimination of the all kind of surpluses in the system,[1]. The top management plays a dynamic role in transformation to lean, they must unite the people and create awareness what will happen during the course of implementation and what is anticipated of them. [2] While implementing lean philosophy change in the system will be both social and technical in nature. Implementation of lean philosophy will bring about the drastic cultural and environmental change in the system,[3]

The concept of Lean manufacturing arrived to India in the mid 1990's from Japan and United States of America, but it was generally the large scale sector exploited the philosophy to gain sustainable competitive edge. Now, medium and small sectors enterprises want to reap the same benefits. After been studying Lean manufacturing conceptually, a curiosity started to grow in my mind how the philosophy actual works out in large Indian companies and how it could be implemented in a small & medium scale enterprises, automotive industry in particular. The lean philosophy encapsulates more than hundred variables which need to be concentrated upon for the successful implementation of the philosophy. As far as SMEs' are concerned, it's not viable to implement complete

philosophy because of the resource constraints; instead they can concentrate upon some important factor. That is why the present study explores the process of implementing green lean manufacturing through extensive literature survey.

Literature Survey

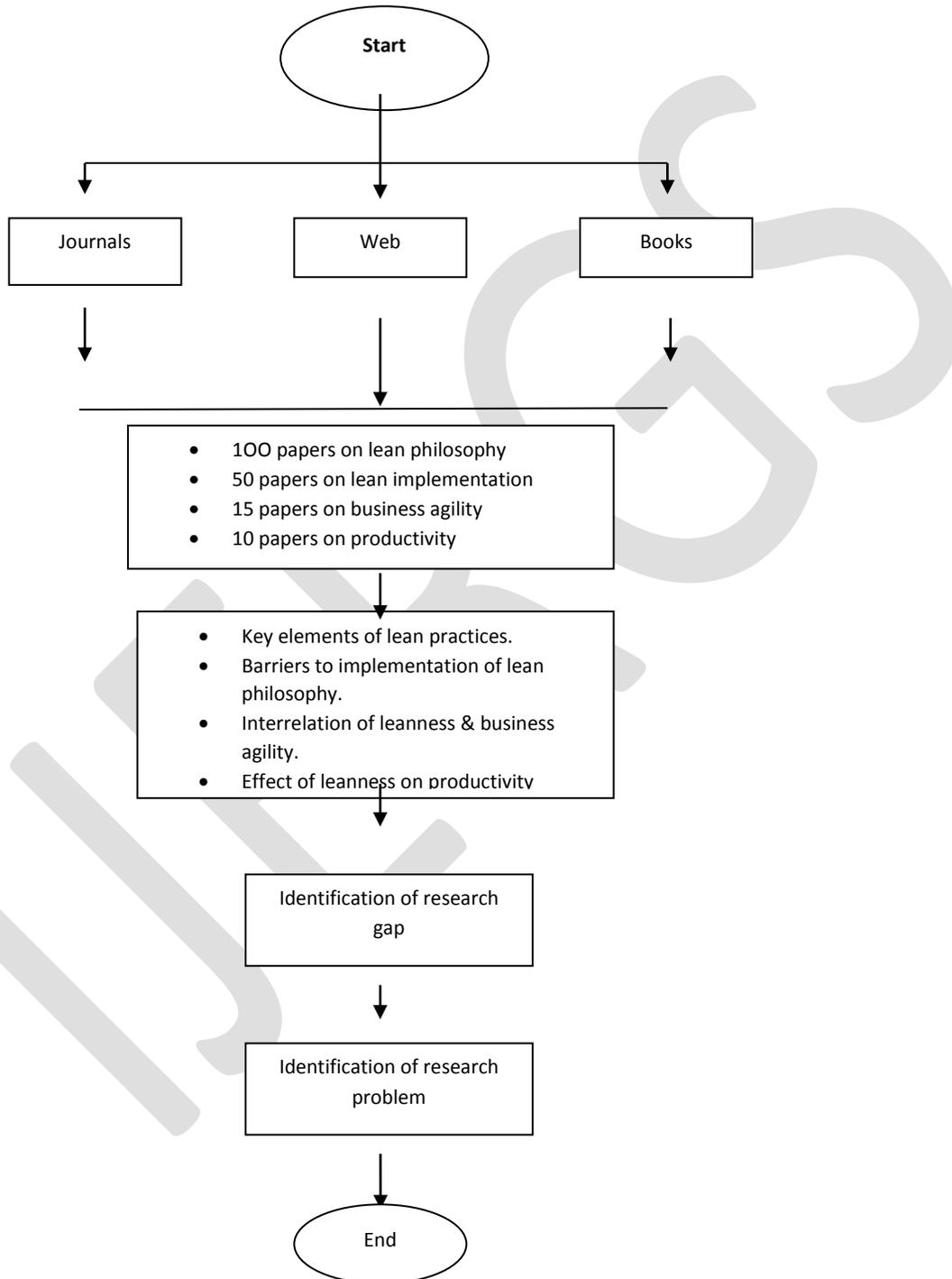


Figure 1: Flow chart of literature survey

1. Evolution of lean philosophy

The philosophy of lean manufacturing is being used mostly in the automotive industry. Toyota Motor Company, is the pioneer in lean manufacturing techniques and has been exploiting the techniques since World War II. They are the leader in successfully practicing the tools and techniques of lean philosophy. The many concepts of lean philosophy is not new, can be found in work of Deming, Taylor & Skinner but not well understood until Toyota implemented them successfully. In the early 1980's, U.S. auto giant like GM and Ford were in watershed. Their market share was fast diminishing and Japanese were gaining. The Japanese automakers were producing better quality cars with lesser defects and lower cost resulted in enhanced customer. In spite of 1973 oil crisis Toyota continued to increase its earnings and captured more market. Till now Toyota is one of the world's most popular automakers that have continuously outclassed their rivals in terms of quality at lower cost and reliability, faster delivery, and after sales service etc. Japanese production systems have been increasingly researched by global academic world. It's a lean philosophy which made Toyota market leader worldwide surpassing older arch rivals like General Motors & Ford. However there are some doubt regarding the relevance and efficacy of the philosophy but numerous cases exists demonstrating the change in manufacturing practices in quest of becoming leaner.

Massachusetts Institute of Technology started a five years study on future of automobile in 1985 with reference to the transition from mass production to lean production in the International Motor Vehicle Program, which becomes a corner stone of the worldwide transition from mass production to, Lean Production. The outcomes were published in the book "The Machine that Change the World", [4]. According to the book, Lean Manufacturing equally efficient in all manufacturing set up, regardless of what they produce and size, and not limited to car manufacturing only, resulting in dramatic improvements in productivity.

However the book was not immune to criticism at various levels, like lean manufacturing was unreasonably glorified without any documentary evidence of its application in all industrial set up, [5]. Another criticism was workers in lean manufacturing setup works in tight compartment without any intrinsic motivation and autonomy, [6]. Lean production system was theoretical, highly superficial and infeasible where the actual was suppressed by what you supposed to be, [7].

There are numerous LM techniques put into practice by different organization worldwide, [8]. The paybacks those can be realized by executing LM manufacturing practices and techniques are cost reductions, reduction in manufacturing lead time results in on-time delivery, less inventory in the manufacturing line and increased availability of machines, [9, 10]. Additionally lean philosophy render's a superior method of waste elimination which results in greater value addition, [11]. Numerous literature available most emphatically suggest that LM philosophy is beneficial to all regardless the type of business and its size, [12, 13].

Studying the present literature delivers a preliminary point in describing lean production. Furthermore, it aids in highlighting the mix-up in the theoretical and the functioning space surrounding lean production and reap a set of operational procedures those can characterize it. While conducting review, I started with the initial publications linked to Japanese manufacturing/production systems, and finished with the current publications connected to lean production. I experienced the initial Japanese books were more accurate in defining TPS and recognizing its primary elements, [14, 15]. Articles concentrated more on defining and describing definite elements of the system rather than the entire picture.

This absence of difference amongst the system and its elements was further intricate by the general point of reference used in its description. Lean production is usually defined from either from a philosophical view point connected to guiding principles and primary objectives, [1, 16] or from the real-world point of view such as set of management practices, tools, or techniques those can be evident, [10, 17]. This dissimilarity in orientation does not essentially indicate divergence, but it does weaken the theoretical clarity.

Definitions of leanness are:

The term "lean" is defined as doing more with a less amount of resources to generate equivalent output to traditional mass production system at a least cost in line with the demands of the customers, [11].

Lean manufacturing is methodology generating value by elimination of all kind surpluses, developing responsive system, improving quality, and increasing effectiveness of all employees, (Massachusetts Institute of Technology).

National Institute of Standards and Technology (NIST) defined lean manufacturing as: “A logical move towards identifying and eliminating all kinds waste through continuous improvement, and making pull of products from the supply chain by the customer.

Lean manufacturing is synchronized integrated comprehensive methodology that includes a broad array of management tools, such as total quality management, total productivity management, JIT, team work, cellular layout, and suppliers management, in pursuit of a stream lined production that can deliver right kind of product, at right place and time at a minimum possible cost by eliminating all kinds of waste in the system,[10].

Lean manufacturing is a continuously self-evolving system, manufacturing system well built on the basis process and quality control supported by healthy work environment in order to deliver quality product at a minimum possible cost by eliminating all kinds of waste, which generate value to customers, society, and economy as a whole.

Lean manufacturing is a philosophy driven with top down approach to create requisite understanding and confidence towards the philosophy in order to reap maximum benefits out of it, [18].

Thus the essence of lean philosophy is to create customer responsive self-evolving productive system, which aim at continuously improving the quality and reduction in cost, delivery time of the product by elimination all kinds of non-value added activities (material handling, changeover, waiting, movement and defects etc.), through fostering conducive work culture with proper training and education to ensure total involvement.

In nutshell the salient features of evolution of philosophy of lean manufacturing can be expressed with the help of following table:

1927 & Before	Henery Ford published his philosophy of mass production known as Ford production system in 1927.
1945-78 in Japan	<ul style="list-style-type: none"> Detailed study of FPS by Toyota motor company and changed the concept from mass production to mass customization known Toyota production system (TPS). Salient points of TPS are cost reduction through elimination of all kinds of waste from the system, Continuous improvements in the quality of products as defined by the customers, quality assurance, production according to the needs and wants of the customers, and at a pace consensus with the customers demand known as JIT system. The details of TPS was published by Ohno publishers in the book “Toyota Production System” in 1978 in Japanese.
1973-78 Migration of TPS from Japan to USA	<ul style="list-style-type: none"> 1973 oil crisis forced USA to think over alternative production system. Started to generate interest on TPS, followed by numerous publications. TPS was published in English in book “Beyond large scale production”. Auto giants such as GM forged alliance with Toyota in 1984.
1988-2000, TPS to Lean	<ul style="list-style-type: none"> TPS redefined as lean manufacturing system, [19]. Details of lean concept has been described in the book “The machine that changed the world” by Womack, Jones, and Roos in 1990, [4]. No specific definition of the concept yet. Guiding principles to implement lean philosophy was published in book “Lean thinking”,[11].
2000 to present	<ul style="list-style-type: none"> Many researchers, practitioners, and consultants tried to define the lean concept through empirical investigation but still no specific definition yet. Toyota Motor Company projected to become number 1 auto maker in North America in 2006.

Table1: Evolution of Lean Philosophy

2. Identification of various lean practices and its function

Problem untaken is related to implementation of lean manufacturing in Indian automotive SMEs. The research starts with identification of factors affecting implementation of lean manufacturing through literature survey.

Five vital lean factors were suggested those could make a difference between life and death of the organization,[1] ----

Specify value from the eyes of the customer. Customers 'need and want is essential right from product design to process design so that the value of the end product can be maximized in the eyes of the customers. Do not manufacture anything which is of convenience to you without listening the voice of the customers.

After the value has been established, map the Value Stream which starts right from the procurement to the end product delivered to the customer and thereafter after sales service, safe disposal of product etc. We need to ensure that value is being added to the product at every stage in the value chain. Value stream mapping is all the activities that process the product. Typical process can be design, planning, production, delivery or after sales service. Value stream mapping gives you the better insight into your business operations.

The principle of flow is essential to add the value to a product as it moves from one stage to another in the value stream by elimination of all kind waste and ensure all the following stages are without any bottlenecks, delays or interruptions. Each stages of value stream should occur sequentially. Principle of flow results in up to 50% enhancement in the productivity

Do not produce anything to store, it's a waste. Produce at a rate synchronized to customers' demand. Customer must pull a product from your value chain rather than you push the product downstream towards the customer. This is known as pull production system or just in time production system. Pull production system results in no stock pileup which is actually a waste seriously compromising the profitability of the organization.

Strive for perfection. Perfection is no way related only quality of end product. Perfection has got broader meaning. It means produce in accordance to customers' requirements, the rate at which customer and at a minimum possible cost by continuously eliminating the all kind of waste in the system.

Few organizations have applied the five principles in hurry without giving any deeper thought to the implementation of the philosophy. Any structure changes should take by changing the attitude of the employees and envisioning the broader picture before the implementation. All the elements of the philosophy must be implemented rather implementing selective few to reap the benefits,[12].

Manufacturing leanness is basically a process optimization to achieve continuous process improvement to create optimum value from the process. Manufacturers can use diverse lean tools and concepts to diminish wastes and thereby increases the value. The lack of an effective plan, methodology, comprehension of lean performance and its measurement are vital factors causing the failure of the lean manufacturing application. Prevailing methods of choosing the suitable lean strategy depends upon the manufacturers' common sense rather than rational justification.

Now days, numerous business are keen to implement lean manufacturing in order to improve their performance to beat intense competition in global market where uncertainty is widespread,[20]. Commitment of suppliers to deliver required quantity of quality raw materials, parts and subassemblies was a critical success factor for the successful implementation of lean manufacturing,[21.] Participation of both top management and employees is essential in performance measures,[22]. Material handling is the important cost factors contributing about 30% to 70% of total operating expenses. Material handling is non value added activity and escalation of cost of material handling is a result of poor layout and selection of inappropriate material handling equipment,[1]. Poor layout design leads to several defects like excessive work in process inventory, and lower machine utilization,[23, 24]. Cellular layout an important component of lean manufacturing was studied in detail with reference to small scale industry,[25]. A number of lean manufacturing practices like JIT(Just in Time), total quality management, total preventative maintenance, and human resource management, pull, one piece flow, low setup cost, total productive maintenance and employees involvement were studied I detail,[25-26-27].

Visual card system such as KANBAN control has been exercised to reduce in process inventory and over production,[28]. Standardization manufacturing processes is essential for efficient, to provide relatively safer work environment and to reduce waste in the systems,[29]. Standardization results in reduction in unnecessary variety and outcome are reduced complexity and chance of error. Complexity can be reduced by reduction in number of parts, sub-assemblies, process simplification and using standard equipment with the necessary features only. Significance of communication and support of management in implementation of lean manufacturing have been studied,[30].

I also discovered numerous literatures, where operational tools were used to measure the elements of lean manufacturing and notice overlaps and confusions amongst the different measures. These operational measures are based on questionnaire administered survey,

where each of the survey questions denotes various lean tools. Generally these tools are referred as variables. These variables may explain the same element of lean manufacturing. Therefore it's become imperative to device some multivariate interdependency statistical analysis so that the overlap amongst these variables can be minimized. Factor analysis could be the ideal choice. Factors are latent variables. Variables explaining the same element can be put to gather under a single factor. Though many literatures are available, however I found only a few researches categorically measure the lean manufacturing. One of such practices is combining total productive maintenance, total quality management, and human resource management to measure lean manufacturing,[10]. These practices are internal to organization to manage its manufacturing operation. On the contrary the other study measures lean manufacturing conservatively using set up time, small batch size, and JIT production only,[16].

Following table provide the comprehensive list of various lean tools cited----

Lean Tools	Function
JIT	Customer pulls the product from the value chain
Kaizen	Continuous improvement
VSM	Waste reduction from Value Stream Mapping (lead time reduction)
Material Requirement Planning	Schedule of production plan to deliver particular end item on specified date
Kanban	Movement of parts based on cards
5S	Sorting, Set in order, Shine, Standardize and Sustain
Waste elimination	Elimination of non-value added activities
Andon	Caution of pending problems in the system.
Visual Management (VM)	Visual Control for excellent management
Poka Yoke	Fool Proofing.
Heijunka	Workflow leveling by volume & variety.
Takt Time	Rate of customer demand.
One Piece Flow	Single piece flow as per customer demand
Total Productive Maintenance (TPM)	Preventive, predictive & autonomous maintenance
Cellular manufacturing	Both volume & variety
Single Minute Exchange of Dies (SMED)	Set up time reduction
Team Work & Employees Empowerment	Working to gather and involvement in decision making
Problem Solving Techniques	Cause & Effect analysis, Fishbone Diagram
Standard Operating Procedure (SOP)	Use of reliable Methods

Table 2: Function of various lean elements

The following figure illustrates the basics & principle of lean philosophy,[30].

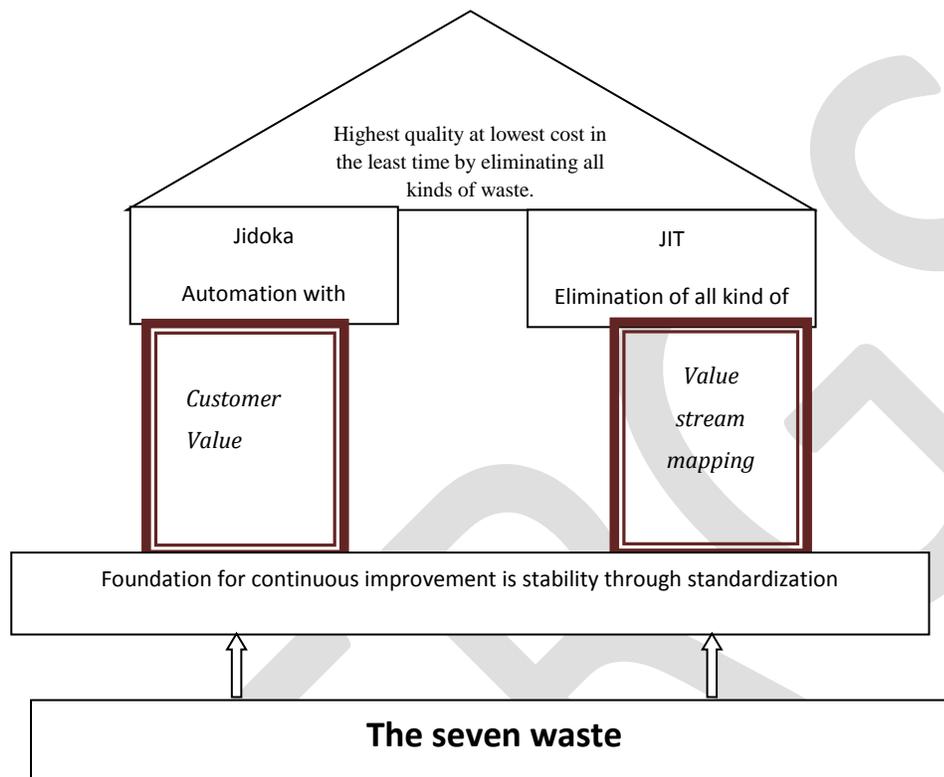


Figure 2: Basics & principles of lean philosophy

3. Lean implementation in small and medium scale enterprises

The literature suggests that it's not feasible for SMEs to apply all LM tools simultaneously due to the lack of expertise and financial constraints,[31]. Therefore sequential implementation starting from easiest and cheapest was suggested for the sustainable improvements in SMEs,[32]. Sequential implementation results in less financial burden and reduced complexities which makes the implementation feasible and manageable. SMEs should implement the most beneficial, feasible, and comparatively easy lean method to reap the maximum benefits as a stepping stone by winning the confidence of the employees, so that resistance to change can be minimized,[33]. Through the extensive literature survey, I managed to gather total 42 lean element with a varying degree of importance and feasibility. The most cited LM practices are a reduction in set up time, kanban control mechanism, small batch size, supplier management, preventive maintenance, multi skilled employees, even workload, total employees involvement, TQM, training, education, teamwork, production smoothing, continuous improvement, 5S and standardization,[34]. Most of the literatures find the frequently applied lean practices are reduced set up time, kanban control, and small batch size. These practices are feasible in most of the work environment and give you the maximum benefits of lean philosophy,[34].

A typical steps of lean implementation cycle are: Identification of value, value stream mapping, flow production system, pull production system, and finally seek perfection, [35].

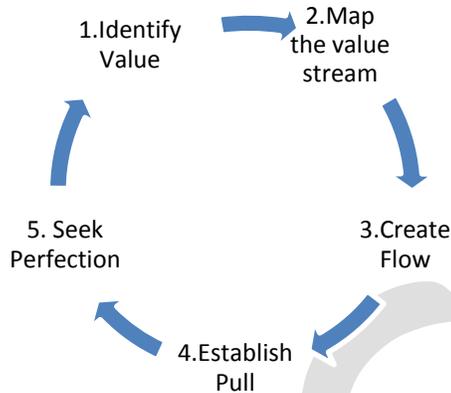


Figure 3: Lean Implementation

The following are the measures of lean manufacturing identified through the literature survey---

1	Maintaining strategic relation with the supplier	[36]
2	set up time, small batch size, and JIT production	[16]
3	Attitude of workforce	[4]
4	Comparative cost payback	[37]
5	Customer determined rate of production	[12]
6	Reducing resistance to change by winning confidence of the employees	[2, 33]
7	Efficient scheduling to cut down waiting time	[4, 38]
8	Statistical quality control & assurance	[14]
9	Increased equipment availability through total productive maintenance	[24]
10	standardization to reduce variety, complication in processing	[12, 29]
11	Capable leadership	[39]
12	Proficient application of novel competitive technology	[40]
13	Team-based cultures	[39].
14	Use of Kanban for better visibility in value chain	[25, 41]
15	Improved ergonomics & safety	[25]
16	Involvement of management, workers & suppliers in decision making.	[29]
17	Flexibility of machines, employees, and reduction in lead time	[42]
18	Optimum use of cubic space available	[23]
19	Striving towards zero defects	[27]
20	Cellular Manufacturing	[23, 25]
21	Total quality management	[43]
22	Elimination of all kinds of waste for maximum value addition	[1]

23	Customer driven quality initiative	[28].
24	Ability and competency of sales workforce	[1]
25	Timely availability of quality of raw material	[10-45]
26	Drive commitment to eliminating problems	[3]
27	Reduction in both in process and end items inventory	[12]
28	Whole hearted commitment of top management	[44]
29	Reduction in unnecessary cost of material handling & transportation	[4]
30	Reduction of total lead time & imparting flexibility to business	[46]
31	Adherence to delivery schedule	[47]
32	Mass customization	[44]
33	Enhanced safety standards leading to higher productivity	[48]
34	Proper training & education to reduce resistance in lean implementation.	[49]
35	Flexible machinery and workers	[50, 51]
36	Maximizing manufacturing productivity through total productive maintenance	[52]
37	Equipment reliability & efficiency	[53]
38	Involvement of customers in quality planning process	[54]
39	departure from the “you operate, I maintain” philosophy	[48].
40	Optimising planning and scheduling	[53]
41	Automation with a Human Touch	[55].
42	Strategic relationship with the suppliers	[12]

Table 3: Measures of lean manufacturing

4. Business Agility

Both agility and leanness emphasize optimum quality product. They also aim at minimization of total lead time taken from the moment customer places the order to the product finally delivered to customer. The ultimate objective of the lean philosophy is to increase customer responsiveness by elimination of all kinds of waste in the system. Reduction in total lead time is sufficient condition for achieving leanness; however degree of leanness is one of the necessary conditions to achieve business agility. Thus leanness is an essential ingredient of business agility. Minimization of total lead time is necessary to impart agility to the organizations due to extremely fickle demand which is difficult to predict [56].

Though, there is no clear demarcation between business agility and leanness in the literature available. But one thing is sure, agile manufacturing is a broader term, which includes both firms' internal and external environment, though lean philosophy is mostly related to firms' internal environment. Both business agility and leanness are essential for sustainable competitiveness and development,[10, 27, 41, 44, 46]. The purpose of this research is to investigate the effect of leanness on the agility of the business. Organizations exploit wide range of practices to upgrade their operational capabilities. Lean manufacturing and agile manufacturing has become buzzword which guarantees you sustainable development. The verbal meaning of lean is something which is not fat and agile means nimble, obviously the lean will be more agile, the same is true in case of business also,[17]. Actually the business agility and leanness are subset of each other,[10, 57]. Though many authors describe agility and leanness differently but ultimately they explain the same dimensions,[46]. One of the differences between the two could be, leanness emphasizes the elimination of all kinds of waste from the system, whereas agility refers to your response to fickle business environment, such as changing taste and demands of the customers,[58]. The basic characteristics of leanness and agility mostly overlap, such as TQM, TPM, SMED, 5S, and continuous improvements etc.

The term agile manufacturing was first put forth by group of researchers at Iaccoca Institute, Lehigh University in 1991,[59]. An agile manufacturing system is capable of responding to unpredictable demand, changing market, and overall environment quickly and effectively in due time,[60, 61]. Exploiting these changes as opportunities, such as quick launching of new product and switching between the products are also referred as agility,[51, 62, 63].

However, there is a lack

5. The impact of element of lean manufacturing on productivity

Productivity is the multiplier effect of efficiency and effectiveness. To become productive one need to produce right kind of product (Effectiveness) rightly (Efficiency). Thus the productivity encapsulates both product quality & quantity. In order to become productive you need to produce right kind of product in right quality at right time at a minimum possible cost. Improving the quality by continuous reduction in, avoidable delay, rework, cost, error, and machine down time & reliability,[4, 64, 65]. Apart from these, motivational level and job skills of the worker also affect productivity. Involvement of customers in quality process planning reduces rework, scrap, and lead by more than 50%, thereby increasing the productivity significantly,[54]. Prevalence of quality culture in the organization also helps in boosting productivity. Productivity is actually an outcome of raw material, conversion process, and outcome,[66].

6. Green lean manufacturing

No manufacturing process can be effective unless it take care of the society and environment as a whole. Lean manufacturing is the methodology of continuously improving the quality of the product by removing all kinds of waste in the system. Any productive manufacturing process utilizes minimum amount of energy, and often releases lesser amount pollutant or waste into the environment,[67]. The Green manufacturing is the technology to reduce emission through the use of renewable source of energy without generation of any waste,[68]. Though, only in recently studies lean manufacturing is linked with environmental safety. Both green practices and lean manufacturing are zero defect process, can be coined as green lean manufacturing. The objective of green lean manufacturing is to reduce the overall cost including the cost to the society, while maintaining all the contemporary performance parameters, [69,70]. Green techniques and lean manufacturing works synchronously by drawing wisdom from Mother Nature, which is actually both effective & efficient in imparting value by elimination of all kinds of waste. Hence the green lean manufacturing can be the most productive methodology,[71]. Though the waste described by the lean philosophy and green practices are different but all the 8 lean waste is having a significant impact on the environment. Waste can be reduced by judicious use of all vital resources including the energy and fuel leading to lower emission in the environment,[68]. The 8 type of waste describe by TPS are over processing, over production, waste of waiting, waste of inventory, waste of defectives, waste of movement, product complexities, and unused potential of employees. Waste can be reduced by judicious use of all vital resources including the energy and fuel leading to lower emission in the environment,[71].

The following table describes the effect of lean waste on environment,[72].

Defect	Description	Effect on environment
Over processing	Incorporating features not demanded by the customer	<ul style="list-style-type: none"> Excess processing Use of more fuel & energy results in greater emission in environment
Over Production	Production of end items to store in anticipation of demand	Excess use of material, leading to higher fuel and energy consumption results in greater emission in the environment
Waste of waiting	Delay because of equipment downtime, bottleneck, under capacity utilization	More energy consumption because of heating, cooling, and lighting leading to higher fuel consumption subsequent more emission.
Waste of inventory	Pile up work in process inventory	Excess use of raw material leading to higher fuel consumption, spoilage, and space results in more emission
Waste of making defective product	Defect can be anything which does add value to the product	<ul style="list-style-type: none"> More rework leading to higher fuel consumption and subsequent greater emission to environment. Results in scrap need to disposed of, leading to environmental pollution
Waste of movement	Unnecessary movement of man and material	Leading to higher fuel consumption and more emission to environment.
Complexity	More parts, subassembly, and number of steps of process	Waste of energy, fuel leading to higher emission
Unused potential of employees	Not using the suggestions and creativity of employees	Dearth of ideas to reduce the waste

Table 4: Relationship between lean waste & green practices

Taking care of environment is the integral part of the lean philosophy,[73]. Lean target all kinds of waste leading lesser emission in the environment. Lean philosophy actually coincidentally and unconsciously safe guards the environment. The main objective of lean philosophy is to acquire production efficiency by optimum use of material, reuse of the material, and energy. Thus lean philosophy actually unconsciously protects the environment by judicious use of all input leading to lesser use of energy, hence lesser emission. But in the recent past energy use has become a part KAIZEN continuous improvement in quest of acquiring energy efficiency to reduce emission in the environment,[73].

Lean philosophy aims at fostering an operational and cultural climate within the organization that is highly encouraging to minimization of waste and subsequent prevention of pollution. Green lean philosophy significantly improves the productivity by continuously increasing efficiency and effectiveness of the organization.

7. Interpretive Structural Modeling (ISM) (Adapted From [74])

ISM is an interactive modeling technique. In this technique, a set of diverse, directly and indirectly related elements are structured into an inclusive methodical model,[75, 76]. The model so formed exhibits the structure of a complex issue or problem in a cautiously designed outline implying graphics as well as words,[77]. Interpretive structural modeling (ISM) is a well-recognized methodology for spotting associations amongst specific items, which define a problem or an issue. For any composite problem under deliberation, a number of factors may be related to an issue or problem. However, the direct and indirect associations among the factors describe the circumstances far more precisely than the individual factor taken into separation. Therefore, ISM gives insights into combined perspective of these associations. ISM starts with an identification of variables, which are pertinent to the problem or issue, and then expands with a group problem solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pair wise assessment of variables. In the next step, the SSIM is transformed into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is obtained. In this approach, a methodical application of some basic concepts of graph theory is used in such a way that theoretical, conceptual and computational influence are exploited to explain the complex pattern of contextual relationship amongst a set of variables. ISM is proposed for use when desired to utilize methodical and rational thinking to approach a complex issue under deliberation. Interpretive Structural Modeling is a computer-aided method for developing graphical demonstrations of system composition and structure. ISM had its foundation in Warfield's perception of them need, when attempting to combine science to policy, for "a set of communication tools which have both a scientific and lay character serving as a linkage device between science and the public, and having sense for all who are involved" and which, in particular, are competent of communicating a generic intellect of the elements and their relations which describe system structure.

It is a modeling technique for portraying the specific relationship and overall structure in a diagraph model. It helps to oblige order and direction on the intricacy of associations amongst various elements of a system. It is largely intended as a group learning procedure, but individuals can also use it,[78].

7.1 MICMAC (Cross-Impact Matrix Multiplication Applied to the Classification analysis) analysis

MICMAC analysis is usually done in order to classifying the factors into four different categories. This classification is based on the driving power and dependency power of the factors. The classification helps in identification of key process enablers.

8. About Fuzzy Comprehensive Analysis (Adapted From, [79])

Fuzzy comprehensive evaluation system is based on mathematics used for complete evaluation of objects in a real world situation that are vague and difficult to define by using the thinking and methods of fuzzy mathematics. Fuzzy mathematics was first noticed in 1965, and pioneer is professor Chad (LAZadeh) who possesses substantial expertise in the area of automatic control mechanism. Like any other concept the fuzzy mathematics also kept evolving for near 38 years. Over the years fuzzy mathematics has witnessed a rapid advancement both in theory and practical. Fuzzy comprehensive analysis is based multi criteria decision making. Through the fuzzy evaluation information about the priority of various alternatives can be served as a reference for decision makers to make decision. You need to select the suitable appraisal indicators, these indicators can be from a different point of view, reflecting different aspects of the evaluation index system of evaluating objects. Fuzzy comprehensive evaluation needs the use of the indicator system comprises of multiple index. Evaluation should follow the principles of purpose, objectivity, comprehensiveness, sensitivity and mutual independence, the comparability and should be easy to operate. In the fuzzy comprehensive evaluation, the importance of weighing the value of different projects is called the weight,[80].

9. Analytical Hierarchical Programming (AHP)

The Analytic Hierarchy Process (AHP) is the most popular method used for multi criteria decision making, put forth by Saaty (1977). In the recent time AHP has been applied by many researcher mainly due to the its clarity and mathematical characteristics. The AHP may be a useful tool to ease out the process of decision making in complex situation involving multi level hierarchical objectives and different alternatives. The pertinent data are extracted by applying a set of pair-wise comparisons. These comparisons give you the weight of the decision criteria and measures of relative performances of each of the alternative. Apart from this, AHP provides mechanism for improving consistency.

The AHP algorithm helps in disintegration of the original problem into series of related sub problems. These sub problems comparatively easier to understand, hence can be better subjectively evaluated. Subjective evaluations are quantified by assigning numerical values, which subsequently rank each alternative on numerical scale.

10. Research Gap

- Though numbers of articles and research papers have been published since 1980 by the various researchers and practitioners on lean manufacturing. There is no consensus amongst researches over the comprehensive list of lean measures .Number of measures of leanness also been suggested but the relationship amongst these measures are confusing and confounding because of their interdependency. Therefore the relative importance of these measures is difficult to adjudge.
- No clear demarcation put forth that proposes, what are the industry specific measures should be taken achieve leanness? Or all the measures should be taken care of, regardless of type and size of industry.
- Similar sort of confusion exists in measures of agility & leanness due to overlapping natures of elements of leanness & agility.
- Moreover I, do not find any literature which explain the relationship between the productivity and agility of the manufacturing organization.
- More than 60 % Indian GDP comes from small & medium scale enterprises. Most of these organizations are using obsolete technologies, suffering from syndrome of non-judicial application all vital resources including excess inventory. Due to this they are the major source of pollution in the country. Production process which pollutes the environment is not at all effective, which is the essential ingredient of the productivity. I decided to target Indian SMEs' automotive sector which is the substantial part of SMEs in India, for the purpose of the current study.

This study will be a sincere effort to fill all the above mentioned gaps meticulously and thoroughly examine the various lean practices in the Indian SMEs' automotive sector and its applicability in improving the productivity.

10. Problem Identification

- Measures of green leanness found through literature survey are not categorical and often confusing in nature. These variables appear to be different however intend to measure the same element of lean manufacturing. There are high degree of interdependency amongst the different measures of leanness. Therefore it's very difficult to develop the model of lean manufacturing and subsequent measurement of leanness. In this research an attempt will be made to classify these variables and put them under different groups. These groups will be almost independent and useful in measuring green leanness. Therefore measuring their relative importance will be easier to measure.
- Since the target industry selected for the research is small & medium scale enterprises related to auto sectors in India. Since there can be lack of expertise, finance, and other vital resources, it's not possible for the SMEs' to implement all the measures of leanness. So it's imperative to identify a few vital lean measures which SMEs' afford to implement to reap the maximum benefits.
- Business agility is an important ingredient of success by beating the cut throat competition. Problem is to find out the interrelation of business agility and green leanness.
- Development of index of agility for small & medium scale enterprises related to auto sector in India.
- To substantiate the fact business agility leads to enhancement in the productivity.

11. Research objectives:

My research objectives are divided into six categories and will be found, answering to the following specific research question-----

RQ1: How green leanness can be comprehensively defined?

RQ2: What are the drivers of green lean manufacturing? Do these drivers independently explain the leanness of the organization?

RQ3: How do these drivers affect the leanness of small & medium scale auto sector in India? And what are the relative importance these drivers specific to India SMEs' auto sector?

RQ4: How to find sustainable green lean practices those Indian SMEs' can afford to implement.

RQ5: How these lean practices related to the agility of SMEs' auto sector in India?

RQ6: How to develop the index of agility to measure agility of Indian SMEs' auto sector?

RQ7: How business agility enhances the productivity of SMEs'.

RQ8: How to develop house of productivity for Indian SMEs' automotive sector ?

12. Research Hypothesis:

Based on extensive literature survey the following research hypothesis is developed:

H1: There is high degree of interdependency amongst the measures of green lean manufacturing and correlation matrix not an identity matrix.

Furthermore the ultimate goal of this study is to make Indian SMEs' auto sector agile by imparting green leanness to the system. Therefore for the purpose of the study I need to hypothesize some kind of relationship between agility and leanness.

H2: There is positive relationship between agility and green leanness, while leanness explains the agility of the business.

H3: Agile organizations are more productive in nature.

13. Frame work of research:

Sampling frame consist of all the manufacturing who have some expertise in implementing lean philosophy and lean implementation experts both in India & outside India. The sampling procedure will be convenient sample. Sample will consist of variety of manufacturing organizations both with respect to type and its size. Sufficient diversity in the sample will be maintained to mitigate biasness due to convenient sampling. Size of sample will be around 200. Elements of sample are mostly consist of operations managers who are having hands on experience of implementing lean philosophy and understanding of vital success parameters affecting lean implementation .

Extensive exploratory study will be conducted using questionnaire administered survey, where in the responded from the sample selected will be asked to rate their perceptions on 42 identified lean practices. Since the population size is limited, all questions in the survey are closed ended in nature in order to gather maximum response. The survey questionnaire was developed based on an extensive literature review,[27]. Questionnaire will be based on five points likert scale, wherein the perceive importance will ranges from 1 to 5 (Where 1 means “Not Important” & 5 means “Most Important”). Questionnaire will be frame using the various lean practices, majority of them found through the extensive literature survey to ensure the reliability and validity of measures of lean manufacturing. These lean practices mostly make use of firm’s organizational and operational performance to measure leanness. Opinion of lean experts will also be taken while using the various lean measures to test its validity of measuring research objectives.

14. Data Analysis

- Analysis of primary data found through the survey starts measuring the relationship amongst them. Interrelationship will be adjudged with the help of correlation matrix. If correlation matrix is not an identity matrix, means there are high degree of interdependency amongst the different measures of leanness. In other words we can say they are overlapping in nature and mostly intend to measure the same thing. This gives an opportunity to reduce data by putting the variables having high coefficient of correlation under on head, known as factor. Factors are the hidden variables which need to discover through the statistical analysis known as factor analysis. Factor analysis is multivariate interdependency analysis. These factors are independent in nature and give you the fair idea about their individual explaining power of leanness. SPSS will be used for extraction of factors and subsequent statistical analysis.
- The most important factors are selected instead of original 42 lean practices which measure the leanness. This results in significant reduction in data. Thereafter relationship between factors extraction and leanness will be analysed. Independent nature of factors extracted facilitates the use of multivariate dependency technique such as multiple regression. Leanness will be taken as dependent variable and factors extracted as independent of explanatory variables. Multiple regression helps in identifying the most important factors, which are critical for explaining leanness of the organization, which one of the objectives of the study.
- Literature survey suggests that the relationship between the leanness and business agility is often confusing and confounding, because of their overlapping characteristics. In most of the real world situation the relationship amongst the variables are vague and difficult to define. But one thing is sure the business agility is broader term which encapsulates leanness. In this research an attempt will be made to develop the index of agility in order to quantify the same. Fuzzy comprehensive analysis could be the ideal choice because it is most suitable for multi criteria decision making in the uncertain environment. Due to vague and confusing criteria in assessment of the agility, a precision appraisal may be unfeasible. Therefore in most of the literature the agility has been assessed linguistically because numerical evaluation in impractical. Informal procedure of using linguistic terms and subsequent associated functions is attribute of fuzzy logic. The linguistic term and associated membership function were found from the literature survey and it is customize in line to the needs of present study.
- Business agility affects the productivity of the organizations. Therefore almost all the factors influencing business agility will also affect the productivity. So it is imperative to quantify the factors of productivity. Literature survey suggest, analytical hierarchical programming could be the ideal choice in this situation.

15. Research Design:

Broad Research Question	Specific Research Question	Methodology
How can we increase the productivity of Indian SMEs' automotive sector using lean practices?	How green leanness can be comprehensively defined?	Literature review
	What are the drivers of green lean manufacturing? Do these drivers independently explain the leanness of the organization?	Literature review Survey, Interview with the experts, and Factor analysis
	How do these drivers affect the green leanness of small & medium scale auto sector in India? And what are the relative importance these drivers specific to India SMEs' auto sector? How to find sustainable green lean practices those Indian SMEs' can afford to implement?	Literature review, Multiple regression, Interpretive Structural Modelling and MICMAC analysis.
	How these green lean practices related to the agility of SMEs' auto sector in India? How to develop the index of agility to measure agility of Indian SMEs' auto sector?	Literature review, Expert Opinion, Fuzzy comprehensive analysis
	How business agility enhances the productivity of SMEs'?	Expert Opinion and Analytical hierarchical programming for quantification of factors of productivity.
	How to develop house of productivity for Indian SMEs' automotive sector?	Using Outcome of Analytical Hierarchical Programming.
	Substantiating index of agility and measures of productivity	Case Study

Table 5: Research Design

Conclusion

A comprehensive literature on lean philosophy is available since 1990, sighting numerous lean practices worldwide. Literature sighted different lean practices along with the relative importance of them. Some of the vital practices are, overcoming employees' resistance through proper training and education, commitment from top management, total employees involvement, improved ergonomics and relation with suppliers, reduced inventory and total lead time etc. Most of the lean practices found are overlapping in nature and difficult to adjudge their individual contribution in explaining leanness. Similar overlapping is found in variables explaining business agility and leanness. Green lean philosophy is an emerging concept and need of an hour for the sustainable development.

Despite offering many benefits for sustainable development, green lean philosophy is not easy to implement. There are many barriers to lean implementation some of them are, lack of awareness about lean philosophy, expertise required, and availability of finance etc. Literature review opens opportunities to new research to determine the industry specific green lean practices, there after its effect on business agility and productivity of manufacturing organizations, Indian SMEs' automotive sector in particular.

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