ASSESSMENT OF ACHIEVING SUSTAINABILITY IN INDIAN AUTOMOBILE INDUSTRY THROUGH LEAN MANUFACTURING

MASTER OF TECHNOLOGY

DISSERTATION REPORT

BY

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(2012PMM5207)

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

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A

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ON

ASSESSMENT OF ACHIEVING SUSTAINABILITY IN INDIAN AUTOMOBILE INDUSTRY THROUGH LEAN MANUFACTURING

SUBMITTED IN PARTIAL FULFILLMENT OF

MASTER OF TECHNOLOGY IN MANUFACTURING SYSTEM ENGINEERING

BY

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UNDER THE SUPERVISION OF

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CERTIFICATE

This is to certify that the dissertation entitled "**ASSESSMENT OF ACHIEVING SUSTAINABILITY IN INDIAN AUTOMOBILE INDUSTRY THROUGH LEAN MANUFACTURING**" being submitted by **Dharmendra Kumar Kumawat (2012PMM5207)** is a bonafide work carried out by him under my supervision and guidance, and hence approved for submission to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the degree of **Master of Technology (M.Tech.)** in **Manufacturing System Engineering**. The matter embodied in this dissertation report has not been submitted anywhere else for award of any other degree or diploma.

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation, entitled **"ASSESSMENT OF ACHIEVING SUSTAINABILITY IN INDIAN AUTOMOBILE INDUSTRY THROUGH LEAN MANUFACTURING"** in partial fulfillment for the award of the degree of **Master of Technology (M.Tech.)** in **Manufacturing System Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my own work carried out by me during a period of one year from July 2014 to June 2015 under the guidance and supervision of **Mr. Mukesh Kumar** of the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur**.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for award of any other degree or diploma.

Dharmendra Kumar Kumawat
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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: -
Place: -Jaipur

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ABSTRACT

At a time where social and environmental systems are showing evidence of damage, sustainable development has the potential to influence or be influenced by human development. The notion of sustainable development can be traced back to the 18th Century as people began to question the impact of rising populations and rapid resource consumption on the Earth's natural assets.

Lean manufacturing is often seen as a set of tools that reduce the total cost and improve the quality of manufactured products. The lean management philosophy is one which targets waste reduction in every facet of the manufacturing business; however, only recently have studies linked lean management philosophies with improving environmental sustainability. These studies suggest that lean manufacturing is more than a set of lean tools that can optimize manufacturing efficiencies; it is a process and mindset that needs to be integrated into daily manufacturing systems to achieve sustainability. Lean manufacturing has proven itself as a model for both economic sustainability and environmental stewardship. Several recent studies have shown that both lean and green techniques and "zero-waste" policies also lead to reductions in overall cost. This report will review the current literature and describe how lean and green can provide a relevant framework for environmental social and economic sustainability.

Depending on the literature reviewed, it has been observed that there is a need to quantify the applicability and effectiveness of lean in achieving sustainability, specially in Indian automobile industry. For that, several variables related to lean have been identified that cover social, technical, economical and environmental aspects of sustainability. Depending upon the variables, a questionnaire has been developed and was sent to the professionals of automobile industries in India. Based on the results and analysis of this survey, important conclusions with points on a scale of 0 to 5 corresponding to each variable/question have been assigned. It can be concluded that lean is indeed an effective tool in achieving sustainability, if applied holistically.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The 21st century raises pertinent questions about our planet earth being able to sustain the ongoing resource absorption and process wastes. The other inter-related macroeconomic issues worldwide such as over-population, resource exhaustion, environmental abasement, rising levels of per capita waste & pollution and natural resource consumption are other issues to be looked at. Although technological innovation and industrial regulations have reduced the overall hazardous impact of the above on the environment, rising consumption rate has outpaced the technological growth causing alarming disbalance to earth's ability to sustain life [1].

As for manufacturing industry, it is extremely resource-consuming & energy-intensive. It generates enormous amounts of toxic and unusable by-products and therefore pushes the manufacturers to comply by the environmental regulations to bring down their share of ecological imbalance.

Growth of manufacturing industry in general and automobile industry in particular is happening at tremendous rate in India. In last 5-6 years, production of vehicles (including 2 wheelers, 3 wheelers, passenger vehicles etc.) has increased by almost 80% (Fig 1). In Year 2014-15, the total production of vehicles (all kind) touched a gigantic figure of 200 lac. Such enormous growth of vehicles will result in significant increases in natural resource demand, fuel consumption, material needs, and greenhouse emissions. As a consequence, sustainability remains a primary issue for the automobile industry forcing manufacturers to further reduce the overall environmental impact of vehicles so that the product is sustainable from environmental standpoint. Moreover, this trend compels the original equipment manufacturers (OEMs) to work for new solutions involving minimum effect on environment by using more efficient processes preserving natural resources.

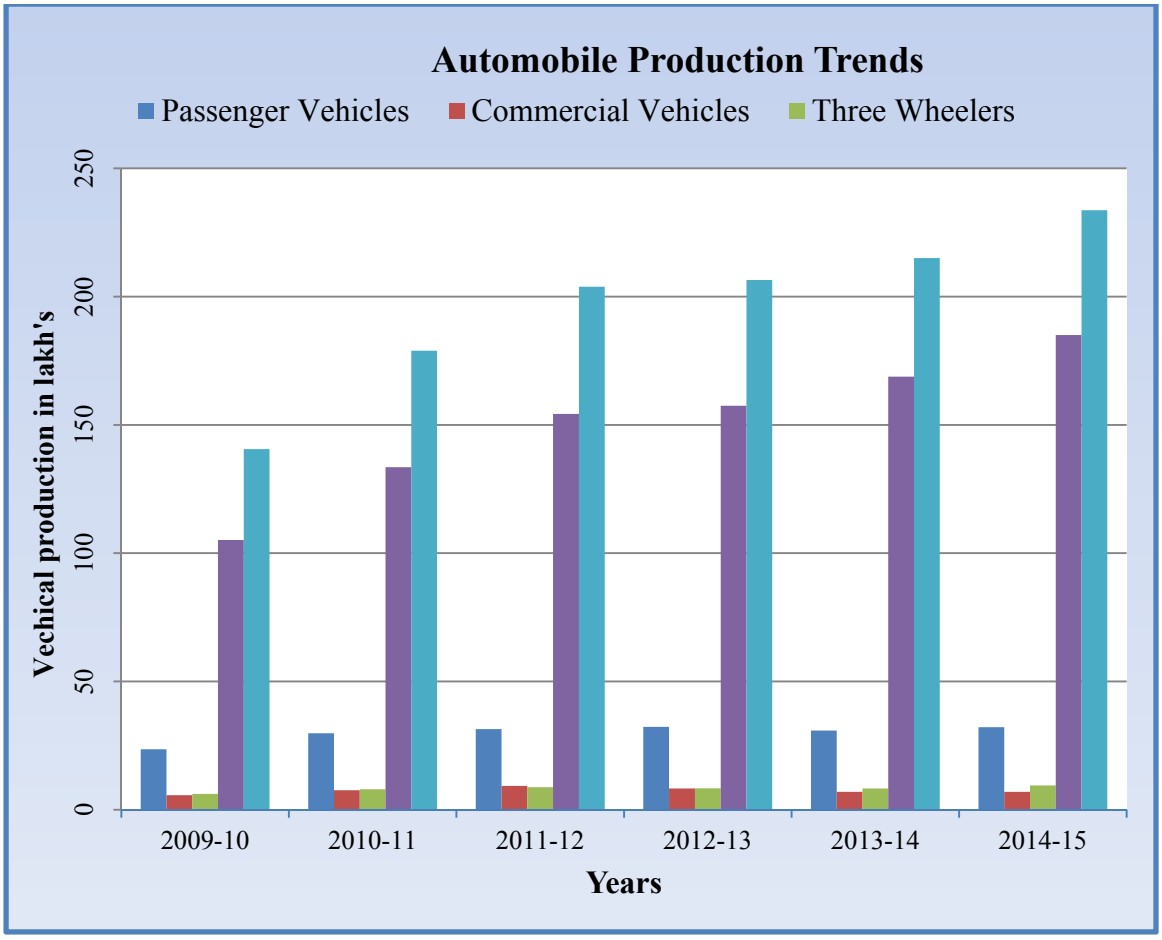

Figure 1: Recent Trend in Indian Automobile Industry (Source: SIAM)

Sustainability is about balancing social, ethical and environmental issues without compromising on economy during the product or service development process. It makes sure that the needs of customer and society are fulfilled while protecting the environment. This definition communicates the inherent complexity in quantifying sustainability and tracking efforts.

There are ways in which sustainability is achieved in the manufacturing processes. One such concept is Lean Technology. Lean is baby-step towards the aforementioned sustainability as these tools may typically be applied to any kind of process, including the environmental ones and consummates our sustainability models thoroughly and may be extended to a much broader goal. Lean is the industrial Holy Grail which improves corporate finances too as it seeks to eliminate reckless misuse and significantly boosts the creativity among employees.

Sustainability essentially applies to organizations of all sizes, with lean, no industry is too small (or large) to utilize it. It requires a change in thoughtfulness, perspective and work-culture. Many leading companies have successfully implemented Lean Manufacturing Systems in the past couple of decades which have contributed to their efficiency, cost-reduction, profitability, and quality & customer response time along with enhanced PR. Many companies have emphasized on negating their operational impacts on the environment. As a result of the "Green Systems", remarkable reductions in energy consumption and waste generation have been observed which, in turn, leads to companies having a better public image.

A Lean aware organization is more likely to adapt to sustainability. It works best when responsible personnel as well as teams across the organization prioritize "Value to customer" and how it can be improved. It works when these personnel and teams are motivated enough to identify opportunities, analyze them and implement their findings and have complete managerial support for it.

The only difference between Sustainability and Lean is the decision-making criteria. The prime focus of sustainability is; profits, people and the planet rather than the customer economy, therefore it is long term. Lean Manufacturing Systems and Sustainability have further been explained in next sections.

1.2 SUSTAINABILITY

Sustainability has more than 100 definitions. The two most well-known and accepted are:
"…*using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be maintained*."[2]
"...*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*."[3]

Sustainable results in contemporary enterprises must take into account these basic boundary conditions - socio-economic and environmental execution, as shown in Fig 2.

In the extensive discussion and use of the concept since then [4-5], there has been a growing recognition of three essential aspects of sustainable development:-

- ✓ Economic
- ✓ Environmental
- ✓ Social

Economic: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable level of government and external department, and to avoid extreme sartorial imbalance which damage agricultural or industrial production.

Environmental: An environment sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource system or environment sink function, and depleting non- renewable resource only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resource.

Social: A socially sustainable system must achieve fairness in distribution and opportunity, adequate provision of social services including health and education, gender equity, and political accountability and participation.

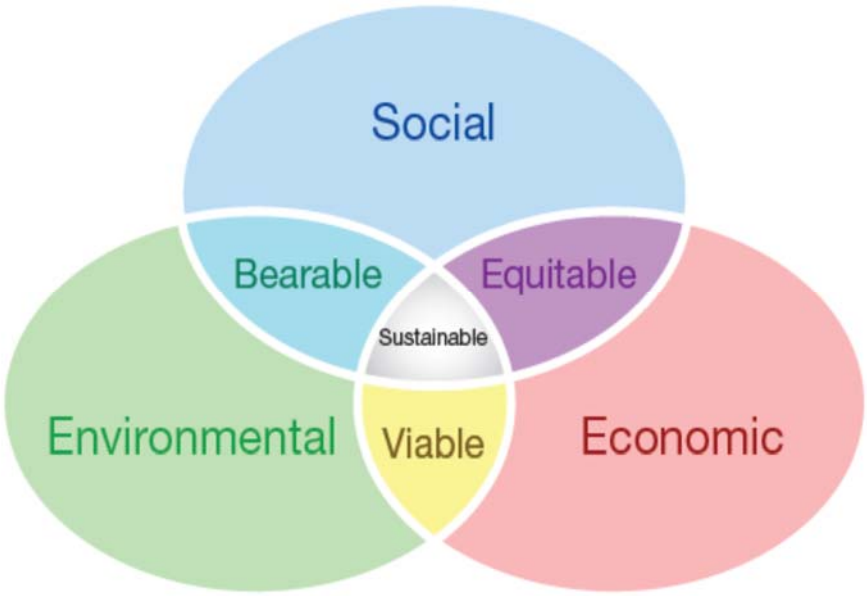

Figure 2: Sustainability

1.3 LEAN MANUFACTURING

"A set of practices focused on reduction of wastes and non-value added activities from a firm's manufacturing operations."[38].

Lean Manufacturing can be defined as Lean manufacturing or lean production, which is often known simply as "Lean", is the optimal way of producing goods through the removal of waste or “Lean manufacturing is the system which aims in elimination of the waste from the system with a systematic and continuous approach” or Lean Manufacturing is an operational strategy oriented toward achieving the shortest possible cycle time by eliminating waste. Lean manufacturing techniques are based on the application of five principles to guide management’s action toward success. [6].

- Value
- Continuous improvement
- Customer focus
- Perfection
- Focus on waste

1.3.1 Lean Goals

Different authors set out various different goals of lean manufacturing processes. While some advocate increased profits, others maintain an inherent focus on improved core product value for the customers. Some commonalities observed are:[7-11]

- Quality improvement: A company must comprehend its customer requirements and alter their manufacturing process to meet them in order to sustain itself in a competitive marketplace.
- Waste removal: Waste consumes tangible and intangible resources without any value addition to the customers.
- Expedited production: Reducing the time to deliver the finished goods is the crux of cost-effectiveness and waste elimination.
- Overall cost reduction: In order to shrink costs, a company must adhere only to customer demands. Overproduction leads to surge in company’s inventory costs due to storage requirements.

1.4 OBJECTIVE OF RESEARCH

The objective of this research is, doing the assessment of achieving sustainability in Indian automobile industry through lean manufacturing. Variables related to

Sustainability of automobile industries are listed from the literature and a questionnaire is prepared based on these variables and then research methodology is applied on the result of survey.

The objectives of the research

- Assessment of achieving sustainability in Indian automobile industry through lean manufacturing
    - Identification of main parameters of sustainability
    - Assessment of relation between Lean and sustainability

1.5 STRUCTURE OF THESIS

The thesis structure has been chosen to most effectively focus the thesis towards the satisfaction of the stated aim and objectives:

Chapter 1 Serves as an introduction to the thesis and acts as a concise rationale for its need. It provides information about future need of sustainability, Present trends of auto industries, lean manufacturing and sustainability. The aim of the research was described as well as its significance.

Chapter 2 In this chapter, Importance of literature is discussed. It also highlights the literature about lean manufacturing, sustainability, lean and green.

Chapter 3 Research methodology, the standard procedure to develop survey form/questionnaire.

Chapter 4 Result and Discussion, in this chapter analysis the collected data and outcome Discus a descriptive summary of study is presented.

Chapter 5 Conclusion, discusses the findings of the study and conclusion drawn from the research.

CHAPTER 2
LITERATURE REVIEW

2.1 LEAN MANUFACTURING

Mejabi O.O. has been described a planning system for Lean Manufacturing that is applicable to a variety of manual and automated manufacturing. It sets up a framework for performance measurement and benchmarking. It was organized 17 metrics into 4 categories of: Process Flow, Quality, Financial measures, and Productivity. The developed framework in the work starts with a definition of standard Lean Manufacturing metrics followed by quantification of the waste in the system. The quantification process involved computing a Cost of Waste value that considers the cost of scrap, rework, inventory holding, labor and capital productivity deficiencies, and production line inefficiencies. The framework provides a benchmarking and Lean Scorecard module for evaluating performance and setting. They developed a software tool for implementation of the planning system for lean manufacturing.[7].

Holweg Matthias has been reviewed how the lean production concept was formulated. This work disseminated several striking facts about the mode and lead-time of adopting complex Industrial practices. According to the work, Lean production not only successfully challenged the accepted mass production practices in the automotive industry, significantly shifting the trade-off between productivity and quality, but it also led to a rethinking of a wide range of manufacturing and service operations beyond the high-volume repetitive manufacturing environment. It has been mentioned that lean concept itself was not a single point invention, but the outcome of a dynamic learning process that adapted practices emanating from the automotive and textile sectors in response to environmental contingencies [8].

Moreira et al. (2010) have been highlighted the contribution of Lean in achieving a better environmental performance of production systems. The process has been identified as an emergent business model for supporting eco-efficiency. The work also identifies the contributions of Lean in reducing environmental impacts caused by industrial activities [9].

Vienazindiene and Ciarniene have been created a model illustrating successful Lean implementation based on prior analysis of Lean implementation progress measurement. The main barriers were identified through a set of actions. According to the work, Lean Manufacturing implementation is a multiplex process, a set of actions that requires planning and the establishment of positive environment, preparation, implementing various tools and techniques. Measurement of progress was done using specific performance metrics [10].

Kumar et. al. developed key areas which would be used to assess the adoption and implementation of lean manufacturing practices. The work provides a framework mechanism for environmentally sustainable manufacturing sectors. It has been suggested that the five Ws (who, what, where, when and why) and two H (how and how much) also help track down the root cause of any problem in complex production environments. The work provides broad perspective on combining lean manufacturing methods with environmental sustainability to assist manufacturing sector in remaining competitive [11].

Verrier et al. have been proposed an approach which adds environmental and social dimensions to the consideration of economic earnings received through Lean actions and propose a framework for Lean and Green management, which include Lean indicators, Green performance indicators and Green intentions indicators. Unlike Lean manufacturing, this focuses on ways to improve operations and cuts waste from the customer's perspective, Green initiatives look at ways to eliminate waste from the environmental perspective. Looking at operations from a "Green" perspective can benefit not only the environment, but manufacturers and customers as well [12].

Brasco Andrea et.al. have been proposed, the Lean & Green Model, where the green concern for environmental sustainability is integrated with lean thinking. The model used Kaizen approach for addressing and improving mass and energy flows in a manufacturing environment. The Model was developed to investigate the potential benefits of integrating green and lean thinking for both the environment and businesses in terms of waste reduction, operational performance and employee commitment. The work confirmed that the Model can reduce resource use from 30 to 50% on an average and reduce the total cost of mass and energy 5-10%[13].

Khadse et al. have been identified the critical lean manufacturing factors responsible for implementation of lean manufacturing in the Indian manufacturing The work focused on identifying barriers and benefits of lean manufacturing. It was found that Lean Manufacturing is not a relatively new term for the majority of Indian industries, still the adoption rate is average. The study suggested that for transformation towards lean system, people should have a better understanding about lean and also need to be aware about the change management principles. The work concludes that strong employee involvement, effective communication and top management support are responsible for successful organizational change towards lean organization [14].

Johansson and Sundin have been compared the lean product development (LPD) and green product development (GPD) concepts. The work pointed at similarities between the concepts like implementation of both calls for a systems perspective where the dimensions of process-people tools/techniques are linked holistically. Differences between the LPD and GPD concepts lie in: their goal and focus, value construct, process structure, performance metrics, and tools/techniques used. The findings do not unambiguously support that "green thinking is thinking lean" and consequently it cannot be argued that LPD and GPD are two sides of the same coin, meaning that LPD automatically leads to greener products or that GPD ensures improvements and efficiency in the product development process. However, it is reasonable to conclude that LPD and GPD belong to the same "currency". That is, the concepts share a number of similarities that indicate a synergistic relationship [15].

Chiarini Andrea has been investigated whether or not Lean Production tools can help reduce the environmental impacts of manufacturing companies using before and after study. They used five Lean tools: Value Stream Mapping (VSM), 5S, cellular manufacturing, Single Minute Exchange of Die (SMED) and Total Productive Maintenance (TPM). It has been reported that VSM can be used to identify the environmental impacts of production processes. 5S can be useful for reducing oil leakage and improving waste management. Cellular manufacturing can lead to a decrease in electricity consumption, whereas TPM can help reduce several impacts of the machines, such as oil leakage and emissions of dusts and chemical fumes into the atmosphere. The work concludes that Lean tools are effective at improving environmental impacts even

though some tools are more effective than others, and that other less measurable aspect and first time can realize a quantifiable correlation between Lean tools and environmental impacts. Lean can become an investigable model for greening production processes. [16].

From the literature review following are 25 essential lean tools. Each tool is distilled into a simple description of what it is and how it helps.

Table 1: Lean Tools

S.No	Lean Tool	What Is It?	How Does It Help?
1	5S	Organize the work area:· **1**.Sort (eliminate that which is not needed) **2**.Set In Order (organize remaining items) **3.**Shine (clean and inspect work area) **4**.Standardize (write standards for above) **5**.Sustain (regularly apply the standards)	Eliminates waste that results from a poorly organized work area (e.g. wasting time looking for a tool).
2	Andon	Visual feedback system for the plant floor that indicates production status, alerts when assistance is needed, and empowers operators to stop the production process	Acts as a real-time communication tool for the plant floor that brings immediate attention to problems as they occur – so they can be instantly addressed.
3	Bottleneck Analysis	Identify which part of the manufacturing process limits the overall throughput and improve the performance of that part of the process	Improves throughput by strengthening the weakest link in the manufacturing process.
4	Continuous Flow	Manufacturing where work-in-process smoothly flows through production with minimal (or no) buffers between steps of the manufacturing process.	Eliminates many forms of waste (e.g. inventory, waiting time, and transport).
5	Gemba (The Real Place)	A philosophy that reminds us to get out of our offices and spend time on the plant floor – the place where real action occurs.	Promotes a deep and thorough understanding of real-world manufacturing issues – by first-hand observation and by talking with plant floor employees.

6	Heijunka (Level Scheduling)	A form of production scheduling that purposely manufactures in much smaller batches by sequencing (mixing) product variants within the same process	Reduces lead times (since each product or variant is manufactured more frequently) and inventory (since batches are smaller).
7	Hoshin Kanri (Policy Deployment)	Align the goals of the company (Strategy), with the plans of middle management (Tactics) and the work performed on the plant floor (Action).	Ensures that progress towards strategic goals is consistent and thorough – eliminating the waste that comes from poor communication and inconsistent direction
8	Jidoka (Autonomation)	Design equipment to partially automate the manufacturing process (partial automation is typically much less expensive than full automation) and to automatically stop when defects are detected.	After Jidoka, workers can frequently monitor multiple stations (reducing labor costs) and many quality issues can be detected immediately (improving quality)
9	Just-In-Time (JIT)	Pull parts through production based on customer demand instead of pushing parts through production based on projected demand. Relies on many lean tools, such as Continuous Flow, Heijunka, Kanban, Standardized Work and Takt Time.	Highly effective in reducing inventory levels. Improves cash flow and reduces space requirements.
10	Kaizen (Continuous Improvement)	A strategy where employees work together proactively to achieve regular, incremental improvements in the manufacturing process.	Combines the collective talents of a company to create an engine for continually eliminating waste from manufacturing processes
11	Kanban (Pull System)	A method of regulating the flow of goods both within the factory and with outside suppliers and customers. Based on automatic replenishment through signal cards that indicate when more goods are needed.	Eliminates waste from inventory and overproduction. Can eliminate the need for physical inventories (instead relying on signal cards to indicate when more goods need to be ordered).

12	KPI (Key Performance Indicator	Metrics designed to track and encourage progress towards critical goals of the organization. Strongly promoted KPIs can be extremely powerful drivers of behavior – so it is important to carefully select KPIs that will drive desired behavior.	The best manufacturing KPIs: **1**.Are aligned with top-level strategic goals (thus helping to achieve those goals) **2**.Are effective at exposing and quantifying waste (OEE is a good example) **3**.Are readily influenced by plant floor employees (so they can drive results)
13	Muda (Waste)	Anything in the manufacturing process that does not add value from the customer''s perspective.	Eliminating muda (waste) is the primary focus of lean manufacturing
14	Overall Equipment Effectiveness (OEE)	Framework for measuring productivity loss for a given manufacturing process. Three categories of loss are tracked: • Availability (e.g. down time) • Performance (e.g. slow cycles) • Quality (e.g. rejects)	Provides a benchmark/baseline and a means to track progress in eliminating waste from a manufacturing process. 100% OEE means perfect production (manufacturing only good parts, as fast as possible, with no down time).
15	PDCA (Plan, Do, Check, Act)	An iterative methodology for implementing improvements: • Plan (establish plan and expected results) • Do (implement plan) • Check (verify expected results achieved) • Act (review and assess; do it again)	Applies a scientific approach to making improvements: • Plan (develop a hypothesis) • Do (run experiment) • Check (evaluate results) • Act (refine your experiment; try again)
16	Poka-Yoke (Error Proofing)	Design error detection and prevention into production processes with the goal of achieving zero defects	It is difficult (and expensive) to find all defects through inspection, and correcting defects typically gets significantly more expensive at each stage of production.

17	Root Cause Analysis	A problem solving methodology that focuses on resolving the underlying problem instead of applying quick fixes that only treat immediate symptoms of the problem. A common approach is to ask why five times – each time moving a step closer to discovering the true underlying problem.	Helps to ensure that a problem is truly eliminated by applying corrective action to the "root cause" of the problem
18	Single Minute Exchange of Die (SMED)	Reduce setup (changeover) time to less than 10 minutes. Techniques include: • Convert setup steps to be external (performed while the process is running) • Simplify internal setup (e.g. replace bolts with knobs and levers) • Eliminate non-essential operations • Create standardized work instructions	Enables manufacturing in smaller lots, reduces inventory, and improves customer responsiveness
19	Six Big Losses	Six categories of productivity loss that are almost universally experienced in manufacturing: • Breakdowns • Setup/Adjustments Small Stops • Reduced Speed • Startup Rejects • Production Rejects	Provides a framework for attacking the most common causes of waste in manufacturing
20	SMART Goals	Goals that are: Specific, Measurable, Attainable, Relevant, and Time-Specific.	Helps to ensure that goals are effective
21	Standardized Work	Documented procedures for manufacturing that capture best practices (including the time to complete each task). Must be "living" documentation that is easy to change.	Eliminates waste by consistently applying best practices. Forms a baseline for future improvement activities.

22	Takt Time	The pace of production (e.g. manufacturing one piece every 34 seconds) that aligns production with customer demand. Calculated as Planned Production Time / Customer Demand.	Provides a simple, consistent and intuitive method of pacing production. Is easily extended to provide an efficiency goal for the plant floor (Actual Pieces / Target Pieces).
23	Total Productive Maintenance (TPM)	A holistic approach to maintenance that focuses on proactive and preventative maintenance to maximize the operational time of equipment. TPM blurs the distinction between maintenance and production by placing a strong emphasis on empowering operators to help maintain their equipment	Creates a shared responsibility for equipment that encourages greater involvement by plant floor workers. In the right environment this can be very effective in improving productivity (increasing up time, reducing cycle times, and eliminating defects).
24	Value Stream Mapping	A tool used to visually map the flow of production. Shows the current and future state of processes in a way that highlights opportunities for improvement.	Exposes waste in the current processes and provides a roadmap for improvement through the future state.
25	Visual Factory	Visual indicators, displays and controls used throughout manufacturing plants to improve communication of information.	Makes the state and condition of manufacturing processes easily accessible and very clear – to everyone.

2.2 SUSTAINABILITY

Vesela and Ellenbecke have been presented eight-step model of sustainability indicator implementation for promoting business sustainability The work proposed a set of twenty-two core indicators (applicable to any organization) and guidance for selecting additional, production-specific indicators. It has been concluded that the creation of a set of meaningful and simple (Indicators of sustainable production)ISPs, applicable to any organization. The very fact of focusing on the issue heightens company's awareness about sustainable production, promotes organizational learning and improves measurement practices. [17].

Comm and Mathaisel have been explained lean sustainability works quite well in manufacturing. It helps identify bottlenecks, work stoppages, lead-time, downtime, throughput time, and quality checking. The examples of its success are many (Dell and Toyota), and even more companies outside of manufacturing have attempted to employ similar methods (discount airlines like Southwest Airlines, and Marriott Hotels with their Fairfield and Courtyard brands). It has been suggested that higher education of lean implementation is most needful for sustainability [18].

Braungart et al. have been explained the central component of the eco-effectiveness concept, cradle-to-cradle design provided a practical design framework for creating products and industrial systems in a positive relationship with ecological health and abundance, and long-term economic growth. Against this background, the transition to eco-effective industrial systems is a five-step process. It begins with elimination of undesirable substances and ultimately calling for a reinvention of products by reconsidering how they may optimally fulfill the needs while simultaneously being supportive of ecological and social systems. This process necessitates the creation of an eco-effective system of ‘‘nutrient’’ management to coordinate the material flows amongst actors in the product system. [19].

Rusinko Cathy A. has been presented an exploratory study of the relationships between specific environmentally sustainable manufacturing practices, and specific competitive outcomes The work suggested that environmentally sustainable manufacturing practices may be positively associated with competitive outcomes, in particular, different types of environmentally sustainable manufacturing practices (e.g., pollution prevention, product stewardship) This study can be helpful to engineering and operations managers as they respond to environmental and competitive demands.[20].

Jovane F.et al. have been presented the necessary steps from economic growth to sustainable development. The reference model for proactive action (RMFPA) is proposed to develop and implement competitive sustainable manufacturing (CSM), at national and global levels. Furthermore, the work also reviewed strategies to pursue CSM at the macro (macroeconomics) to meso (production and consumption paradigms) to field (products/services, processes, business models).level. It has been concluded that CSM is

the main enabler of sustainable development (SD), as it generates wealth, sustains jobs (directly and through related services) and manage human and physical resources, from materials to energy. Sustainable development relate on economy, society, environment and technology [21].

Jayal A.D. has been presented an overview of some recent trends and new concepts that are emerging for evaluating the sustainability contents at the product, process and system levels for enabling sustainable manufacturing. It further highlighted the fact that although achieving overall sustainability requires a holistic view spanning the entire supply chain, including manufacturing systems and processes, and involving multiple product life-cycles the study suggested some recent trends for improved and simplified sustainability by scoring methods for product and process design, develop predictive models and optimization techniques for sustainable manufacturing. [22].

Ahmed. M. D. has been proposed a system model for the new green manufacturing paradigm by control metrics as well as various green tools in wood industry. The model captured various planning activities to migrate from a less green into a greener and more eco-efficient manufacturing. They composed this model was two stage, first describes the design and planning processes of the green manufacturing systems and the second describes the control process that controls the design and planning process at each level The system approached recognizes that the green transformation is carried at different levels, mainly operational (machine), process and finally system level. [23].

Gunasekaran and Spalanzani have been attempted to understand the complexities of sustainable business development, the challenges and their sources, and the advances made so far to address the SBD issues. The work offers a critical assessment and identification of gaps in both research and in practice. A framework for sustainable development along with strategies, techniques and tools has been developed. The study presented some important performance measures and metrics for sustainable business development in manufacturing and services [24].

Chun and Bidanda have been reported a broad literature related to sustainable manufacturing published over the past 50 years in IJPR. It established research frontiers and contributions in the sustainable manufacturing and the related impact to

environmental sustainability. The work identified commonly used analytical tools and methodologies [25].

Haapala Karl R.et al. have been explored recent research into concepts, methods, and tools for sustainable manufacturing. The study addressed issues and challenges of manufacturing process level and engineering related to planning, development, analysis, process improvement, facility operation, production planning, scheduling, and supply chain design. Several of these challenges relevant to manufacturing process and system research, development, implementation, and education are highlighted. Sustainable manufacturing required simultaneous consideration of economic, environmental, and social implications associated with the production and delivery of goods. Fundamentally, sustainable manufacturing relies on descriptive metrics, advanced decision making, and public policy for implementation, evaluation, and feedback [26].

Kurdve et. al..have been explained how operations management and environmental management can be integrated on an operational level and include the waste management supply chain. The work implements a waste flow mapping (WFM) method on a set of manufacturing sites and reveals potentials in terms of reducing material losses and inefficiencies in the handling of materials and waste [27].

Table 2: Sustainability Indicators/impact variable, (Lowell Center for Sustainable Production)Vesela and Ellenbecke[17]

Sustainability Indicator/impact variable	
1	Freshwater consumption (total and per unit of product)
2	Materials used (total and per unit of product)
3	Energy use (total and per unit of product)
4	Percent energy from renewable sources (e.g. solar, wind, hydro-, biomass)
5	Kilograms of waste generated before recycling (total and adjusted for production)
6	Global Warming Potential (GWP)
7	Acidification potential (to air)
8	Kilograms of persistent, bio accumulative and toxic (PBT) chemicals used
9	Costs associated with EHS Compliance
10	Rate of customer complaints and/or returns
11	Organization's openness to stakeholder5 involvement in decision-making process
12	Community spending and charitable contributions as percent of revenues
13	Number of employees per unit of product/dollar sale
14	Number of community company partnerships
15	Lost workday injuries and illness case rate (LWDII)
16	Rate of employees' suggested improvements in quality, social and EHS performance
17	Turnover rate (or average length of service of employees)
18	Average number of hours of employee training
19	Percent of workers who report complete job satisfaction
20	Percent of products designed for disassembly, reuse or recycling
21	Percent of biodegradable packaging
22	Percent of products with take back policies in place

Typically identifies seven or eight specific types of waste that must be attacked on the Environmental sustainability are presented in Table 3.

Table 3: Environmental impacts linked with manufacturing waste (source: EPA, 2003)

Waste type	Environmental impact
Defects	Raw materials consumed in making defective products Defective components require recycling or disposal More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Waiting	Potential material spoilage or component damage causing waste Wasted energy from heating, cooling, and lighting during production downtime
Overproduction	More raw materials consumed in making the unneeded products Extra products may spoil or become obsolete requiring disposal
Movement and transportation	More energy use for transport Emissions from transport More space required for work-in-process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption More packaging required to protect components during movement
Inventory	More packaging to store WIP Waste from deterioration or damage to stored WIP More materials needed to replace damaged WIP More energy used to heat, cool, and light inventory space
Complexity and over processing	More parts and raw materials consumed per unit of production Unnecessary processing increases wastes, energy use, and emissions
Unused creativity	Fewer suggestions of pollution and waste minimization opportunities

2.3 LEAN AND GREEN MANUFACTURING

Bergmiller and McCright have been confirmed that strength of green management system correlates with business results for both Lean and Green Programs through hypothesis. The study indicated that Lean and Green Programs lead to improved business results and minimal environmental impact from their operations may naturally adopt some methods of Lean Production in order to reduce wastage [28].

C.K. Stuart So. have been developed theoretical model to study the relationship between lean supply strategy and continued adoption of sustainable lean manufacturing in an electronic-enabled manufacturing supply chains (EMSC) environment. this study concluded that supplier integration supported by an EMSC environment with the implementation of lean performance-based supplier selection policies significantly influences the use of lean manufacturing as sustainable practice [29].

Yang et. al. have been explored the relationships between lean manufacturing practices, environmental management (e.g., environmental management practices and environmental performance) and business performance outcomes (e.g., market and financial performance). The study suggested that prior lean manufacturing experiences are positively related to environmental management practices. Environmental management practices alone are negatively related to market and financial performance. The work found lean manufacturing as an important antecedent of environmental management practices. And effective implementation of environmental management practices it is essential to recognize the value of environment performance [30].

Fadly et.al. have been showed a relationship between sustaining lean improvements (SLI) and sustainable performance(SP).The study attempted to gain a picture of the current theme of emphasis on sustaining lean improvements indicators among the automotive manufacturing companies in Malaysia and also on sustainable performance. The work carried out the theoretical study on the determinants of critical success factors (CSF) of SLI namely (i) standard work (ii) SP. it is concluded that SLI implementation gives many benefits to social, economic, and environmental aspect [31].

Kováčová Ľubica has been discussed the similarities and differences between lean and sustainability, defined lean production and sustainability. It suggested that Kanban, pull system and SMED tools can potentially improve the environmental performance. lean journey, moving toward sustainability is relatively easy. Many lean tools are easily adapted and extended for sustainability. This study addressed the issues of integration of lean and sustainability [32].

Jadhav et.al. have been developed the framework for sustainable Lean implementation using interpretive structural modeling (ISM) approach. This study makes two broad

conceptual contributions. First, it explored Lean practice bundles for successful implementation of Lean and second, it provides brief description of eight Lean practice bundles that will be helpful for further study. They used interpretive structural modeling (ISM) for JIT or Lean systems and developed relationship between each of critical Lean practice bundles [33].

Faulkner and Badurdeen have been developed a methodology to prepare a sustainable VSM (Sus-VSM) which includes metrics to evaluate the environmental and societal sustainability performance of a manufacturing line. Following a comprehensive reviewed, a set of fundamentally essential metrics are identified for inclusion in the Sus-VSM; visual symbols are created for each proposed metric on the Sus-VSM to ensure visual clarity and the usefulness will be still maintained. They suggested that VSM is one of the most widely used techniques in lean manufacturing to identify waste [34].

Koho Mikko et al. have been suggested that the DMAIC (define, measure, analyze, improve, control) structure guides companies in defining objectives for sustainability performance improvement and measurement, in selecting relevant performance indicators, and, eventually, in improving and managing sustainability performance. This study reported the current situation concerning sustainable development and sustainable production, as well as the challenges confronting their realization in Finnish manufacturing industry [35].

CHAPTER -3
RESEARCH METHODOLOGY

The methodology plays a vital role in corroborating the findings. It can be concluded from the literature that in order to find out the lean manufacturing benefits for sustainability in industries, one must have the real industrial input/data vis-à-vis usage of lean. Following is the methodology framework.

3.1 Methodology Framework

Any study based on surveys and its analysis starts with identifying variables that affect the subject of study significantly. Preparation of questions for survey is the next step. Data collection, analysis and inference are next steps which will be discussed subsequently. The same has been elaborated using following flowchart

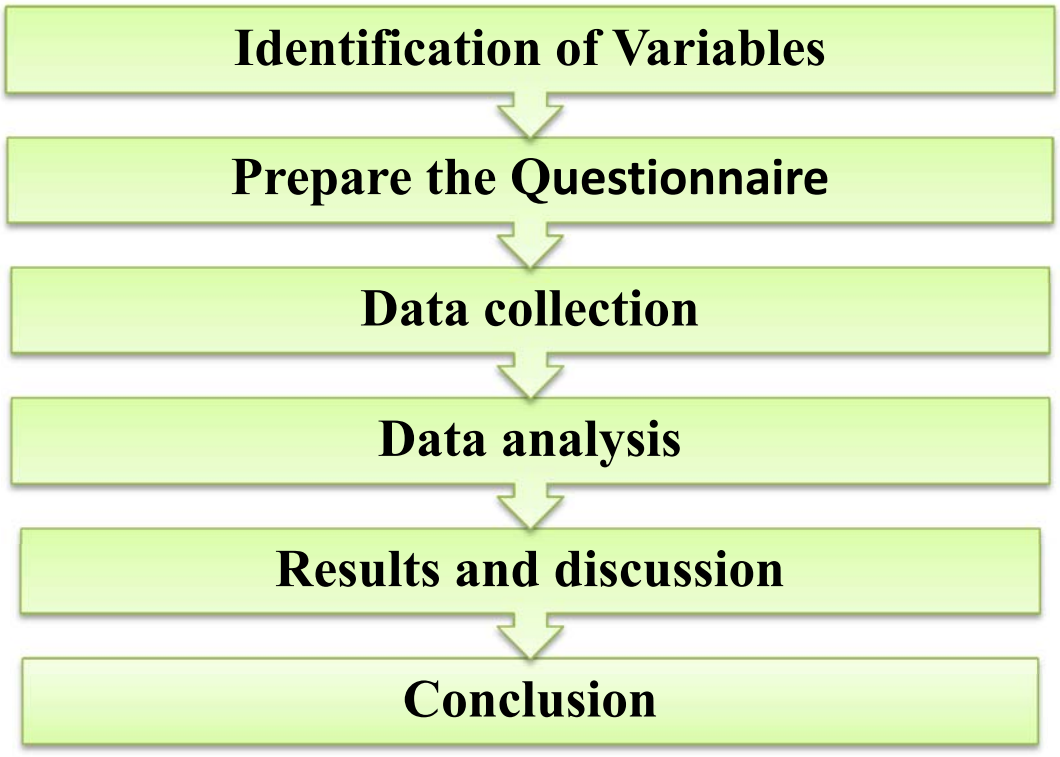

Figure 3: Various step of Research Methodology

3.2 Identification of variables

Based on the study of literature and experience of the experts, 18 variables have been identified for the study [17-35].

3.3 Preparation of Questionnaire

In order to conduct the credible survey on Lean technology, first task is to choose industries with credible credentials and experience in the field. For this, the reputation of organization, respondent and its experience are vital. Thus following few introductory questions have been kept to start with in Part A of the questionnaire.

1. Name of the Organization
2. Name of the person responding
3. Number of Years' Experience
4. Number of employees in the organization
5. Certification/awards for organization

Part B of the questionnaire contains technical survey on achieving sustainability using lean technology in automobile industries. In order to ascertain the extent of usage of lean technology, its duration, its utility and its role in reliability and growth of the industry, one needs a set of questions. In Part B, Section A, Questions 6-10 are related to the above which are as follows:

6. Does your company apply the philosophy of lean manufacturing?
7. For how many years your organization has been using lean activities/tool?
8. Is lean manufacturing system an effective tool for performance and productivity improvement in automobile industry?
9. How was the growth of organization after applying Lean Manufacturing tools?
10. How much reduction in plant breakdown was observed after applying Lean Manufacturing tools?

Environment, as discussed in previous chapters, is one of the most important factors in sustainability. Thus, the effect of using Lean on environment is a critical issue in manufacturing industry. The next questions 11-15 deal with positive environmental

impact of applying Lean. The variables considered in this survey for the study of impact on environment are most fundamental in nature which are directly related to planet's natural resources, viz. waste reduction, reduction in greenhouse emissions, reduction in waste water generation, saving in fuel and electricity and waste recycling. Questions are as follows

11. How much reduction in waste has been achieved by your organization?
12. How much greenhouse gases are being reduced by your organization?
13. How much waste water generation is reduced by your organization?
14. How much fuel and electricity saving is recorded by your organization?
15. How much waste is recycled by your organization?

As discussed in previous chapters, social aspect of sustainability is another most important factor apart from environment. Thus, the effect of using Lean on social sustainability is yet another important aspect in manufacturing industry. The next questions 16-20 deal with the social impacts of applying Lean. The variables considered in this survey for the impact on social sustainability are most fundamental in nature which are directly related to social welfare of people, viz. employee satisfaction, training, social welfare activities and incentives. The corresponding questions are following

16. Does your company consider employees observations/views for up-gradation of the system?
17. Does your company provide training to the employees for implementing sustainability in production?
18. Does your company organized programs for social welfare of employees?
19. How much work satisfaction is provided by your organization to employees?
20. Does your company provide incentives for promoting sustainability in your organization?

Economic sustainability is considered to be the most important factor in sustainability. It affects industry, employees and customers hugely. Thus, the effect of using Lean on economic sustainability is most important aspect in manufacturing industry. The next questions 21-24 deal with the economic impacts of applying Lean. The variables considered in this survey for the impact on social sustainability are- life cycle assessment,

reduction in O&M costs, local infrastructural development and budget for environmental protection. Questions are as follows

21. Does your company have the policy of life cycle assessment?
22. Does your company implement preventive measure/innovations to reduce operating and maintenance cost.
23. Does your company provide economic support to local infrastructure development?
24. What is the budget of your organization for environmental protection?

A structured questionnaire has been prepared on five point Likert scale. It is a well-known interval scale used in research field [36]. Explanation of five points is as follows:

[1] Not at all
[2] Low
[3] Medium
[4] High
[5] Highest

To ensure the validity of content, a "dry run" has been conducted in which few questionnaires were sent to leading professionals, consultants and academicians. Based on their expert comments, the form was further amended and the final version (current) was developed. It was sent to the professionals of 150 leading companies in Automobile sector through the Society of Indian Automobile Manufacturers (SIAM) 2015. 70 industries responded to the questionnaire and out of them, 49 valid responses were incorporated in the current study. The response rate is around 47%.

3.4 Data collection

It consists of administration of questionnaire and respondent profile. The questionnaire was e-mailed to respondents and later, they were reminded about same on phone. A survey form was developed on Google form to conduct online survey.

The data was collected in the excel sheet for the analysis in SPSS 21.0.

The research methodology is based on the survey data collected through the above online questionnaire. The objective of this survey is to examine the effect of lean manufacturing on Sustainability in Indian automobile industries.

3.5 Data analysis

After the data were collected, the analysis was done. The data were entered in SPSS 21.0, software used for statistical analysis. First of all the inter-item analysis was done to check the consistency and reliability of the data. The reliability of the data was checked using reliability test, calculating Cronbach's alpha coefficient. After checking the reliability further analysis was done.

Table 4 shows Cronbach's Alpha values calculated (through SPSS 21 for windows) for scales used. Cronbach's alpha values for each scale is more than 0.5, which is considered adequate for exploratory research [36].

Table 4: Reliability Statistics Using Cronbach's Alpha for Scales (Source: SPSS V21)

Scales Used	No. of Item	Cronbach's Alpha
Apply lean manufacturing system	5	0.863
Environment Sustainability Effect	5	0.917
Social Sustainability Effect	5	0.896
Economic Sustainability Effect	4	0.856

Figure 4 shows the statistics of the respondent companies that responded to the questionnaire. The pie chart includes statistics of general information of respondent companies and professionals. As shown in Pie chart, 53 respondents who took part in the survey hail from automobile industry and 10 are from other fields.

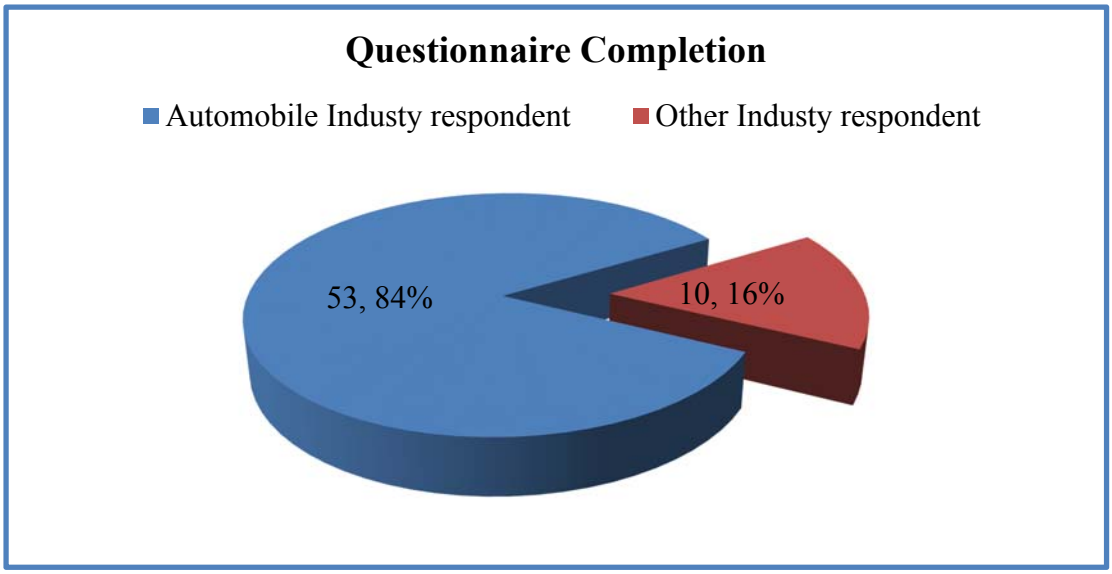

Figure 4: Questionnaire Completion

Survey Selection Process:-

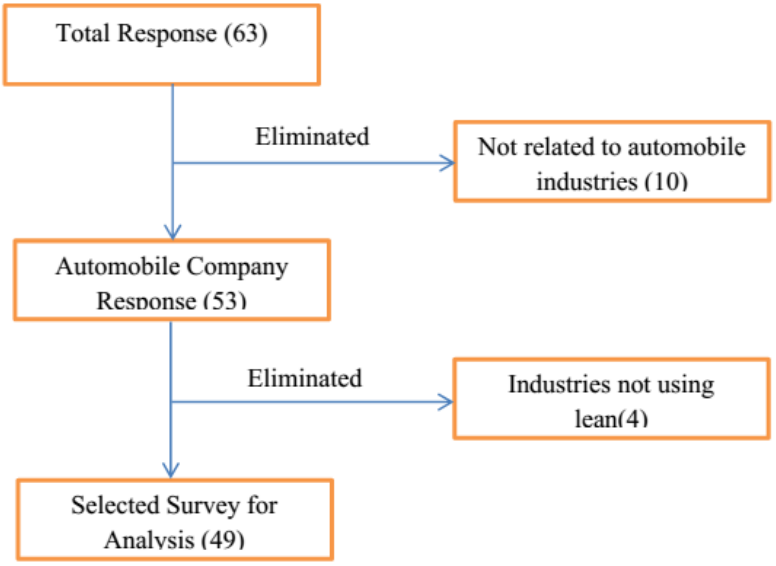

Figure 5: Survey Selection Process

Figure 6 shows the statistics of the respondent's experience in the industry. 25 (51%) respondents were having 1 to 5 years of experience, 18 (37%) had 5 to 10 years. 6 (12%) were having experience upto 10 to 15 years.

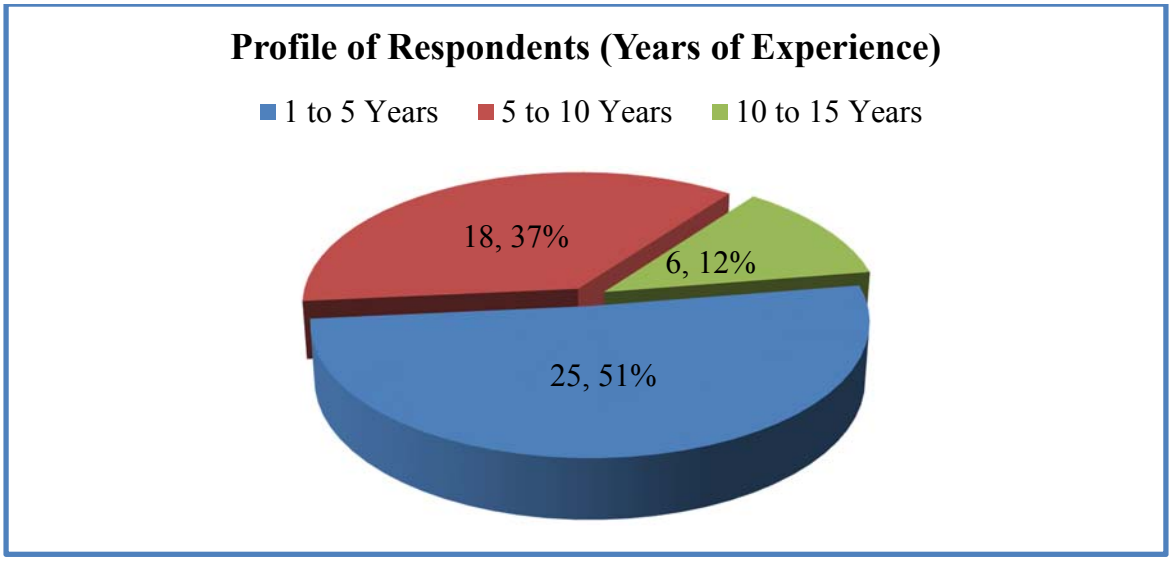

Figure 6: Profile of Respondents

Another important issue in the survey is the stature of organizations in terms of number of employees. The pie chart of this analysis is shown in figure 7. 2 (4%) of small scale industries were having number of employees up to 50. 10 (20%) of the companies have number of employees between 51 to 499, 16 (33%) have between 500-2000 and a whopping 43% have above 5000 employees in their companies. To summarize, 24% are small scale industries, 33% are medium and 43% are large scale that participated in the survey.

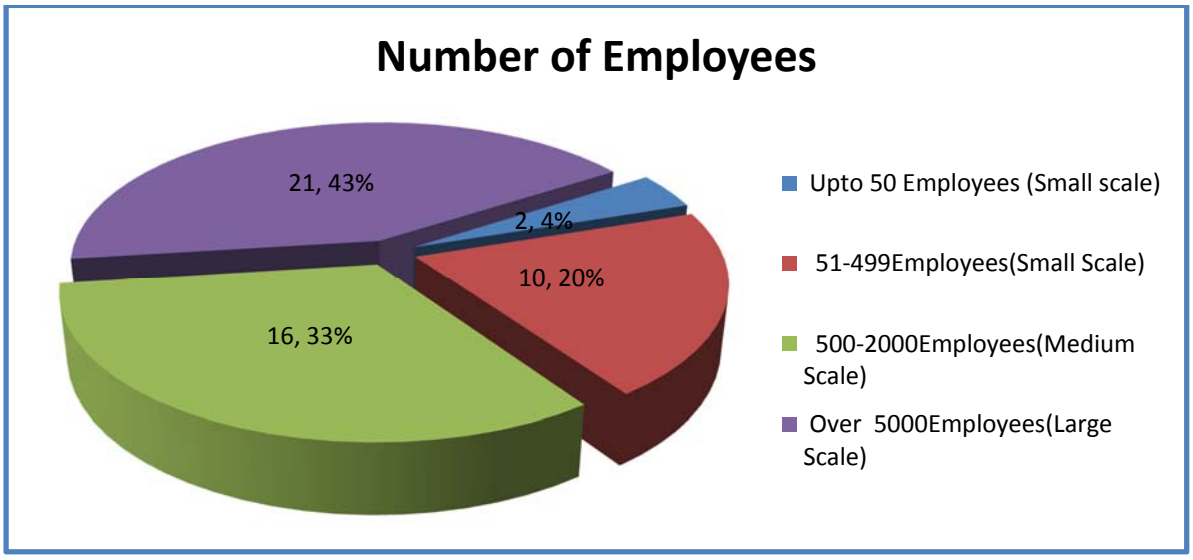

Figure 7: Number of Employees

After the reminders through phone calls and emails, 63 filled responses were received out of 150 and out of those filled ones, 49 were selected for the study (response rate 47%). Table 3 shows the average statistics of the respondents. It is observed that the average experience of respondents is 5 years within range 2 to 10 years; the average number of employees is above 4000. Selected respondents' company profile is mainly automobile and auto parts manufacturing as shown in Table 5.

Table 5: Average Statistics of the Respo

Parameter	Sample average	Range
Experience	5	[1, 15]
Number of employees	>4000	[100,>5000]
Organization certification/Awards	ISO9001, TPM, TQM, Manufacturing excellence, Sustainability business award,	
Company profile	Automobile company, Auto parts manufacturing,	

A number of responses against the questionnaire from industries have been received. The survey results and the analysis are covered in next chapter.

CHAPTER 4
RESULTS AND DISCUSSION

From the discussion above, it can be concluded that lean strategies benefit sustainability, without the need for special sustainable toolkits or a separate focus on sustainable considerations. Many areas of lean are being targeted for studies and activities surmounting Sustainability management, namely: community partnerships, organizational & managerial structure, supply chain, manufacturing process etc. As the industries across the globe have recognized the potential, it has to create constructive environmental outcomes by waste elimination.

A descriptive study for assessment of achieving sustainability in automobile industry through lean manufacturing system would be handy and is thus carried out in this section. A questionnaire, as discussed previously, has been shared with industry professionals for this purpose. A total of 150 automobile related industries were approached, out of which, 70 responded. 52 of them seemed valid which have been considered for finding out the results. Against every question in the questionnaire, a pie chart has been plotted based on the survey response. And to establish the validity of the responses, Cronbach's Alpha for each response has been found out.

For each response, a detailed analysis with pie charts and tables has been carried out as follows.

LMSQ.6. Does your company apply the philosophy of lean manufacturing?

Table 6: Respondents Statistics of LMS Q-6

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	4	8		
2	Low	5	9		
3	Medium	12	23	3.88	0.99
4	High	16	30		
5	Highest	16	30		
	Total	53			

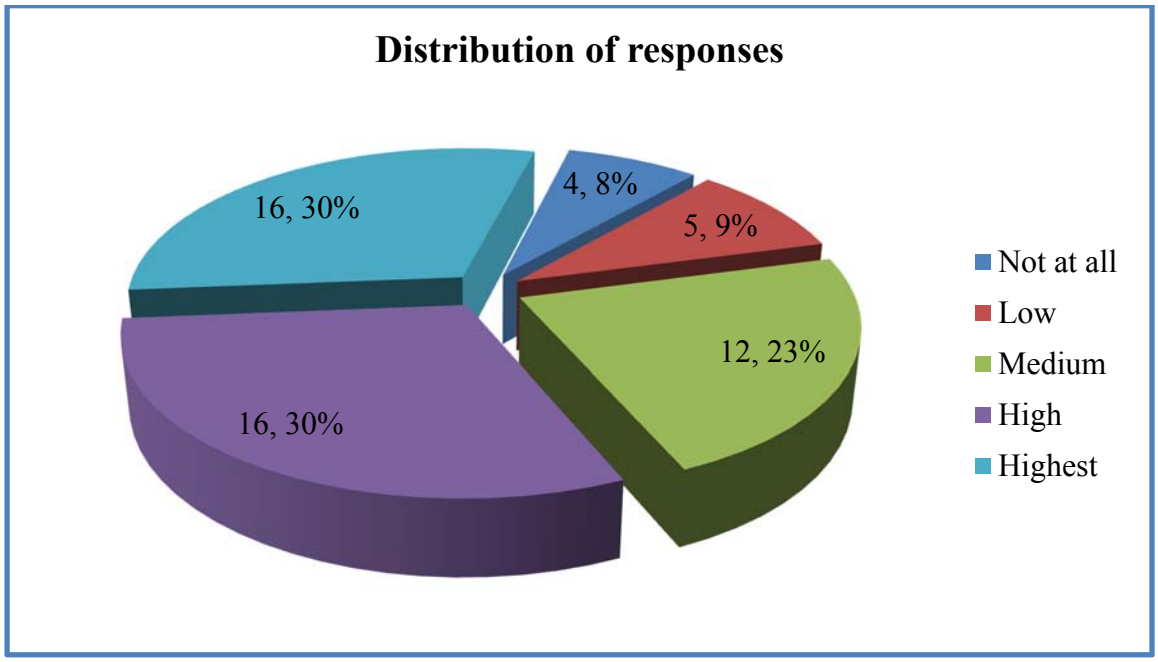

Figure 8: Respondents Summary of LMS Q-6.

From the table and pie chart, it is seen that 30% respondents apply lean on highest priority in their industries for achieving sustainability. A whopping 30% think of lean as high priority. 23% professionals consider it as medium. 9% find it low priority. Whereas 8.2% people don't consider lean for their processes at all. To sum up, around 80% of automobile manufacturers apply lean to achieve sustainability. On the scale of 5, professionals give 3.88 (mean of respondents' ratings) points to lean usage in industries indicating lean as important tool for attaining sustainability.

LMSQ.7. For how many years, your organization is using lean activates/tool?

Table 7: Respondents Statistics of LMS Q-7.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D.
1	Less than 1 year	0	0		
2	Less than 2 year	4	8		
3	Less than 3 year	9	19	4.24	1.03
4	Less than 5 year	7	14		
5	More than 5 year	29	59		
	Total	49			

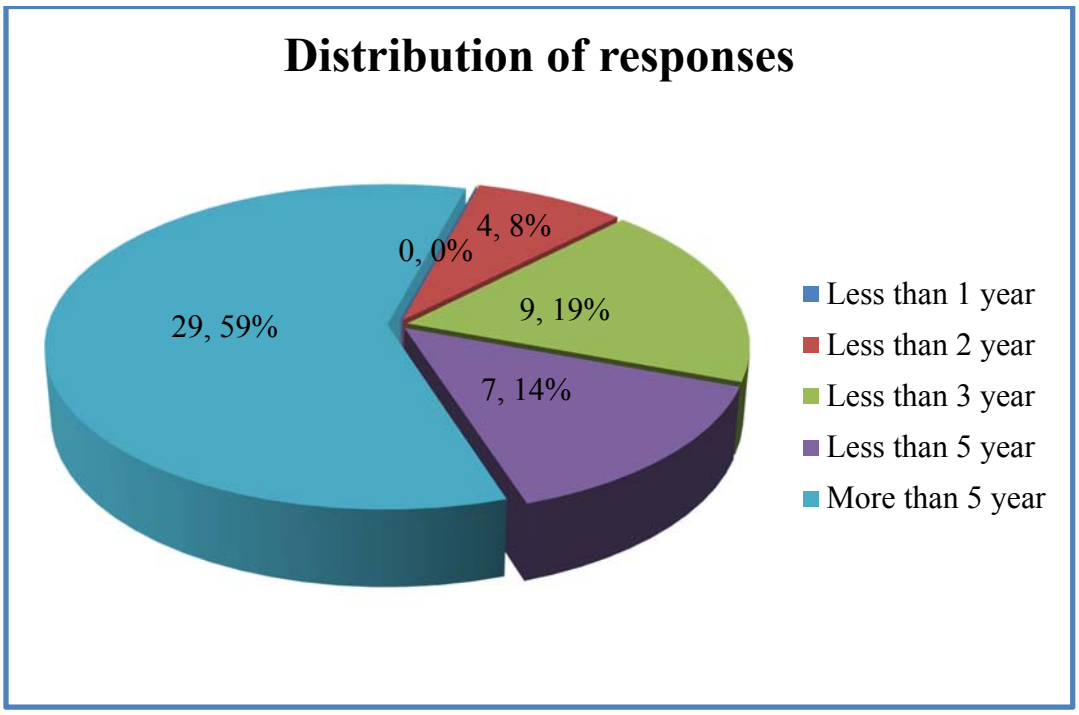

Figure 9: Respondents Summary of LMS Q-7.

From the table and pie chart, it is observed that a majority of 59% industries considered in the survey have been using the lean technology for more than 5 years. 14% have been working on lean principles for 3-4 years. 19% industries are trying to achieve sustainability through lean principles for more than 2 years. 8% have been using lean for more than an year and 1.7% have recently started using it. To sum up, around 73% of automobile manufacturers have been using lean principles for more than 4-5 years to achieve sustainability. Around 30% of industries have started using lean recently indicating the growing trend of using lean as gateway to sustainability. As for since how long the lean technology has been in use, on the scale of 5, professionals give 4.24 points suggesting the overall trend of around 4-5 years of lean usage in industries.

LMS Q. 8. Is lean manufacturing system an effective tool for performance and Productivity improvement in automobile industry?

Table 8: Respondents Statistics of LMS Q-8.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Low	1	2		
3	Medium	12	24	4.1	0.85
4	High	17	35		
5	Highest	19	39		
	Total	49			

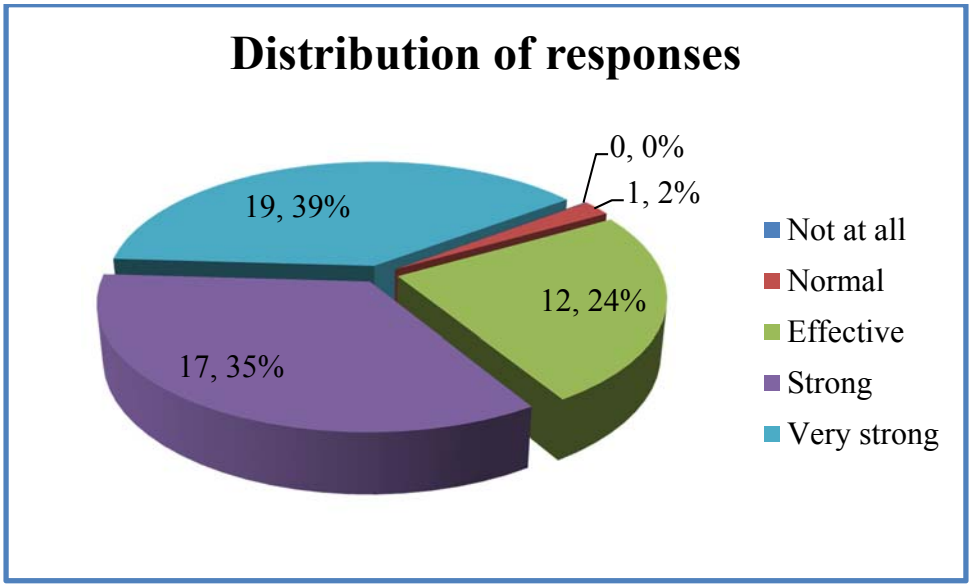

Figure 10: Respondents Summary of LMS Q-8.

From the table and pie chart, it is observed that 39% of total respondents believe that the philosophy of lean is a very strong tool for enhancing performance and productivity. 35% believe lean to be a strong tool for same. 24% consider lean as an effective tool that can boost performance of the industry. Only a negligible fraction believed lean to be ineffective. To sum up, around 98% of automobile manufacturers think that lean is the effective tool to achieve sustainability in automobile industry. On the scale of 5, professionals give 4.1 points which prove that lean is an essential component for sustainability.

LMS Q. 9. How is the growth of organization after applying Lean Manufacturing tools?

Table 9: Respondents Statistics of LMS Q-9.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Normal	5	10		
3	Effective	16	33	3.8	1
4	Strong	14	28		
5	Very strong	14	29		
	Total	49			

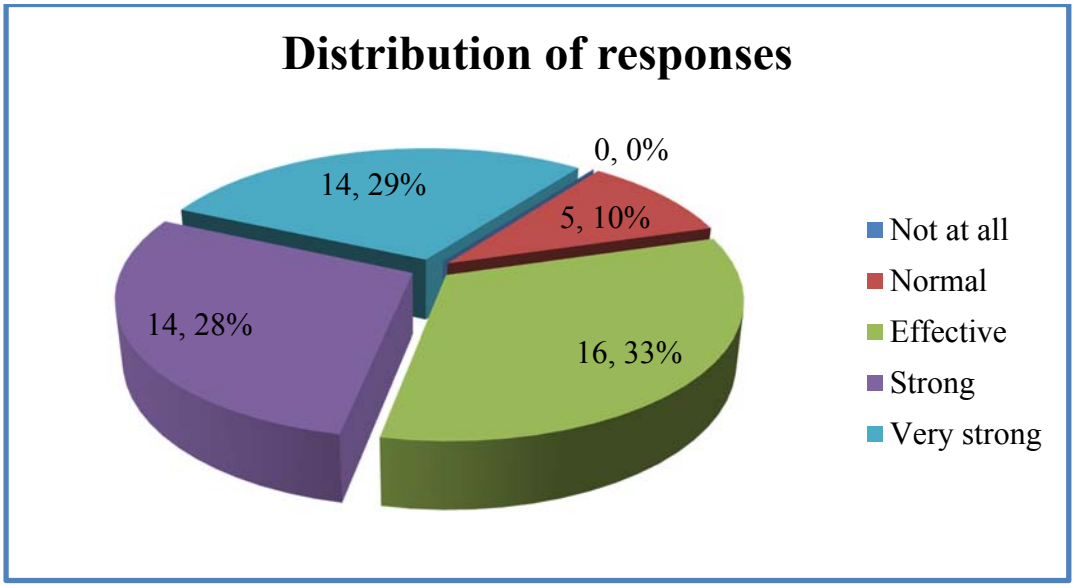

Figure 11: Respondents Summary of LMS Q-9.

From the table and pie chart, it is observed that 29% of professionals in the survey admitted that they observed very strong growth in their organization after applying lean. An equal number 28% believes that their organizational growth increased strongly after using lean. A whopping 33% observed effective growth in their organization through lean. Around 10% found lean to be normal. To sum up, huge majority of 86% have observed effective growth in their organization after applying lean. On the scale of 5, professionals give 3.8 points which proves lean to be an essential component in the industrial growth.

LMSQ.10. How much reduction in plant breakdown is observed after applying Lean Manufacturing tools?

Table 10: Respondents Statistics of LMS Q-10.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	1	2		
2	Low	4	8		
3	Medium	14	29	3.69	0.96
4	High	20	41		
5	Highest	10	20		
	Total	49			

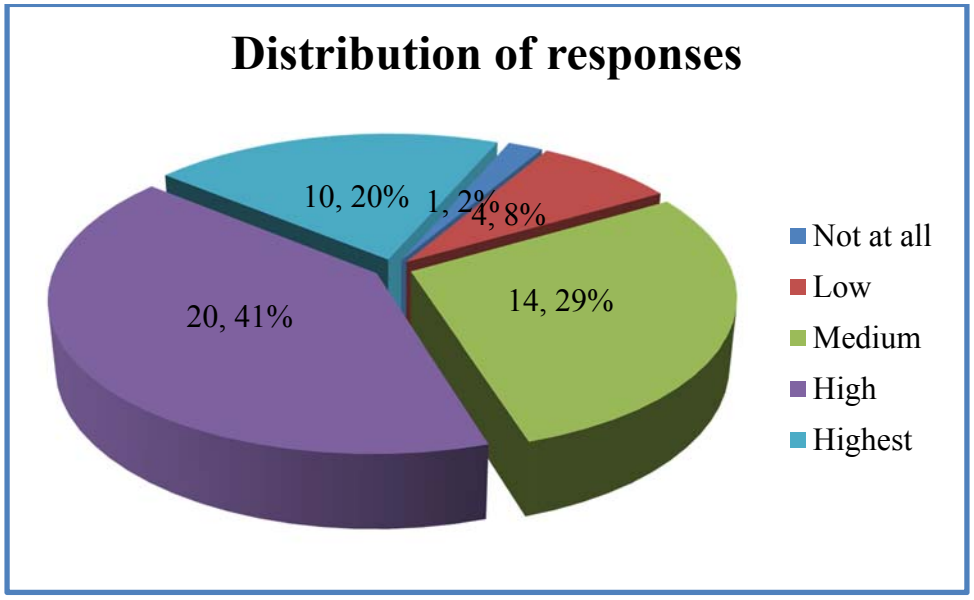

Figure 12: Respondents Summary of LMS Q-10.

From the table and pie chart, it is observed that 20% of professionals in the survey admitted that they observed very strong reduction in the plant breakdown after applying lean. A major chunk of 41% observes strong reduction in plant breakdown by using lean. According to 29% of the respondents, lean is neither very strong nor very weak tool for reduction in plant breakdown. To sum up, majority of 60% related to automobile industry have observed effective reduction in the plant breakdown in their organization after applying lean. On the scale of 5, professionals give 3.69 points suggesting lean to be an essential component in the industrial growth.

ES Q. 11. How much reduction in waste by your organization?

Table 11: Respondents Statistics of ES Q-11.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	1	2		
2	Low	2	4		
3	Medium	17	35	3.71	0.91
4	High	19	39		
5	Highest	10	20		
	Total	49			

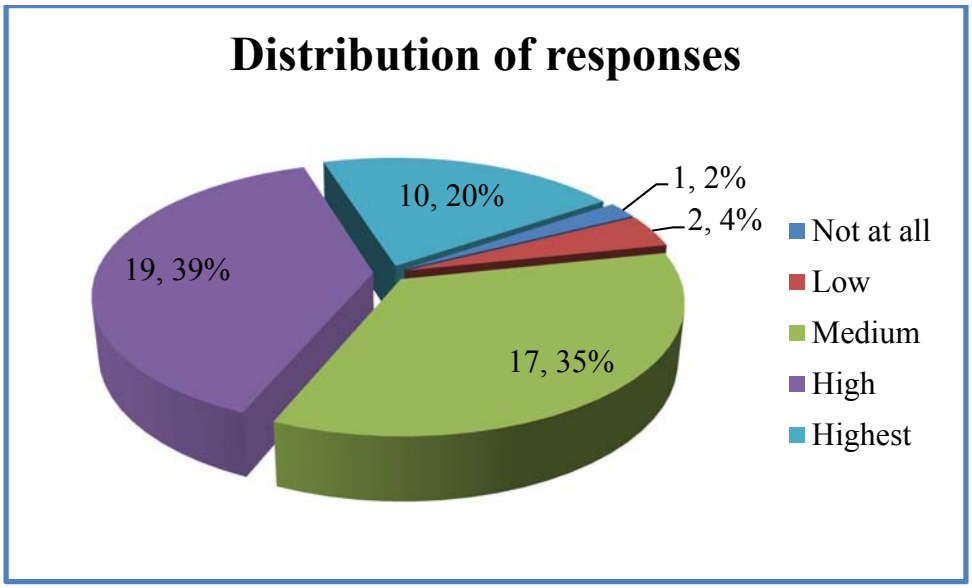

Figure 13: Respondents Summary of ES Q-11.

From the table and pie chart, it is observed that 20% of professionals in the survey admitted that they observed very strong reduction in waste after applying lean. A major chunk of 39% observes strong reduction in waste by using lean. According to 35% of the respondents, lean is neither very strong nor very weak tool for waste reduction. To sum up, around 85% people related to automobile industry have observed effective reduction in the waste after applying lean. On the scale of 5, professionals give 3.71 points proving lean to be an essential tool for industrial growth.

ES Q. 12. How much greenhouse gas emissions are being reduced by your organization?

Table 12: Respondents Statistics of ES Q-12.

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	4	8		
2	Low	3	6		
3	Medium	17	35	3.45	1.1
4	High	17	35		
5	Highest	8	16		
	Total	49			

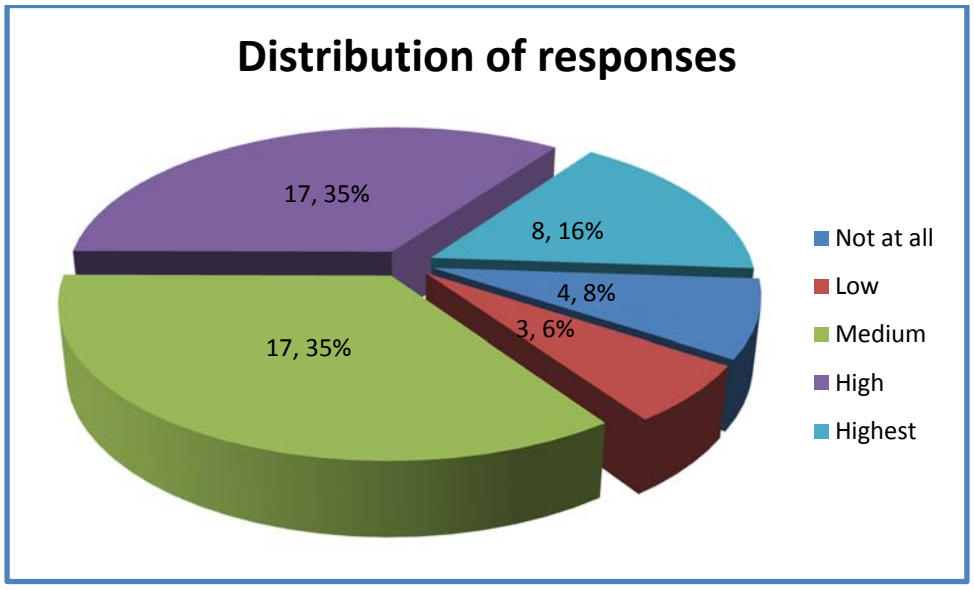

Figure 14: Respondents Summary of ES Q-12.

From the table and pie chart, it is observed that 16% of professionals in the survey admitted very strong reduction in GHG emissions after applying lean. A whopping 35% believe lean to be a strong tool that can reduce GHG. According to 35% of the respondents, lean is neither very strong nor very weak tool for GHG reduction. To sum up, around 86% people related to automobile industry have observed effective reduction in GHG emissions after applying lean. On the scale of 5, professionals give 3.45 points suggesting lean to be an essential component in the industrial growth.

ES Q. 13. How much waste water generation is reduced by your organization?

Table 13: Respondents Statistics of ES Q-13

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	1	2		
2	Low	8	16		
3	Medium	15	31	3.51	1.06
4	High	15	31		
5	Highest	10	20		
	Total	49			

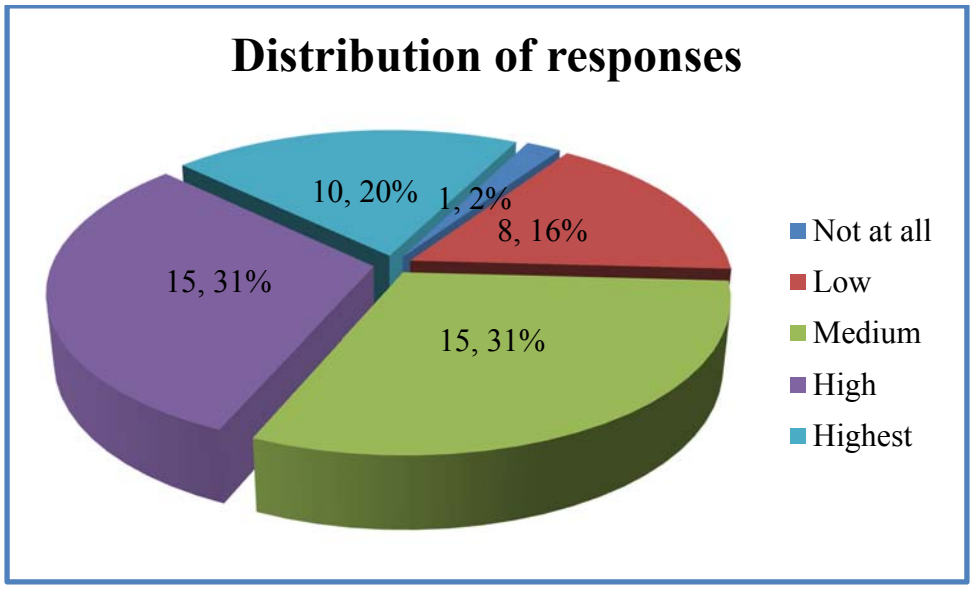

Figure 15: Respondents Statistics of ES Q-13

From the table and pie chart, it is observed that 20% of professionals in the survey admitted very strong reduction in waste water generation after applying lean. A whopping 31% believe lean to be a strong tool that can reduce waste water generation. According to 31% of the respondents, lean is neither very strong nor very weak tool for waste water reduction. To sum up, around 82% people related to automobile industry have observed effective reduction in waste water after applying lean. On the scale of 5, professionals give 3.51 points proving lean to be a critical component in the industrial growth.

ES Q. 14. How much fuel and electricity saving is recorded by your organization?

Table 14: Respondents Statistics of ES Q-14

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Low	1	2		
3	Medium	16	33	3.9	0.82
4	High	19	39		
5	Highest	13	26		
	Total	49			

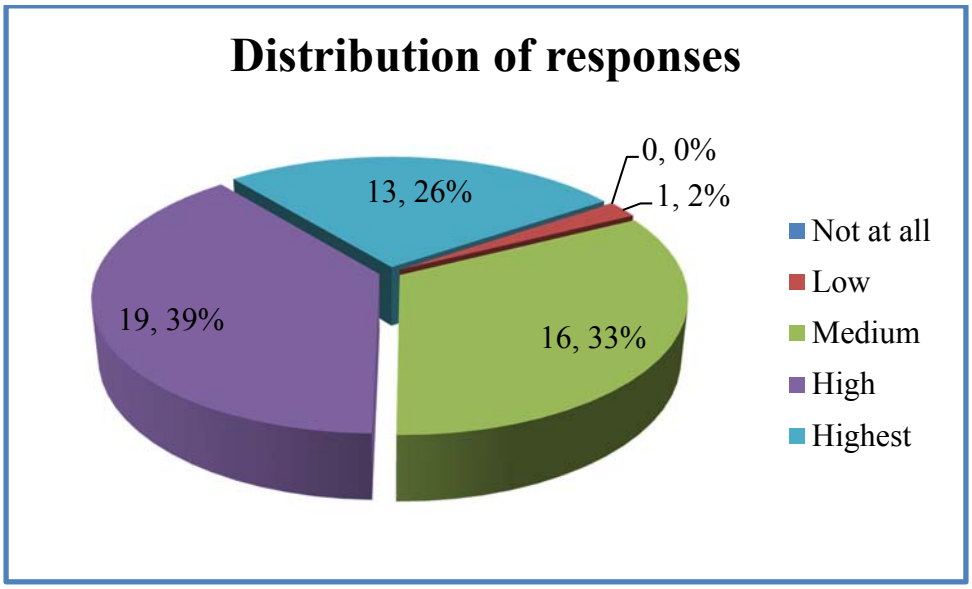

Figure 16: Respondents Statistics of ES Q-14

From the table and pie chart, it is observed that 26% of professionals in the survey admitted very strong patterns of fuel and electricity saving after applying lean. A whopping 39% believe lean to be a strong tool that can help industry save energy. According to 33% of the respondents, lean is neither very strong nor very weak tool for saving fuel and electricity. 2% believe that lean has a low impact on energy saving. To sum up, around 98% people related to automobile industry have observed effective saving of fuel and power after applying lean. On the scale of 5, professionals give 3.9 points indicating lean to be an essential component for sustainability.

ES Q. 15. How much waste is recycled by your organization?

Table 15: Respondents Statistics of ES Q-15

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	3	6		
2	Low	6	12		
3	Medium	10	20	3.67	1.21
4	High	15	31		
5	Highest	15	31		
	Total	49			

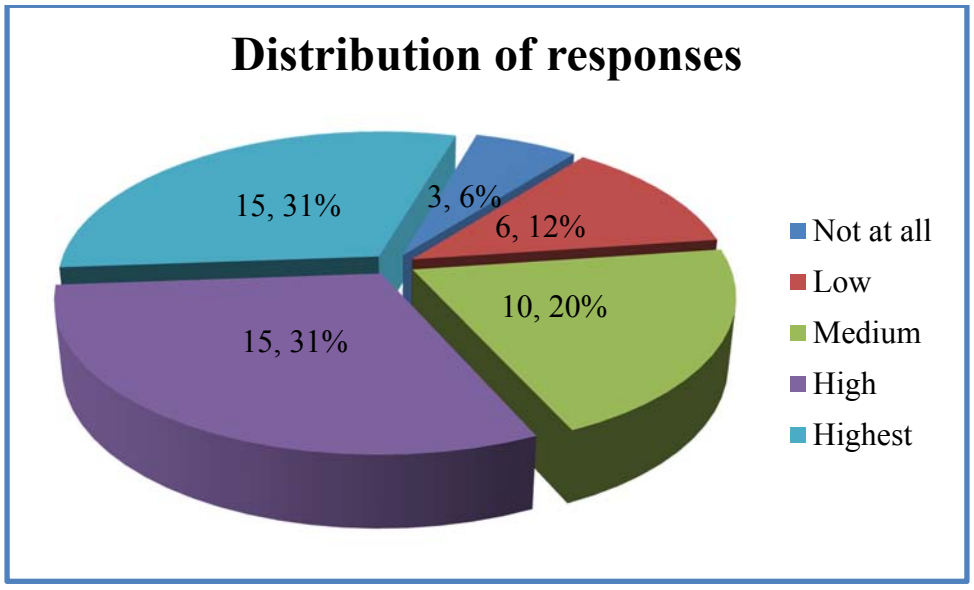

Figure 17: Respondents Summary of ES Q-15.

From the table and pie chart, it is observed that 31% of professionals in the survey admitted that they observed very strong waste recycling after applying lean. A major chunk of 31% observes good waste recycling by using lean. According to 20% of the respondents, lean is neither very strong nor very weak tool for waste recycling. Around 20% don't consider lean as an effective tool in waste recycling. To sum up, around 82% people related to automobile industry have observed effective waste recycling after applying lean. On the scale of 5, professionals give 3.67 points suggesting that lean is an essential component in the industrial growth.

SS Q. 16. Does your company consider employees' observations/views for up-gradation of the system?

Table 16: Respondents Statistics of SS Q-16

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Low	1	2		
3	Medium	14	28	3.96	0.82
4	High	20	41		
5	Highest	14	29		
	Total	49			

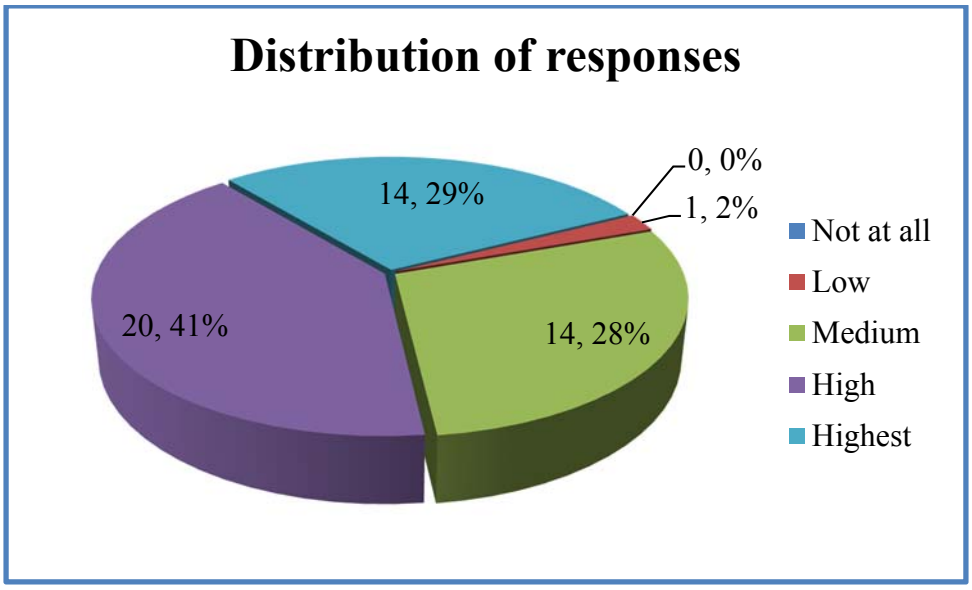

Figure 18: Respondents Summary of SS Q-16.

From the table and pie chart, it is observed that 29% of professionals in the survey agree that their companies give utmost priority to employee's observations/views on system up gradation. A major chunk of 41% agreed that company gives high priority to what its employees say on system up gradation. According to 28% of the respondents, their company is not too high or too low in considering employees' views. 2% believe their companies do not value their employees' views at all. To sum up, around 98% people related to automobile industry have observed effective role of employees' views on system up gradation in the companies. On the scale of 5, professionals give 3.96 points suggesting lean to be an important part in the industrial growth.

SS Q.17. Does your company provide training to the employees for implementing sustainability in production?

Table 17: Respondents Statistics of SS Q-17

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	At low level	2	4		
3	At medium level	15	31	3.9	0.8
4	At high level	20	41		
5	At highest level	12	24		
	Total	49			

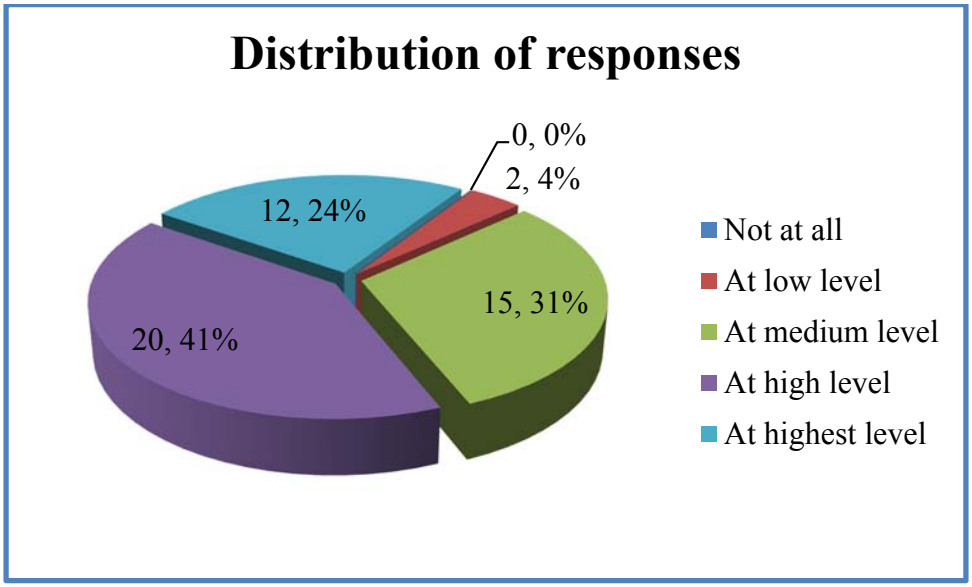

Figure 19: Respondents Summary of SS Q-17.

From the table and pie chart, it is observed that 24% of professionals in the survey agree that their companies provide training at the highest level to the employees for implementing sustainability in production. A major chunk of 41% agreed that company gives training at high level its employees for the same purpose. According to 31% of the respondents, their company is not too high or too low in conducting such trainings. Only 4% have the opinion that such training is low priority for their organization. To sum up, around 96% people related to automobile industry have observed effective training of employees for implementing sustainability in production. On the scale of 5, professionals give 3.9 points indicating lean to be an essential component in attaining sustainability.

SS Q.18. Does your company organize programs for social welfare of employees?

Table 18: Respondents Statistics of SS Q-18

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	1	2		
2	Low	6	12		
3	Medium	13	27	3.6	1
4	High	19	39		
5	Highest	10	20		
	Total	49			

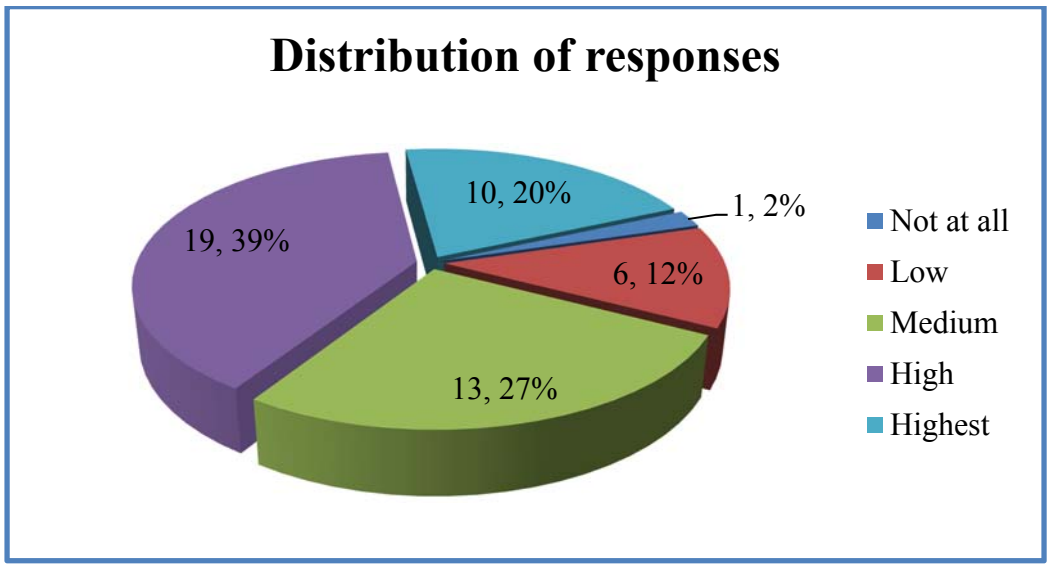

Figure 20: Respondents Summary of SS Q-18.

From the table and pie chart, it is observed that 20% of professionals in the survey maintain that their companies organized social welfare programs for their employees at highest priority. 39% of them consider it as high priority and submitted that their organizations keep organizing social welfare programs for employees. 27% organize same but not often. Around 12% are those that conduct such events occasionally or not at all. To sum up, around 86% people related to automobile industry have observed effective social welfare programs being conducted by their companies. On the scale of 5, professionals give 3.6 points suggesting that lean is an important tool for sustainability.

SS Q.19. How much work satisfaction is provided by your organization to employees?

Table 19: Respondents Statistics of SS Q-19

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Low	4	8		
3	Medium	16	33	3.7	0.9
4	High	20	41		
5	Highest	9	18		
	Total	49			

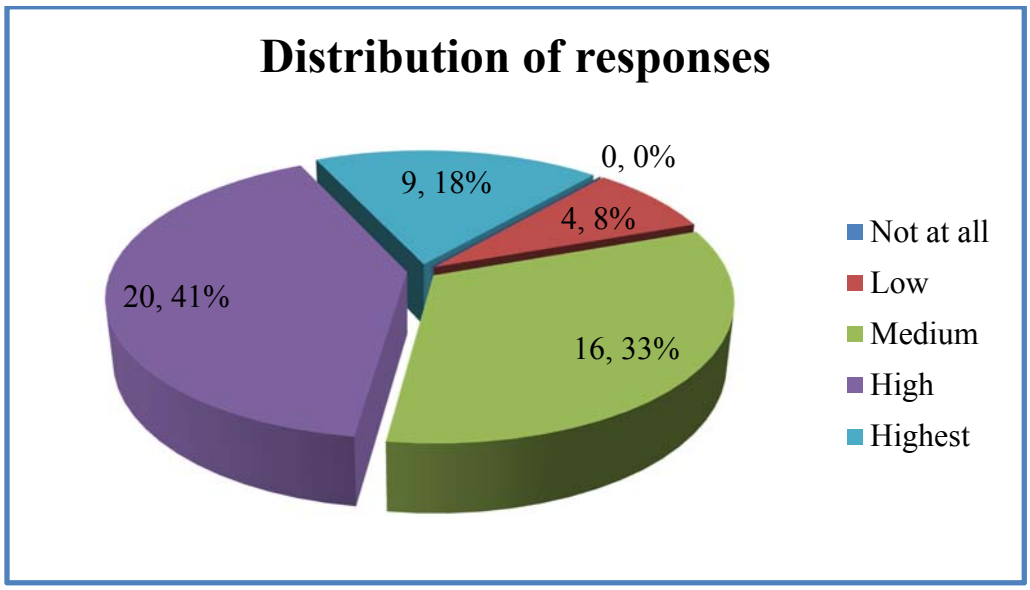

Figure 21: Respondents Summary of SS Q-19.

From the table and pie chart, it is observed that 18% of professionals in the survey maintain that their companies provide work satisfaction to their employees at highest priority. 41% of them consider it as high priority and submitted that their employees' satisfaction is met. 33% believe that work satisfaction is normal, not too high not too low in their organizations. Around 8% are those that believe work satisfaction is low or zero. To sum up, around 92% people related to automobile industry consider work satisfaction to be an important aspect of industry. On the scale of 5, professionals give 3.7 points indicating lean to be an important player in industrial growth.

SS Q.20. Does your company provide incentives for promoting sustainability in your organization?

Table 20: Respondents Statistics of SS Q-20

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	3	6		
2	Low	11	23		
3	Medium	14	29	3.3	1.2
4	High	11	22		
5	Highest	10	20		
	Total	49			

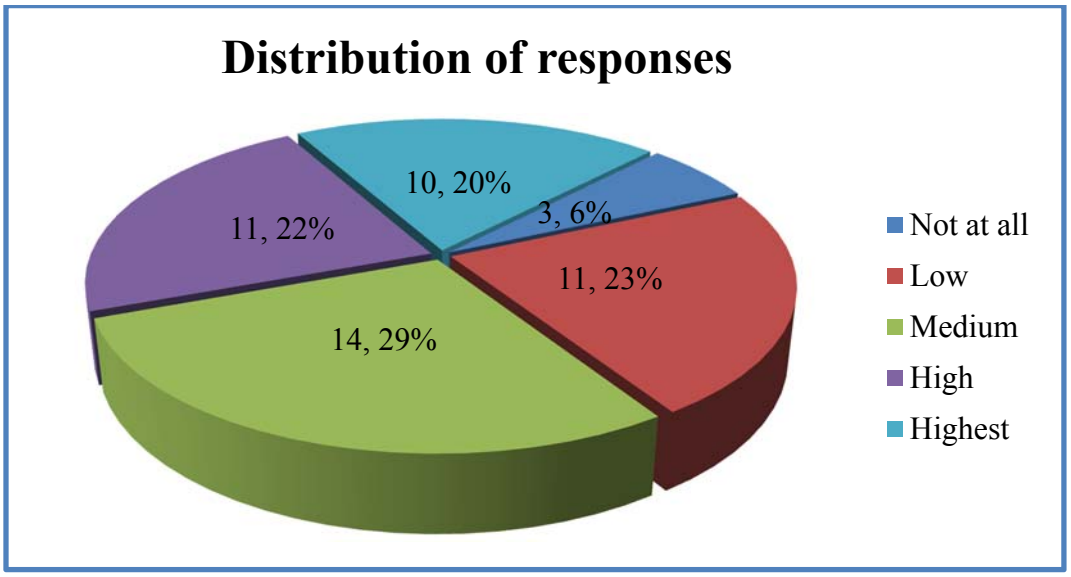

Figure 22: Respondents Summary of SS Q-20.

From the table and pie chart, it is observed that 20% of professionals in the survey maintain that their companies provide incentives for promoting sustainability on highest priority. The same 22% maintain that offering incentives for sustainability is high priority in their companies. 29% consider it as medium, 23% consider it low and 6% completely deny any incentives for promoting sustainability. To sum up, around 70% people related to automobile industry have observed effective trends of providing incentives for promoting sustainability. On the scale of 5, professionals give 3.3 points suggesting lean to be an essential component in the industrial growth.

EC.S Q.21 Does your company have the policy of life cycle assessment?

Table 21: Respondents Statistics of ECS Q-21

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	2	4		
2	Low	4	8		
3	Medium	22	45	3.47	1.4
4	High	11	23		
5	Highest	10	20		
	Total	49			

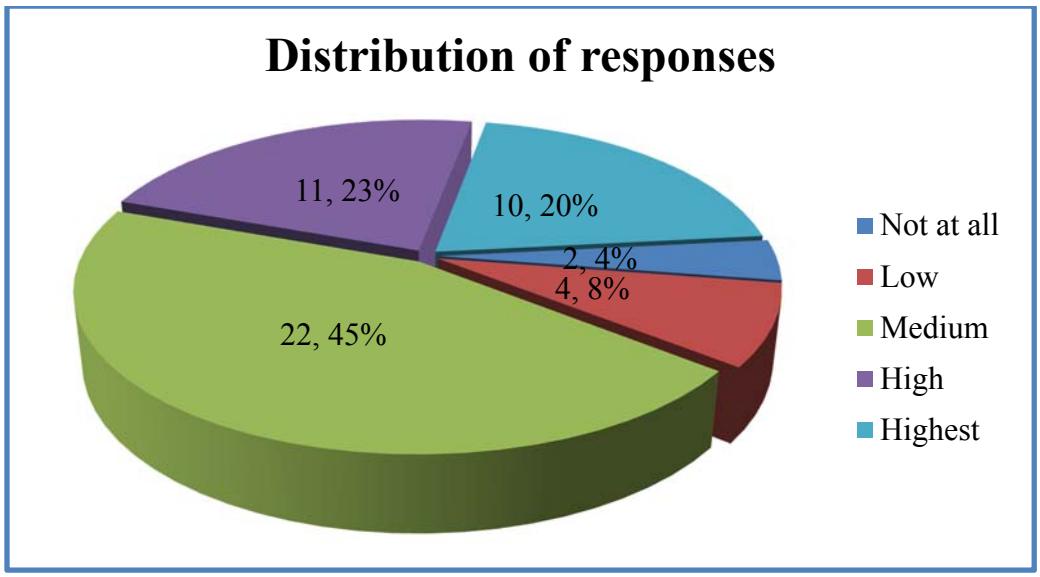

Figure 23: Respondents Summary of ECS Q-21.

From the table and pie chart, it is observed that 20% of professionals in the survey maintain that their companies very strongly follow policy of life cycle assessment. 23% of them have this policy as an important one. Major chunk of 45% observed that life cycle assessment is neither a high priority nor is it completely out of the picture. Around 12% consider it either low or zero priority in their companies. To sum up, around 88% people related to automobile industry have observed effective use of life cycle assessment policy in their companies. On the scale of 5, professionals give 3.47 points and believe lean to be an effective tool for attaining sustainability.

EC.S Q.22 Does your company implement preventive measures/innovations to reduce operating and maintenance cost?

Table 22: Respondents Statistics of ECS Q-22

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	1	2		
2	Low	1	2		
3	Medium	9	18	4	0.8
4	High	26	53		
5	Highest	12	25		
	Total	49			

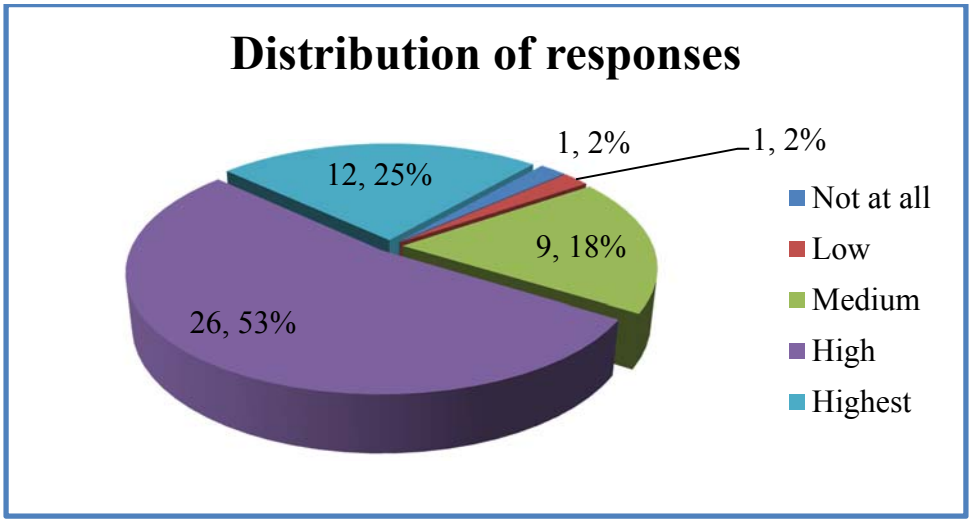

Figure 24: Respondent Summary of ECS Q-22.

From the table and pie chart, it is observed that 25% of professionals in the survey implemented very strong policies for coming up with innovations to bring down O&M costs. A whopping 53% maintain that innovations for reducing O&M are high priority for their organizations. According to 18% of the respondents, this is neither very high priority nor very low priority policy for bringing down O&M costs. 4% believe that their organizations do not consider reducing O&M costs for sustainability. To sum up, around 96% people related to automobile industry have observed effective use of innovations for bringing down Operations and maintenance costs in their companies. On the scale of 5, professionals give 4 points indicating lean as important player in industrial growth.

EC.S Q.23 Does your company provide economic support to local infrastructure development?

Table 23: Respondents Statistics of ECS Q-23

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	2	4		
2	Low	6	12		
3	Medium	14	29	3.5	1.1
4	High	18	37		
5	Highest	9	18		
	Total	49			

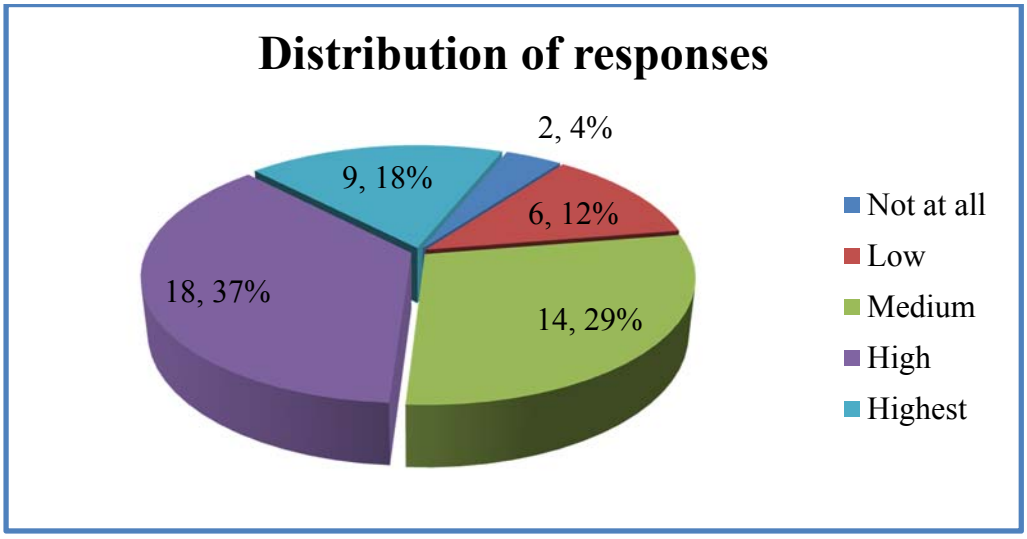

Figure 25: Respondent Summary of ECS Q-23.

From the table and pie chart, it is observed that 18% of professionals in the survey implemented very strong policies for providing economic support to local infrastructure development. A whopping 37% consider it as high priority in their organization. According to 29% of the respondents, this is neither very high priority nor very low priority policy of the organization. 16% believe that their organizations do not provide economic support to local infrastructure development. To sum up, around 84% people related to automobile industry have observed effective use of policy providing support to infrastructure development by their companies. On the scale of 5, professionals give 3.5 points and believe lean to be the essential component in the industrial growth.

EC.S Q.24 What is the budget of your organization for environmental protection?

Table 24: Respondents Statistics of ECS Q-24

S.no.	Particulars	No of respondents	Percentage	Mean	S.D
1	Not at all	0	0		
2	Low	6	12		
3	Medium	16	33	3.59	0.91
4	High	19	39		
5	Highest	8	16		
	Total	49			

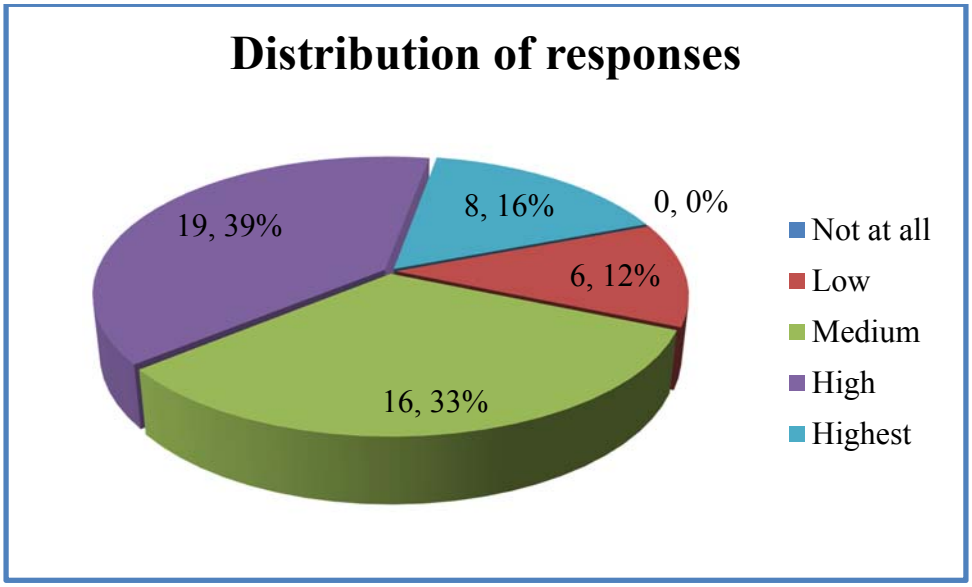

Figure 26: Respondent Summary of ECS Q-24.

From the table and pie chart, it is observed that 16% of companies have a very strong budget for environmental protection. 39% have considered environment protection as high priority and have allocated funds for same. According to 33% of the respondents, this is neither very high priority nor very low priority policy of the organization. Around 12% believe that their organizations do not have budget for same. To sum up, around 88% people related to automobile industry have implemented policy of allocating budget for environmental protection in their companies. On the scale of 5, professionals give 3.59 points indicating lean's importance in the industries.

Correlation

After collecting the data, correlation was applied on same through SPSS. Correlation is applied to find out the strength of relation between the elements of a construct. The correlation has been applied to elements of all four construct separately. The result of correlation is tabulated in Table25

Table 25: Pearson Correlation between impact variable of environment sustainability

ESQ11ReduceWaste	1				
ESQ12Reduce Greenhouse gases	.711**	1			
ESQ13Reduce Waste Water Generation	.669**	.726**	1		
ESQ14Saving Fuel and electricity	.709**	.650**	.704**	1	
ESQ15Recycled Waste	.591**	.658**	.745**	.696**	1
	ESQ11Reduce Waste	ESQ12Reduce Greenhouse gases	ESQ13Reduce Waste Water Generation	ESQ14Saving Fuel and electricity	ESQ15Recycled Waste
** Correlation is significant at the 0.01 level (2-tailed).					

Table shows the correlation between five different environmental sustainability impact variables. Some variable are significantly correlated ($p \leq 0.01$) with others. The result of reliability analysis (Cronbach's alpha = 0.917) shows internal consistency among variables.

Table 26: Pearson Correlation between impact variable of Social sustainability

SSQ16 Up-gradation of employees	1				
SSQ17 Training of employee	.568**	1			
SSQ18 Social welfare of employees	.611**	.767**	1		
SSQ19 Work satisfaction of employees	.539**	.707**	.719**	1	
SSQ20 Incentives for employee	.583**	.615**	.683**	.758**	1
	SSQ16 Up-gradation of employees	SSQ17 Training of employee	SSQ18 Social welfare of employees	SSQ19 Work satisfaction of employees	SSQ20 Incentives for employees

** Correlation is significant at the 0.01 level (2-tailed).

Table shows the correlation between five different social sustainability impact variables. Some variable are significantly correlated ($p \leq 0.01$) with others. The result of reliability analysis (Cronbach's alpha = 0.896) shows internal consistency among variables.

Table 27: Pearson Correlation between impact variable of Economic Sustainability

ECSQ21Life cycle assessment	1			
ECSQ22Implement preventive measure	.735**	1		
ECSQ23Local infrastructure development	.617**	.491**	1	
ECSQ24Budget of environmental protection	.557**	.576**	.874**	1
	ECSQ21 Life cycle assessment	ECSQ22Implement preventive measure	ECS Q23Local infrastructure development	ECS Q24Budget of environmental protection
** Correlation is significant at the 0.01 level (2-tailed).				

Table shows the correlation between four different economic sustainability impact variables. Some variable are significantly correlated ($p \leq 0.01$) with others. The result of reliability analysis (Cronbach's alpha = 0.856) shows internal consistency among variable.

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

Depending upon the results and their analysis, some main conclusions have been presented in the form of charts in section 5.1. Future scope and recommendations have also been given in subsequent section.

5.1 CONCLUSIONS

Depending upon the different aspects of lean philosophy and sustainability, results have been analyzed for each finding in detail in previous chapter. The main findings and conclusions of the work for all aspects are following

1. Environmental Sustainability- For five variables related to environment considered in this work viz. waste reduction, GHG reduction, waste water reduction, saving fuel and electricity and recycling waste, around 80-90% respondents from industries believe them to be crucial or useful for achieving sustainability (Figure 27)

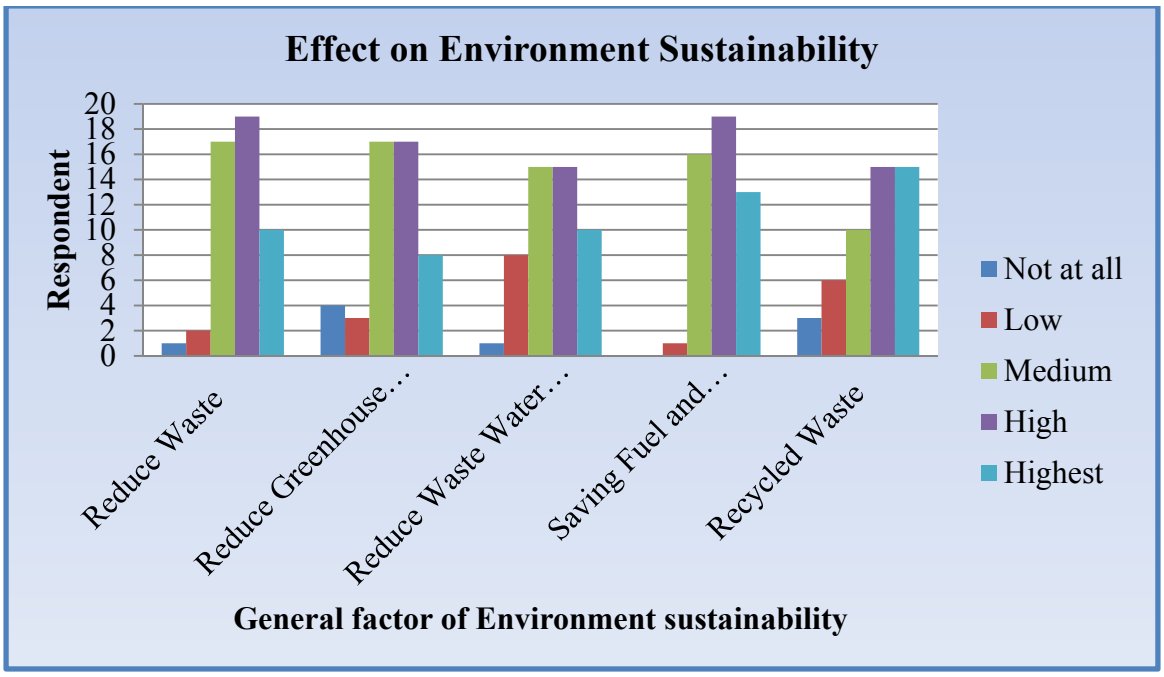

Figure 27: Effect on Environment Sustainability

2. Social Sustainability- Five variables related to social sustainability considered in this work are upgradation in job profile of employees, training, social welfare, work satisfaction and incentives for employees. Out of total respondents, more than 90% believe these variables to be essential or useful for achieving sustainability (Figure 28)

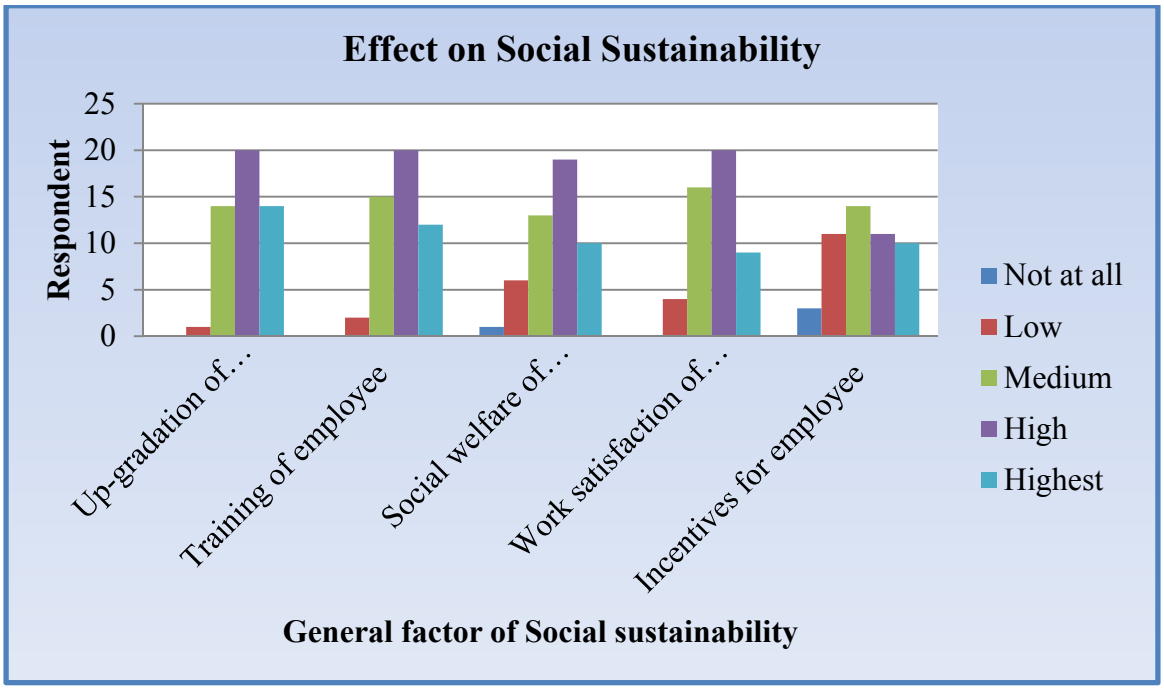

Figure 28: Effect on Social Sustainability

3. Economic Sustainability- For four variables related to economic sustainability considered in this work viz. life cycle assessment, implementation of preventive measures, local infrastructure development, and budget for environmental protection, around 70-90% respondents from industries believe them to be crucial or useful for achieving sustainability (Figure 29).

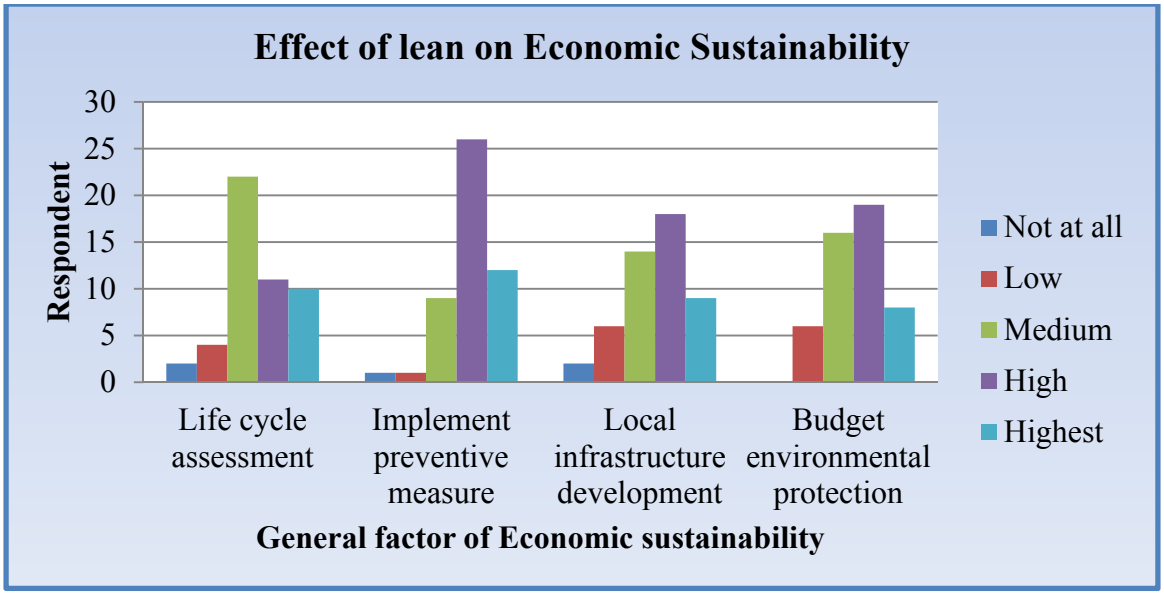

Figure 29: Effect of lean on Economic Sustainability

The overall scenario for the effect of lean on all the three aspects of sustainability- environmental, social and economical has been depicted in Figure 30.

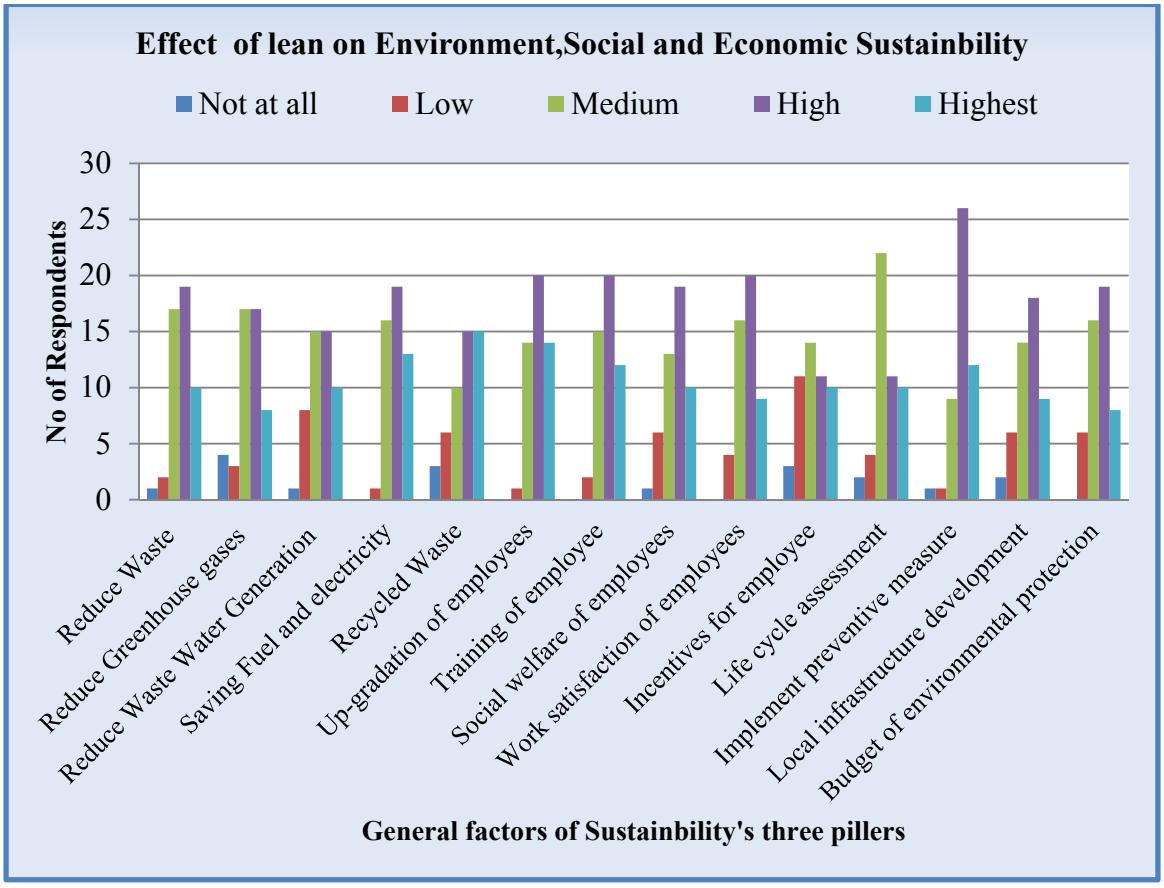

Figure 30: Effect of lean on Environment, Social and Economic Sustainability

Figure 31 shows the respondents' rating for various sustainability factors. It also shows the variation in rankings as function of number of years for which the lean strategy has been implemented. It is observed that the industries using lean strategies for around 1-2 years rate the various variables of sustainability aspects at around 3 out of 5. However, the industries with 4-5 years of lean's experience rate them at 4 out of 5. From Fig also, it can be concluded that the effectiveness of lean is felt more and more with continuous usage. The usefulness of lean philosophy becomes more and more evident with time.

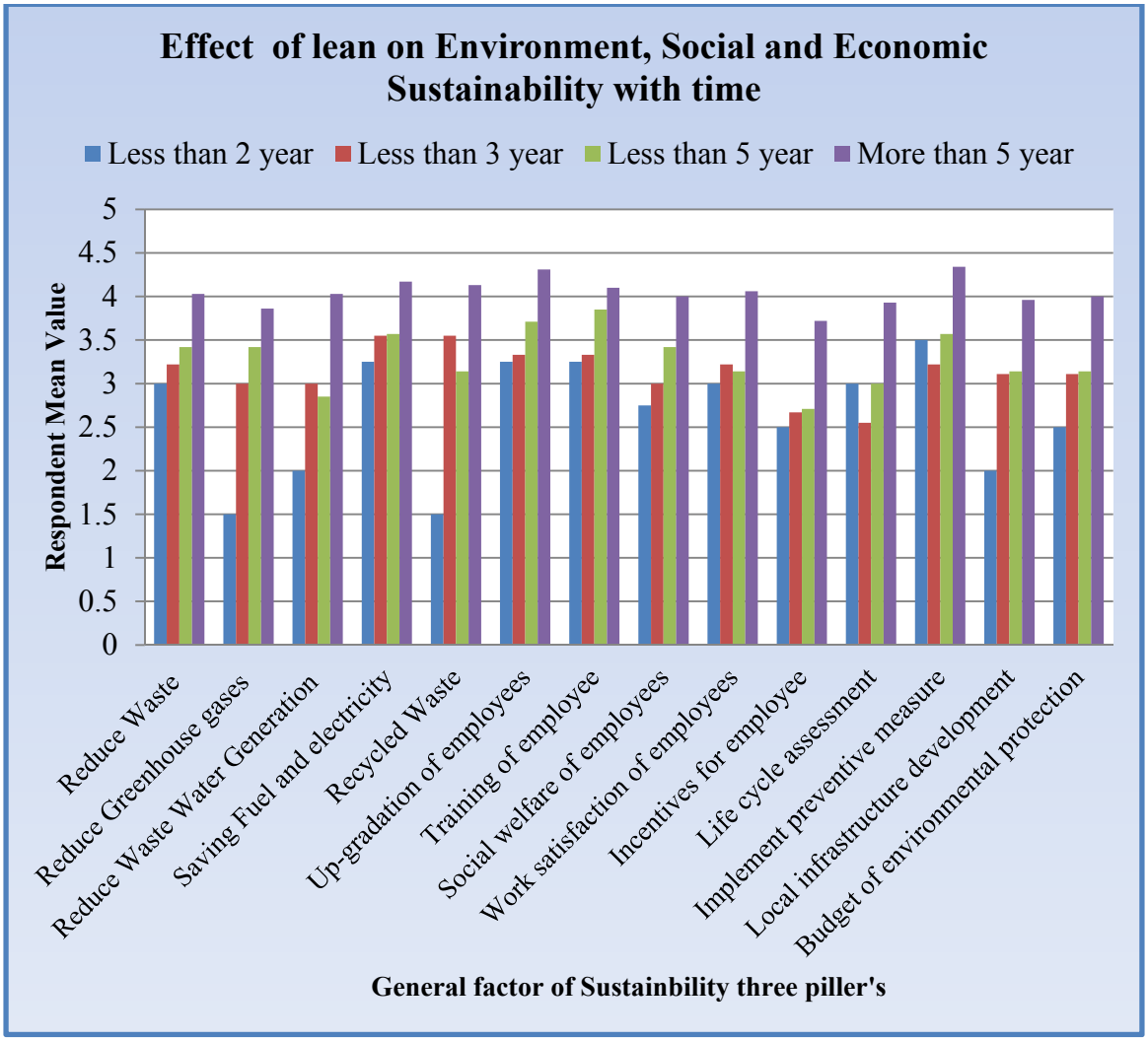

Figure 31: Effect of lean on Environment, Social and Economic Sustainability with time

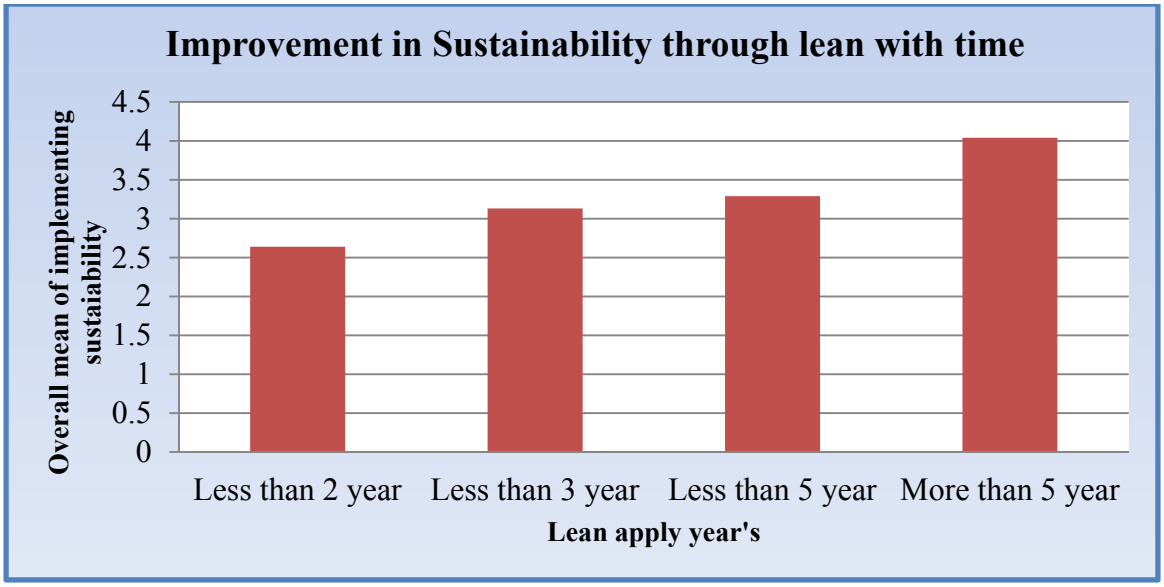

Figure 32: Improvement in Sustainability through lean with time

Finally, after the detailed analysis was carried out, it is concluded that sustainability can be achieved using lean manufacturing system. However, lean takes some time to get reflected in real experiences. In the words of Kidwell [40] "Lean strategies coincidentally benefit the environment, without the need for special ―environmental toolkits or a separate focus on environmental considerations." The same has been inferred from the current study.

5.2 RECOMMENDATION FOR FUTURE RESEARCH

The following improvements can be made in the existing work to make it more effective and reliable.

1. Sample size can be increased for a more inclusive data
2. More variables affecting sustainability can be added to the survey
3. The quantification of variables done through survey could also be approached analytically.

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Assessment of Achieving Sustainability in Indian Automobile Industry through Lean Manufacturing

PART A: Organization Profile

1. Name of the Organization:

.....

2. Name of the person responding:

.....

3. Number of Years' Experience :

.....

4. Please indicate the number of employees in your organization.
Mark only one oval.

- ◯ 0-50
- ◯ 51-499
- ◯ 500-2000
- ◯ Over 5000

5. Does your organization have any certification /awards.
Check all that apply.

- ☐ ISO9001
- ☐ TPM
- ☐ TQM
- ☐ Manufacturing excellence
- ☐ Sustainability business award
- ☐ Other

PART B :(A) Lean Manufacturing System

6. Does your company apply the philosophy of lean manufacturing?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

7. For how many years your organization is using lean activates/tool.
Mark only one oval.

- less than 1 year
- less than 2 year
- less than 3 year
- less than 5 year
- More than 5 year

8. Is lean manufacturing system is an effective tool for performance and productivity improvement in automobile industry.
Mark only one oval.

- Not at all
- Normal
- Effective
- Strong
- Very strong

9. How was the growth of organization after applying Lean Manufacturing tools?
Mark only one oval.

- Not at all
- Normal
- Effective
- Strong
- Very strong

10. How much reduction in plant breakdown is observed after applying Lean Manufacturing tools?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

(B) Environment sustainability after applying Lean Manufacturing Tool

11. How much reduction in waste by your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

12. How much greenhouse gases are being reduced by your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

13. How much waste water generation is reduced by your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

14. How much fuel and electricity saving is recorded by your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

15. How much waste is recycled by your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

(C) Social sustainability

16. Does your company consider employees observations/ views for up gradation of the system?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

17. Does your company provide training to the employees for implementing sustainability in production?
Mark only one oval.

- Not at all
- At low level
- At medium level
- At high level
- At highest level

18. Does your company organized programs for social welfare of employees?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

19. How much work satisfaction is provided by your organization to employees?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

20. Does your company provide incentives for promoting sustainability in your organization?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

(D)Economic sustainability

21. Does your company have the policy of life cycle assessment?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

22. Does your company implement preventive measure/innovations to reduce operating and maintenance cost.
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

23. Does your company provide economic support to local infrastructure development?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest

24. What is the budget of your organization for environmental protection?
Mark only one oval.

- Not at all
- Low
- Medium
- High
- Highest