

STUDY OF LEAN, GREEN AND LEAN-GREEN MANUFACTURING PRACTICES IN MANUFACTURING SECTOR

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ABSTRACT

Lean production and lean manufacturing refer to the use of systematic methods to reduce costs by eliminating wastes and non value-added activities, while delivering what the customer wants, on time. Lean manufacturing was originally developed by the Toyota Motor Co. in Japan based on concepts pioneered by Henry Ford, and is now being applied beyond mass production, into service-oriented businesses, agencies and offices.

Even without explicitly targeting environmental outcomes, lean efforts can yield substantial environmental benefits. However, because environmental wastes and pollution are not the primary focal points, these gains may not be maximised in the normal scheme of lean.

The two strategies can be integrated and offered simultaneously. The approaches have similarities, in that they strive to eliminate non value-added components, assess baseline conditions and operations, capture the details of process inputs and outputs, and strategize to design and incorporate changes that will reduce environmental or productivity inefficiencies.

As soon as your operations implement Lean you will become more capable of enabling increased capacity by freeing up underutilised office and plant space. Your people will be capable of reducing wasteful outsourcing, increasing production flexibility to add product lines and additional services, or economically and faultlessly delivering more of what you already provide, without acquiring new facilities or higher overheads.

Moving ahead, Green Implementation will make you able to respond to changing customer demand with high variety, high quality, low cost, and much improved throughput without destroying the environment. Green practices will also help you simplify business and earn greater value to your on-going business transformation.

Keywords: *Environment, Green Implementation, Production Flexibility, Reducing wasteful, value-added activities, Value added component*

I. INTRODUCTION

There is a great need for an environmental, economic and social sustainable society, meeting the needs of the present without compromising the ability of future generations. Focusing on environmental sustainability,

legislation and industrially accepted emission targets have emerged, on an overall level represented by the Kyoto protocol. Green as well as Lean production has thus become a more and more important topic in recent years. Based on the gigantic need for technologies and strategies that will reduce CO₂ emissions globally, as well as customer demands for cost efficient and environmental friendly goods and processes, companies are starting to change their principles towards Green and Lean philosophies. In Green and/or Lean development, like other systematic approaches towards improved processes, business sustainability comes first.

II. LEAN

The history of lean began in early 1950s in Japanese's car maker factory, Toyota. Toyota was into textile manufacturing in the beginning, then they shifted to be a car manufacturing. In 1937 by the name of "Toyota Motor Company" they started manufacturing cars. The world was facing war and by the force of the military government they had to change their direction from car manufacturing to truck vehicle provider. And soon after the war they came back to their primary product and made themselves competitive in the car market. The problems that they faced were. By the time they returned variety of problems were waiting for them.

- A small Domestic market was demanding large variety.
- Employees powers were restricted and work union, work laws had gained strength.
- World War had weaken Japan economy, which restricted import of western technology to Japan.
- They couldn't compete with huge companies such as Ford in foreign market.

So they soon realised, with current methods they cannot compete in international market. Taiichi Ohno, production manager of Toyota, found new methods which later became the fundamental of lean production.(Womack et al. 1990).One of the concepts that Ohno was going to change was the press machine or in general machining. In mass production system, different parts was produced in huge numbers in one go. This used to involve many machines and manpower for all the time. These parts were stored in inventory and then they changed the setup of the machines to produce the other part. As changing dies or other setups was so time consuming and needed experts, this mass production approach was implemented.. Ohno applied his experience and observations to improved the process of changing the dies. He could reduced the setup up time for machines and used regular operator to make the production line more flexible. Doing this he made it possible to produce different parts with the same machine and the same day. By this improvement he reduced the number of machines needed for the production line, reduced the inventory and the cost of inventory and transportation and also improved the quality of the production line during the production process.

The impact of this change was wide spread. It also reduced the rework as the defected part would be identified immediately and the failure reason would be repaired before making another defected batch.(Womack et al. 1990) Liker in his book describes this achievement as "when you make lead times short and focus on keeping production lines flexible, you actually get higher quality, better customer responsiveness, better productivity, and better utilization of equipment and space."(Liker 2007)

By studying mass production Ohno realized that there are so many wastes in material, effort and time in the production system which enforced extra cost to the company and also its customers. To reduce these wastes,

Ohno formed teams with team leaders. These teams were responsible for the jobs in the process, cleaning the work place, doing small repair and solving the quality issues. Ohno believed in finding the roots of any defected part immediately before the next defected part get to produce. As a consequence everyone in the production line could stop the whole line to identify the roots of the mistaken part and whole team would come together to solve the problem and rerun the line. As a result of this there was no defected car at the end of the assembly line and by improving the teams, number of stops in the line also reduced almost to zero.(Womack et al. 1990)

According to Liker in his book, *The Toyota Way*, Ohno knew that Toyota did not have as much capital as Ford did and the technology and the machining facilities of Toyota were so tiny. Therefore it was not feasible for Toyota to have the same system as Ford had and could not make a huge number of works in process inventory and have mass production. Hence he tried to use the idea of Frederick Taylor, as also Ford has tried to use it, but in another way. Taylor's idea was to have a continues flow in order to have high productivity.(Liker 2007)

In lean everything will focus on customer (internal or external) point of view. In each process there is a question: "What does the customer want from this process?" By answering this question we can divide the activities in the process into two types: value added and non-value added activates. Any non-value added activity will produce waste of material or at least waste of time and money in customer perspective. Toyota has categorized these wastes in eight categories:

- Over production: producing items where there is no order for them.
- Waiting: operators time waiting for a reason than lack of order.
- Transportation: any transportation is a waste however sometimes it is necessary.
- Over processing: having extra step in the process or rework or producing defected items.
- Inventory
- Unnecessary movement
- Defects
- Unused employee creativity.

Ohno believed that the most important waste is over production; hence it can produce other waste by itself. By having over production, an inventory of works in process is unavoidable and thus continues flow and perhaps quality in process will be affected.(Liker 2007) Womack and Jones at 1996 in their book, *Lean Thinking*, give us a whole picture of lean system based on their study of Toyota and other Japanese company and also comparing them with the American lean manufacturers. They describe the whole system on the five basic principles:

- Specifying the value
- Identifying the value stream
- Flow
- Pull system
- Perfection

In the system, the "Value" is defined by the customer. It is the costumer who specifies the value of a product. By this background anything (activities, movement, service or process) which is not involved in making this

value, is a waste in the system. Value stream is the chain of steps in the system which prepares the final product to the customer. By mapping this chain of steps or processes we can easily identify the steps which are adding value to the product and the ones that are not adding value to the product. The next step is to ease the flow of material and information in the value stream by reducing the non value added steps of the process. In the pull system (in order to reduce the inventory between steps) each step will proceed and operate a new part only if the next step needs a part. Perfection in this system means that we produce based on the customer order (eliminating the overproduction, one of the eight wastes) and at the exact time that the customer needs it (Just in Time) and in the least waste process. (Womack et al. 1996)

Bergmiller and McCright has drawn a lean System Model based on the Womack theory about lean and other best practices and prizes such as Shingo prize for improving the manufacturing processes. Their coherent model is shown in the figure below. (Bergmiller & McCright 2009b)

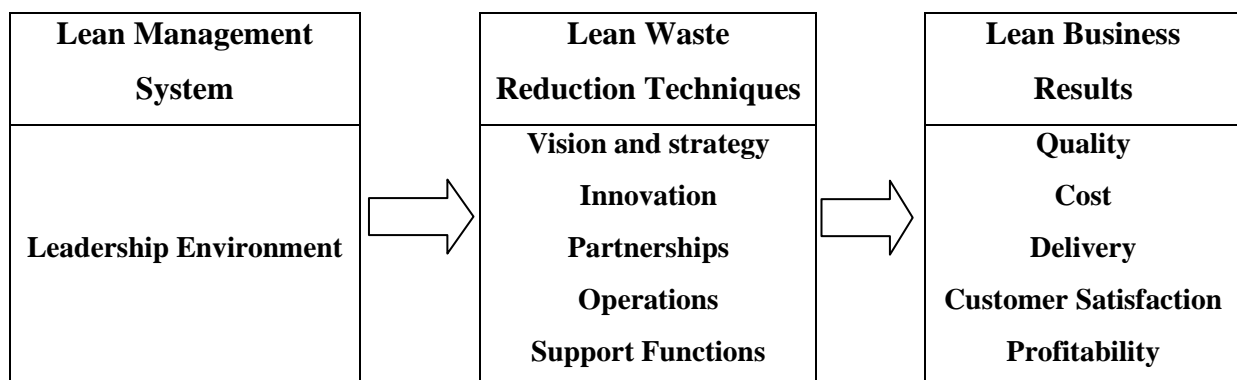


Figure 1 Advanced Lean System Model (Bergmiller & Mccright 2009)

One of the key steps in lean system is providing a good map and understanding over the value stream in order to be able to find and reduce the wasted steps and ease the flow in the value stream. One of the tools which has been used widely is value stream mapping.

Lean business can be defined as one which eliminates waste, embraces sustainability practices and adapts the techniques of lean manufacturing. An emphasis on sustainability can improve the performance of an organisation in long run. Well structured lean manufacturing programs leads to waste elimination and the involvement of employees in improvement initiatives. In time to come, as the cost of material and energy continues to increase, costing of the products and services for organisations is going to be biggest challenge. Any lean program's success is predicated on four essential components:

- **Clarity of the lean philosophy**, to one and all in the organisation is must. All the employees must, understand the lean philosophy, Lean Tools and the targeted results.
- **Active Participation Employees** and their direct-indirect contribution lean implementation's outcomes.
- **Management of the Organisation must offer** a sound platform for enterprise's over all improvement.
- **Financial Support**, Lean Implementation process must be fully funded,

Lean Production has common goals with environmental production in some parts, e.g. during improving manufacturing efficiency, energy and environmental benefits are often also attained. When using lean principles to achieve environmental production, it will bring us considerable cost benefits besides green production.(Florida 1996; King & Lenox 2001; Rothenberg et al. 2001). Environmental analysis of a process or green manufacturing has some different sections such as raw material, energy, water and hazardous material etc.

III. ENVIRONMENTAL (GREEN) PRODUCTION

In the recent decades as a consequence of fast growth in the population, industrialization, usage of fossil fuel, growth in the economy and need of accelerated production, mankind has started a massive use of natural resources to meet its demand in a way that in some area it has passed the limitation of sustained trend of resources. On the other hand such a massive consumption has ended up in polluting the environment by the waste of its product and production. Thus there has been such pressure on the companies to minimize their emission and pollution of their activities from their supply chain to their product.(Hart 1995; Corbett & Klassen 2006). Hart has introduced three strategies from the natural resource perspective to the firms (Hart 1995):

Strategic Capability	Environmental Driving Force	Key Resource	Competitive Advantage
Pollution Preservation	Minimise Emission, Effluent and waste	Continues Improvement	Lower costs
Product Stewardship	Minimise life Cycle cost of product	Stakeholder integration	Pre-empt Competitors
Sustainable Development	Minimise environmental burden of firm growth and development	Shared vision	Future position

Figure 2 (Hart 1995)

Pollution prevention argues about changing the focus of the firm from investing in the “end of pipe” strategies (trying to recycling the waste or putting filters for the air pollution) to the more continues development methods.(Rooney 1993; Florida 1996) Product stewardship is a strategy that aims to combine the customer needs with environmental issues in the design phase of the product life cycle. In sustainable development strategy, the aim is to bring the environmental perspective to the long term plan and strategy in the companies. Making the shared vision for the top managers of the companies about the environmental issues not only in the developed countries but also in the developing countries (where the 90% of the raw material for the developed countries are coming from) is the main line of this strategy (Hart 1995)

Companies and also environmental organizations have shown more interest in Preventive Actions comparing to end-of-the-pipe strategies. Florida has concluded from a survey that companies have three main elements in their pollution preventive strategies:

- Utilize source reduction
- Recycling
- Production process improvements

Companies who involved in the survey mentioned that: “The implementation of new technologies in the form of production process improvements is a central factor in the development of joint improvements in environmental and manufacturing methods.” (Florida 1996)

Wide usage of quality management systems is irrefragable. TQM and ISO standards are the example of these families. Based on the brilliant philosophy of these methods, in the field of environmental management, there exist TQEM and ISO 14000 families. Florida defines TQEM as:

“Total quality environmental management (TQEM) extends the principles of quality management to include manufacturing practices and processes that affect environmental quality.”(Florida 1996)

The first stage in environmental production system (like other management systems) is top management engagement. An Environmental Management System (EMS) is a good frame work for the whole organization which should be established from the top level management. “The EMS defines the corporate environmental policies and procedures that assure good environmental performance” (Bergmiller 2006) however EMS, itself does not reduce the environmental impact of the production but it makes the whole system proper for being more resource saver and makes the suitable environment for performing the practical solutions for being green. One of the well known standards for EMS is ISO 14001 which is widely used in the industries and also service companies nowadays. Three disciplines which are helping reduce the resource and energy usage in a manufacturing process are (Bergmiller 2006):

1. Design for Environment: it has an engineering perspective in to a production process and the scope is the whole life cycle. “The premise of Design for the Environment is to design a product with minimum impact on the environment. It is during the design phase that almost all potential environmental effects of the product are determined.”(Bergmiller 2006)
2. Total Cost Accounting.
3. Industrial Ecology

Later on Bergmiller and McCright in 2009 by studying other best tested Green System models draw their own aggregative Advance Green System model. Their model is shown in the figure below. (Bergmiller & McCright 2009b)

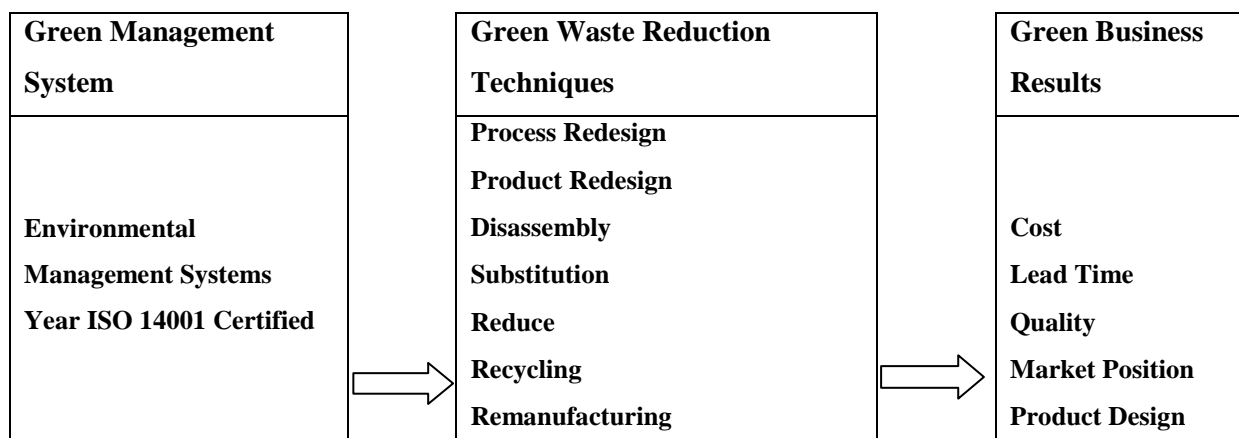




Figure 3 Advance Green System (Bergmiller & Mcwright 2009)

Natural Drivers of The Green Wave

“Smart companies use environmental strategies to innovate create value and build competitive advantages”

The top ten environmental issues for organisations to understand and consider the impact of are

1. Climate change
2. Energy
3. Water
4. Biodiversity and land use
5. Chemicals, toxics, and heavy metals
6. Air pollution
7. Waste management
8. Ozone layer depletion
9. Oceans and fisheries
10. Deforestation.

Green to Gold, Daniel C. Esty and Andrew S. Winston (Yale University)

Leading companies, such as those participating in the Lean to Green consortia, understand that “green” isn’t as much about becoming more “socially responsible” or environmentally friendly; it’s about running a better business

IV. LEAN GREEN PRODUCTION

It has been thought that industrial performance (cost efficiency) is in a “tradeoff” relation with environmental performance. The only motive or actual pressure for the companies to take action in environmental performance improvement is the regulations and policies. The results of these regulations are the end-of-the-pipe methods to reduce the environmental emission and wastes. (Florida 1996)

There are some empirical and theoretical researches and scholars that have argued to neither sacrificing environmental performances nor cost performances for the other one. In other words they tried to proceed some innovative methods in production and operation management to reduce the environmental emission and cost of

the process at the same time.(Rothenberg et al. 2001; King & Lenox 2001; Helper et al. 2002; Florida 1996; Miller et al. 2010; Mollenkopf et al. 2010)

Florida in his survey research concludes that companies prefer “source reduction, recycling and production process improvement” over the end of the pipe treatment. In overall of his study he provided a conclusion that: “firms and plants that are R&D-intensive and manufacturing innovators possess the capacity to both improve productivity and reduce environmental costs and risks.”(Florida 1996)

In the line with Florida, Helper et al. support this idea and make it clearer by studying some examples of empirical practices and quoted that: “firms were simultaneously able to reduce pollution and increase efficiency by adopting innovations in manufacturing practice (lean manufacturing) and in environmental management (pollution prevention).”(Helper et al. 2002) the issues that are involved in success of lean system in the pollution prevention management are:

- Reducing set-up times
- Less inventories
- Root cause of defects and therefore less scrap

“In sum, these efforts are directed toward preventing the generation of waste in the first place, in ways that actually reduce production cost” (Helper et al. 2002)

The essence of lean production system, the most famous innovative production system, is “to produce more with less”.(Found 2009) This phrase suggests that lean firms use less non renewable resources in the position of raw material and also are more energy saving in their process. “This concept can be extended to determine whether Lean thinking can be applied to producing less pollution and emissions and whether Lean manufacturers are therefore more eco-friendly than traditional manufacturers.” (Found 2009) King and Lenox propose in their study that “lean production is complementary to environmental performance”. They believed that adopting the lean production system will reduce the overall cost of pollution prevention by decreasing the source wasting in the firms. Consequently they assert that “lean is green”. (King & Lenox 2001)

From a systematic point of view to the green lean production, and based on the management system models that we have seen before in this research, now we can think of a cumulative management system model for green lean system. According to the best practices and comparing the two models of management systems for environmental management system and lean management system, and similarities between their business results and waste reduction techniques Bergmiller et. al. has suggested a comprehensive “Lean and Green System Model”. The figure below is his model which is so similar to its parents; lean model and green model.(Bergmiller & McCright 2009b)

Lean / Green Management	Lean / Green Waste Reduction Techniques	Lean Green Business Results
Leadership Empowerment	Vision and Strategy Innovation Partnerships - Alliance Support Functions Process and Product Redesigns	Quality – Cost Delivery Customer Satisfaction Profitability

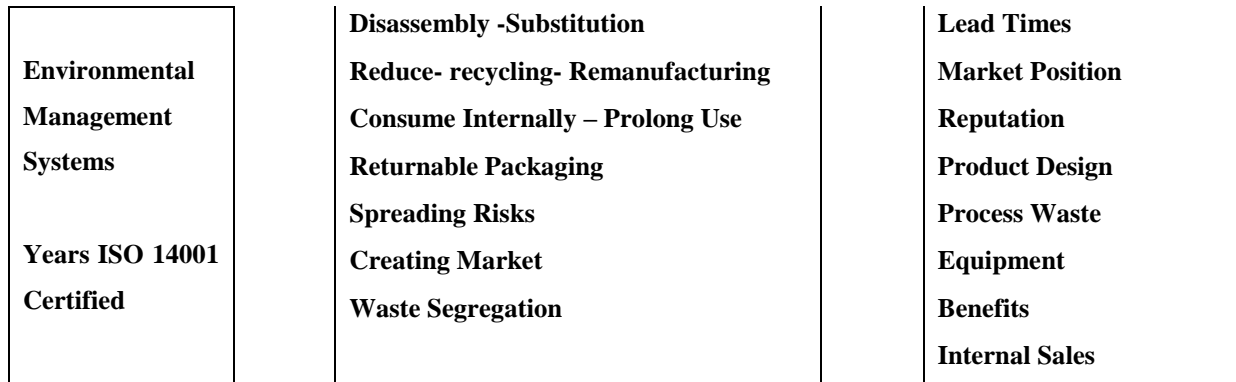


Figure 4 Comprehensive Lean And Green Systems Model (Bergmiller & Mccright 2009)

Overall looking to the literature and researches beside the best practices in green lean, we can conclude that there exist strong similarities between lean system and green system and in fact they seem to go a parallel path through the manufacturing system. (Bergmiller & McCright 2009b) these two systems mainly act complimentary to each other. Some aspects of lean like; inventory minimization, work system and human resource practices can end up with the environmental resource inventory reduction, environmental improvement due to the personnel continues improvement and can make the whole organization and people more amendable for the further environmental training.(Rothenberg et al. 2001) A statistical survey shows that “plants with Lean systems yield higher Green Results”.

It seems that having lean system will act as catalyst to implement environmental best practices. (Bergmiller & McCright 2009a)

However lean and green seem so complimentary to each other but sometimes some conflict may occur. For instance the quality technology which might be used in lean system may not satisfy properly the environmental expectation. (Rothenberg et al. 2001) Or some other aspects such as JIT and one piece flow, while they can reduce the in-process inventory, they may cause over transportation, more packaging and handling which are not so convenient from environmental point of view. (Mollenkopf et al. 2010)

It appears that lean and green combined system is not initiatively considered as win-win situation for plants however these firms can use innovative technology or solution to overcome these conflicts like using reasonable batch size or reusable packages.(Mollenkopf et al. 2010; Rothenberg et al. 2001)

Tools and Techniques to Go Green from Lean

A range of tools and techniques mentioned below can make the path smoother towards Lean and further to Greening the company.

- Draw a Value Stream Map of the material conversion processes or water usage
- Undertake a Mass Balance of all energy and materials into and out of a process
- Conduct a material waste assessment of your organisations
- Develop a Waste Reduction Action Plan (WRAP)
- Assess requirements and prepare for Waste wise accreditation

- Create a Deployment Chart to demonstrate the link between specific improvement initiatives and a Sustainability strategy that links with the other strategic goals of the organisation

V. SIGNIFICANCE OF THE RESEARCH & RESEARCH METHODOLOGY

After doing extensive literature study on Lean, Green, Lean-Green and Lean to Green systems researcher wanted to design a frame work for Indian companies. Lean manufacturing has its advantages and disadvantages when it is studied in context of environmental care and protection. In order to sustain global competition researcher wish to produce in-depth understanding for Indian companies on Green Manufacturing.

- The research will establish Green Manufacturing frame work and bring about its benefits for Industry.
- The research will be focused on factors responsible for Organisation's Environmental Productivity Enhancement. The important factors are sustainable development, cost benefits, resource reduction and manpower, special skill requirement, waste management, working conditions, working environment, hygiene etc.
- The research will be focused on Industry conditions in implementing Green manufacturing and suggest a roadmap for Industries.

5.1 Aims and Objectives of Research

After exploring various dimensions of Green manufacturing researcher proposes following objectives.

- To understand the Employee Productivity in relation to Green Manufacturing.
- Elaborate and explain concept of Green Performance and productivity.
- Understand the green manufacturing application status in manufacturing Industry.
- Establish understanding and application of tools of Green Manufacturing Technique in general to enhance Eco-friendly production.
- To know the reasons for not implementing green manufacturing in manufacturing Industry
- To explore the motive of implementing Green Manufacturing.
- To analyze the cases where Green Manufacturing is implemented and being practiced in Industry fully or partially.
- To analyze critical success factors for green manufacturing Implementation in Manufacturing Industry.
- Evolve green manufacturing framework for Manufacturing Industry.
- To validate the comprehensive roadmap / framework with the case studies.

5.2 Key Areas to Investigate

Companies who are complied with Lean to Green practices shall be investigated and analysed to fulfil following objectives.

Lean to Green

- What is the impact on landfill
- Does the approach affects energy consumption in organisation.
- How much is the reduction on carbon footprint.
- Finding the savings on water consumption
- How much is reduction on landfill waste from per month.

5.3 Proposed Guide For Going Lean And Green (Shall Be Tested And Analysed During Study)

1. Know what Lean and Green really means. It is a process where you use more eco-friendly processes and products that help reduce or eliminate the 7 wastes in Manufacturing processes plus the 8 wastes of Environment.
2. Identify, assess and manage risks to employees, customers, suppliers, contractors, visitors and the environment.
3. Conduct operations in compliance with all relevant legislation & other requirements as a minimum condition.
4. Consult and communicate regularly with employees about Lean Environmental Health & Safety (LEH&S) issues, improvements and about individual responsibilities.
5. Develop improvement strategies and Key Performance Indicators (KPIs) on a continual basis, with appropriate targets, which aim to eliminate unsafe conditions, reduce non-value wastes and prevent environmental pollution.
6. Prepare and provide the necessary resources and investment in time to meet the targets.
7. Continually conduct a Plan-Do-Check-Act (PDCA) review on performance and reassess the goals.
8. Develop procedures, work instructions, and training material to assist the workforce to develop;
 - A Safer place to work
 - Lean Systems to reduce non-value steps
 - Processes that eliminate environmental pollution and energy wastes

5.4 Research Methodology & Design (Plan Of Research)

The purpose of this research is to determine how business functions are affected by 'going Lean to Green'. Firstly, the problem statement and objectives of the research project are provided. A theoretical exposition of what 'Lean to Green' entails and the impact thereof on business functions will be outlined. Thereafter, the research methodology of the study will be highlighted. The research results will be given, followed by the main conclusions and guidelines for businesses to implement green issues within business functions.

1. Collection of data through literature survey, interviews, group discussions, questionnaires, seminars, short term training program, journals, conferences etc.
2. Analysis of data using analytical and statistical tools / software.

3. Establishment of framework for Lean to Green manufacturing with Employee productivity, production functions, Waste reduction and Management, efficiency and quality of the product and employee work life in Industry in India.
 4. Validation of Framework through Problem identification and analysis..
- The research work will be exploratory in nature and shall be corroborated through case studies.

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