

CHAPTER 2

LITERATURE REVIEW

The key to the vast storehouse of published literature may open doors to sources of significant problems and explanatory hypothesis and provide helpful orientation for definition of the problem, background for selection of procedure and comparative data for interpretation of results. In order to be creative and original one must read extensively and critically as a stimulus to thinking.

Charter V. Good (As cited in Singh, 2005, p.83)

Every research begins from where the previous researches have left it, and goes forward, may be one inch or even less, towards finding the solution of a problem or answer to a question. Therefore, for every researcher, it is essential to acquaint himself or herself with what has already been thought of, expressed and done about the problem under investigation. This is possible only if he or she reviews and surveys the various books, journals, newspapers, records, documents, thesis, indexes, abstracts dissertations and other sources of information directly or indirectly connected with the problem of investigation. This chapter deals with the extensive survey of all the available past studies relevant to this field of investigation. Review of literature has been studied under different heads as shown in Figure 2.1.

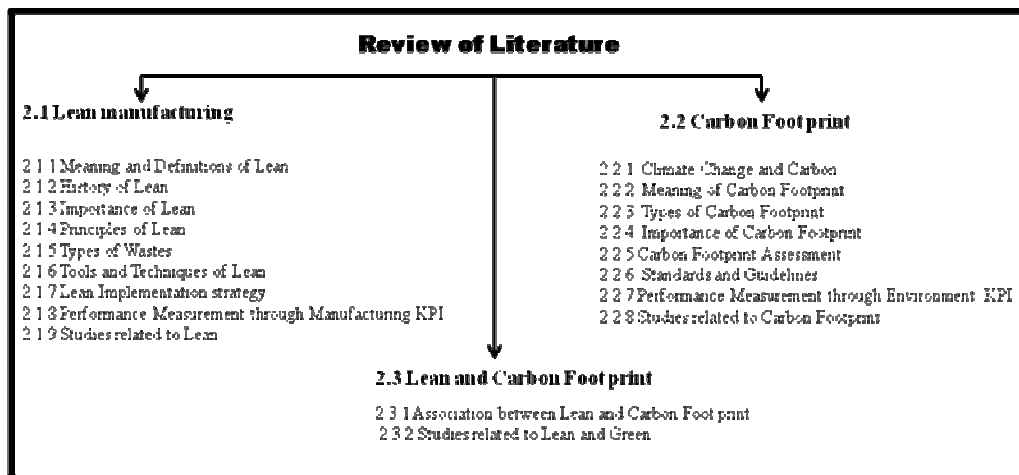


Figure 2.1. Sub-headings of the literature review.

2.1 Lean Manufacturing

2.1.1 Meaning and definitions of lean.

"If you understand only one thing about Lean, it should be that Lean is about removing waste."

Chris Holloway (as cited in "Lean manufacturing quotes," n.d.)

The concept of lean manufacturing was developed by Taiichi Ohno at Toyota Motor Company in the 1950's as "an innovative technique based on the mind and hand philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordism, and adding the glue of teamwork for good measure"(as cited in Fricke, 2010) . Lean manufacturing is an assembly-line manufacturing methodology developed originally for Toyota and for the manufacturing of the automobiles. This business philosophy goes by different names like the Agile manufacturing, Just In Time manufacturing, Synchronous manufacturing, Repetitive manufacturing, Stockless manufacturing, Toyota Production System, World Class manufacturing, and Continuous Flow manufacturing. All the terms are used in parallel with lean manufacturing (Altekar & Burte, 2003; Gaither & Frazier,2004). 'Leané focuses on abolishing or reducing wastes and on maximizing or fully utilizing the activities that add the value from the customer's perspective. There are sets of tools that were developed at Toyota and those can be utilized to eliminate or at least reduce the sources of waste (Saeng – xuto, n.d.).

The dictionary meaning of the word "lean" with reference to a person is "a person who is fat free or a person who does not have extra fat in his body"(Joinwal,2014,p.1). Based on this definition, the emphasis of lean manufacturing is given on the customer and products or services are provided at truly economical rates by streamlining all involved processes, ensuring better coordination among them, ensuring better participation of employees and thereby reducing and eliminating the wastage of all types of resources in the organization (p.40).

Lean system aims at half the human effort in the factory, half the manufacturing space, and half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site,

resulting in many fewer defects, and producing a greater and ever growing variety of products (Womack et al., 1990).

Definitions of lean.

- a) The term “lean” as Womack and Jones (1994) define it denotes a system that utilizes less, in terms of all inputs, to create the same outputs as those created by a traditional mass production system, while contributing increased varieties for the end customers. Lean is to manufacture only what is needed by the customer, when it is needed and in the quantities ordered. The manufacturing of goods is done in a way that minimizes the time taken to deliver the finished goods, the amount of labour required, and the floor-space required, and it is done with the highest quality, and usually, at the low cost(as cited in Abdullah,2003,p.1).
- b) “Researchers of the Lean Aerospace Initiative (Massachusetts Institute of Technology) describes lean as adding value by eliminating waste, being responsive to change, focusing on quality, and enhancing the effectiveness of the workforce”(as cited in Cook & Graser,2001,p.8).
- c) The National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership’s Lean Network offers the following definition of lean manufacturing: “A systematic approach to identifying and eliminating the waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection.”(As cited in (as cited in IFS Research & Development [R&D], 2004, p.4).
- d) Lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including Just in Time, quality systems, work teams, cellular manufacturing, and supplier management in an integrated system. The core thrust of lean production is that these practices can work synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste (Shah & Ward, 2002, p.2).Its aim is “to get the right things to the right place at the right time, the first time, whilst minimizing waste and facilitating change openly.”

- e) Michel Ghouse (2008) describes lean manufacturing as a “production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination” (as cited in Gamage , Piyanka , Jayathilake , Perera, & Gamage, 2012b,p. 437).
- f) According to Wilson(2010,p.59) Lean manufacturing is a manufacturing system that has a focus on quantity control to reduce cost by eliminating waste, is built on a strong foundation of process and product quality, is fully integrated, continually evolving and is perpetuated by a strong healthy culture that is managed consciously, continuously, and consistently. At the heart of lean, is its long-term philosophy of growth by generating value for the customer, society, and the economy with the objectives of reducing costs, improving delivery times, and improving quality through the total elimination of waste.
- g) Aitken (2011,p.2) also gave another philosophical definition of lean-“lean is not merely a business improvement tool, it is a philosophy which needs to be driven from the top team down, if it is to generate required levels of understanding and belief.”
- h) According to Charles Dagher (2009, p. 20), “Lean manufacturing is a holistic – systems approach that creates a culture in which everyone in the organization continuously improves the processes and production.”It is an ultimate system for manufacturers, focusing on timeliness, quality and cost effectiveness.

Almost all the above definitions have associated lean with reduction and elimination of waste by involving the workers to use the tools and techniques in a suitable environment which is leaner, favorable, flexible and more responsive. It lays stress producing high value products only, on customer demand with special emphasis on continuous efforts of improvement in search of perfection. A comprehensive definition that describes the essence of lean manufacturing is as follows:-

“Lean manufacturing is the production of the product for the customers’ maximum daily demand in a balanced sequenced flow process with minimal lead time using only the value-added elements of that process. All non –value added activities such as material handling, changeover, waiting, moving and defects manufacturing are either eliminated or minimized in the lean manufacturing.” (Green, 2000).

Lean manufacturing is visualized as a house where each element plays an important role to the entire structure. The house of lean is a metaphor that was designed by Ohno to fit objectives, strategy, tactics, skills and foundational elements of lean together (Wilson, 2010). This model as visualized in Figure 2.2 gives an idea of which tools can be used for what outcome.

The strong foundation of the house is the constitution of four elements – philosophy, visual management, stability and standardization, implying its importance or presence before any other part of the structure could be made. The first element of lean is its organization's 'philosophy' providing guidance for everyone regarding the direction the organization is taking and the way the organization wants to reach its goals. The second foundational element, 'Visual Management', indicates that everything that is being done within the organization should be visualized so that the current state of any process becomes instantly clear and transparent. Elements 3 and 4 are referred to as 'Heijunka' and 'stability and standardization' stating that processes are made reliable and leveled in both volume and variety, so that inventories are made limited. The two pillars of the house are 'Just in Time (JIT)' production on one side and 'automation with human interaction (Jidoka)' on the other side. Just-in-time production means that only the parts in the quantity needed at a given time are processed, thereby reducing inventory to the minimum as per the need. Autonomation prevents the production of defective parts as the autonomous machines detect defects as they occur through the ongoing inspection and hence stop automatically when non-conformance is detected.

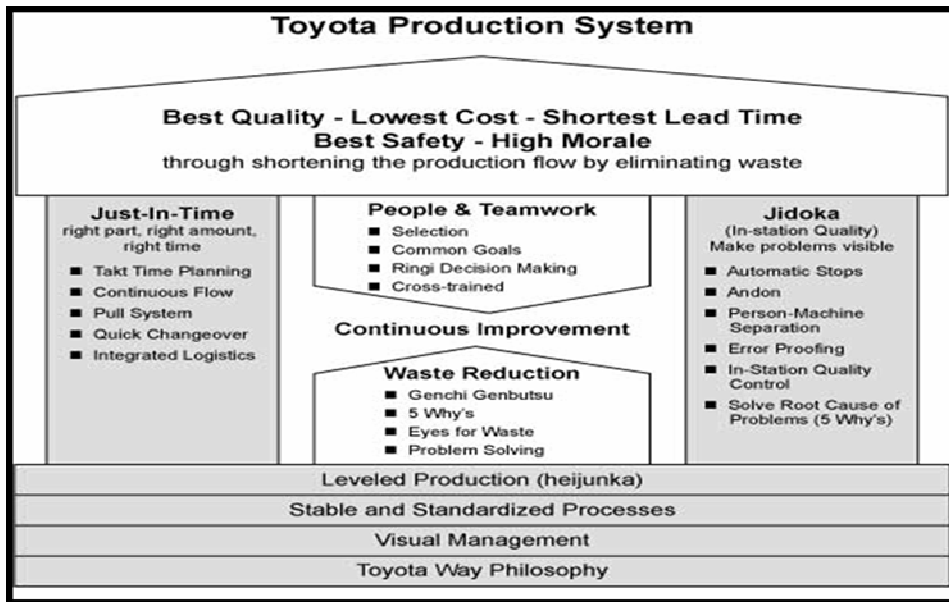


Figure 2.2. House of lean. Adapted from “*The Toyota way.*” by Liker, 2004, p.33.

The heart of the house is the involvement of the workforce, which must be a flexible, motivated team continually seeking improvement and the aim of the reduction of waste within the system. Finally, the overall goal of lean production is represented by the roof of the house, ‘customer focus’, which is to deliver the highest quality to the customer at the lowest cost in the shortest lead-time. High employee morale and safety is important to create a positive working environment, which helps to achieve the company’s goals (Fricke, 2010).

2.1.2 History of lean.

“No new idea springs full-blown from a void. Rather, new ideas emerge from a set of conditions in which old ideas no longer seem to work.”

Womack et al.(1990,p.17)

The Toyota Production System, which is a pursuit of the most efficient production method, traces its roots to Sakichi Toyoda’s automatic loom. It has been evolved through many years of trials and errors to improve. After World War II, Japanese manufacturers were faced with the dilemma of vast shortages of raw material, financial, and human resources. In 1950s, young Toyota Chairman, Eiji Toyoda, paid a visit to Ford’s Rouge plant in Detroit with the aim of finding out what he could learn from the huge vehicle manufacturer to assist Toyota in Japan with its problems (Womack et al., 1990).After the visit, he concluded that mass production is

not a solution for Japan as Japanese manufacturers were faced with different problems as compared to those of their western counterparts. The problems were the demand of full range and sizes of vehicles by the small domestic market, new labour laws restricting the rights of management to lay off workers and reinforcing the bargaining power of company unions, unavailability of guest labour even at high pay, to work in substandard conditions, shortage of capital and foreign exchange after the war and high unaffordable massive machines with the latest technology.

Toyota Motor Company (TMC), led by its president, Eiji Toyoda recognized that the American automakers of that era were out-producing their Japanese counterpart, in the mid 1940s. Together with his engineers- Shigeo Shingo and Taiichi Ohno, Eiji built a system whose objective was to minimize consumption of those resources that did not add value to the finished product. Firstly, Ohno grouped workers into a team led by a team leader and allowed the team to decide how best to perform all activities to complete an assembly on their part of the production line. Secondly, Ohno empowered each team member to stop the production line when a problem was discovered to allow the team to fix the problem immediately. The idea behind this philosophy was to fix a problem so that it would not occur again. Ohno realized that it will be necessary for the suppliers to start using the same lean production system to maintain single-piece flow in the factory. Toyota achieves this by creating closer relationships with fewer suppliers to ensure a steady stream of quality supplies. Suppliers that had met the quality standards could have their goods brought directly to the production line without it being counted or inspected (Womack et al., 1990).

The automatic loom invented by Sakichi Toyoda not only automated the work that used to be performed manually, but also built the capability to make judgments into the machine itself. By eliminating both defective products and the associated wasteful practices, Sakichi succeeded in tremendously improving both productivity and work efficiency. This system became known as the Toyota Production System (TPS), which laid the foundation of today's lean manufacturing. It took Ohno almost 30 years to perfect the system and drive it through Toyota Motor Company. During the 1960s and 1970s, the system was spread to suppliers and later to other industries in Japan. Many Japanese companies gained strategic advantages over their American counterparts through the use of lean manufacturing techniques (Saeng – xuto, n.d.).

In the late 1980s the term “Lean Production” was introduced in a book titled “The Machine That Changed the World” written by Womack, Jones & Roos (1990). The term ‘Lean’ was coined by International Motor Vehicle Program(IMVP) researcher John Krafcik as it used less of everything compared with mass production that is half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it required keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products (Womack et al., 1990). This book awoke the US manufacturers from their sleep as it underscored the great success of Toyota at New United Motor Manufacturing Inc. (NUMMI) and brought out the huge gap that existed between the Japanese and Western automotive industry.

Today, Toyota is considered one of the most efficient manufacturing companies in the world and this company that sets the standard for best practices in lean manufacturing. Presently, lean manufacturing has increasingly been applied by leading manufacturing companies throughout the world as these companies try to find ways to compete more effectively against competition from Asia.

2.1.3 Principles of lean.

“Our business practices and activities based on the core principle created values, beliefs and business methods that over the years have become a source of competitive advantage.”

Fujio Cho (as cited in Liker, 2004,p.35)

There are many principles, ideas and tools that are being used to make up lean manufacturing system, and all of which have the same ultimate goal of eliminating waste and non-value added activities at every production or service process in order to bring the most satisfaction to the customer. In the book “The Machine that Changed the World” (Womack et al., 1990), five lean principles were given which literally meant life or death for a company. These principles were renewed in the book Lean Thinking (Womack & Jones, 1996), emphasising on many different ways in which a manufacturing unit can become more efficient by working smarter and not harder. As

these principles are fundamentally customer value driven, they are suitable for application in any of the manufacturing environments.

These five Lean principles are described as follows:

Principle 1. Accurately specify the value of the products or services.

Value of the product must be specified according to the customer in terms of a customer requirement of a specific product, price, place and time, it is as simple as the old expression “give the customer what they want” and not what is convenient for the manufactures.

Principle 2. Identify the value stream for each product or service and remove wasted actions.

Each and every step in the entire process of making a product is specified very clearly without any ambiguity so that the unnecessary steps and other forms of waste are continuously identified and reduced.

Principle 3. Make the product or service value flow without interruptions.

Components of the final product must flow smoothly through the plant, starting from one station to other stations without waiting of time in between, hence creating a smooth one piece flow.

Principle 4. Let customers pull products or services from the producer.

Production of the product must be tied to the demand; no products are manufactured until downstream demand for it occurs. The idea with lean is to push this point as long upstream in the product making process as possible, wait for a demand and then make the product fast and with high quality. So, if the delivered products have any defect, only a small batch of products get affected (Andersson, 2007).

Principle 5. Pursue perfection and continuously improve.

The last principle seems more possible after the other 4 principles .Manufacturing units must always strive for improving their efficiencies, cutting costs, and improve the quality of their products. Transparency must be created in a

lean system where it becomes easier to discover better ways at doing the daily things in order to create value for the customer (Womack & Jones, 1996).

These five lean principles work together and are the fundamental to the elimination of waste. These principles are also accepted by such organizations which require complete transformation and successful lean implementation in their current business system.

Another set of fourteen principles were identified by Jeffrey K. Liker (2004) of the Toyota while studying Toyota Manufacturing Company for 20 years. All these principles were categorized into four sections and all are beginning with letter 'P' namely philosophy, process, people and partners and hence it's called the '4P model of the Toyota Way'. The 4P model is shown in Figure 2.3.

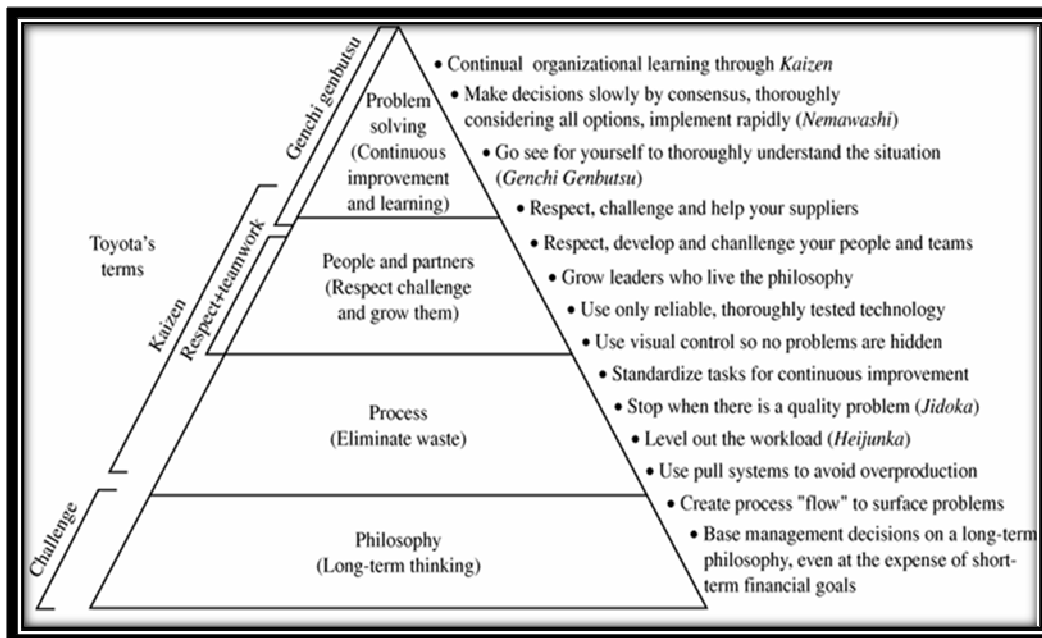


Figure 2.3. 4P model of the Toyota way. Adapted from "The Toyota way," by Liker, 2004, p.6.

Most of the five Lean principles coined by Womack and Jones (1996) are found in Liker's second category of Processes. Most of the manufacturing companies in their journey to be lean, successfully implement the principles of the right processes to achieve flow throughout their processes and pull systems to avoid overproduction. But to become lean, specific way of thinking is required, and without adopting all 4P's, the sustainable development is not possible. Most of the

manufacturing units just concentrate on only one level that is the process level, hence lag behind those companies that adopt culture of continuous improvement. Principles of lean production can be applied equally in every industry across the globe and the conversion to lean production has a profound effect on the human society, truly changing the world (Womack et al.,1990). Importance of following all 14 principles for the complete lean success can be judged by words of Fujio Cho , President of Toyota Motor Company ,“The Key to the Toyota Way and what makes Toyota stand out is not any of the individual elements.....But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner –not in spurts” (Liker 2004, p.xv) .

2.1.4 Importance and benefits of lean.

“To curd the competition in the fast moving world it has become very important to focus on Operational Evolvment. “Evolve” the way we look at products, process, people and technology.”

Amit Gugnani (2011,p.72)

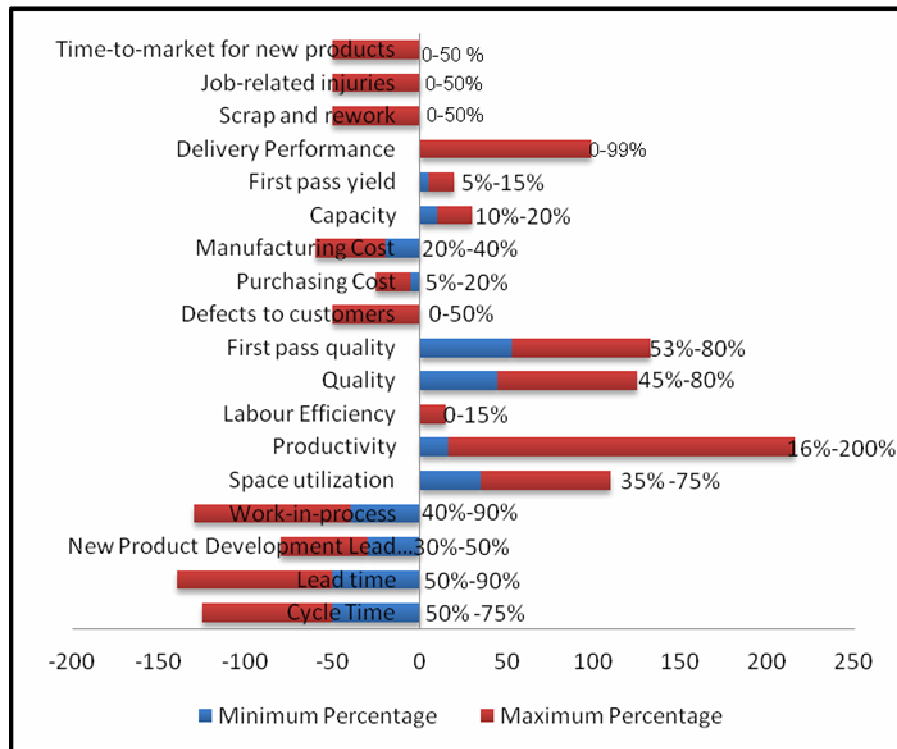
‘Lean’ has been a hot topic in management science in the second decade of the 21st century and continues to remain so. Garment manufacturers of developing countries are now a days facing an intensive global competition as the developed countries are on the lookout for new sourcing countries except China. This search offers a wide opportunity for the third world countries to compete and gain business. The key to compete in the international market place is to simultaneously bring about innovative products and improve both the quality and the productivity on continual basis. But, as most of the Indian garment industries are small scale and traditional in their operations, they face problems like low productivity, longer production lead time, high rework and rejection, poor line balancing, low flexibility of style changeover, labour issues, and price pressures (Nayas,2012). Moreover, due to short span of apparel style, uniqueness of each product development and technology, it has become more crucial to perform better as well as fast to compete.

Various modern management philosophies are available which can provide the competitive advantage to its followers in a free market system by addressing these

issues. Lean manufacturing is one such philosophy of continuous development, which makes the competition viewed as co-existent, leading to soaring of profits and helping turn the expansion plans into a reality. It is also appropriate for the garment industry where there is a strategic priority to shorten the production cycle time to the absolute minimum as a source of competitive advantage. All manufacturing processes are driven by three controls-cost, quality and delivery and the garment manufacturing industry is no exception to it. Implementation of lean tools like Cellular Manufacturing, Single Piece Flow, Work Standardization, and Just in Time production in the unit can add more value to all its products and processes boiling down to optimization of the cycle time, greater product variety and quality and the most economical output.

Lean manufacturing is about “delivering the extra-ordinary, through ordinary resources by building the extra-ordinary processes”. The processes are built on the guidelines of reduction of waste and losses and potentially acting as a powerful tool for competitive coexistence. Lean can deliver huge benefits to any business by following the proven path. Lean production raises the threshold of acceptable quality to a level that mass production cannot easily match. It offers ever-expanding product variety and rapid responses to changing consumer tastes. It lowers the amount of high-wage effort needed to produce a product, and it keeps reducing it through continuous incremental improvement.

Sizeable portion of the literature supported the benefits of lean through the empirical research are available as an evidence. Different percentage variations are found in operational improvements throughout the manufacturing units after the Lean adoption, such as, reduction in lead time (cycle time), work-in-process, inventory, product complexity, raw materials ,changeover times and space utilization, increase in productivity and improvement in quality diagrammatically demonstrated in Figure 2.4 (Buker, Inc., n.d. ;Farhana & Amir,2009b; Gomes, 2012; Hallam,2003; IFS R&D, 2004 ; Kumar & Sampath ,2012c ; Yamashita,2004)



*Figure 2.4.*Percentage improvements after lean adoption. Adapted from Buker,n.d.; Farhana & Amir,2009b ; Gomes, 2012;Hallam,2003;IFS R&D , 2004; Kumar & Sampath ,2012a ;Yamashita,2004.

Effective implementation of the lean management leads to improved customer response levels, reduction in paperwork, staff turnover and documentation and streamlining of processing steps (Aitken, 2011;IFS R&D, 2004). One improvement always stimulates a better change in some other areas. This leads to a huge change in the organization, even in the areas where one has not intended to have an improvement with the action he or she took. Therefore the synergy effect is a very important advantage in the lean manufacturing. Figure 2.5 shows the various benefits of lean adoption.

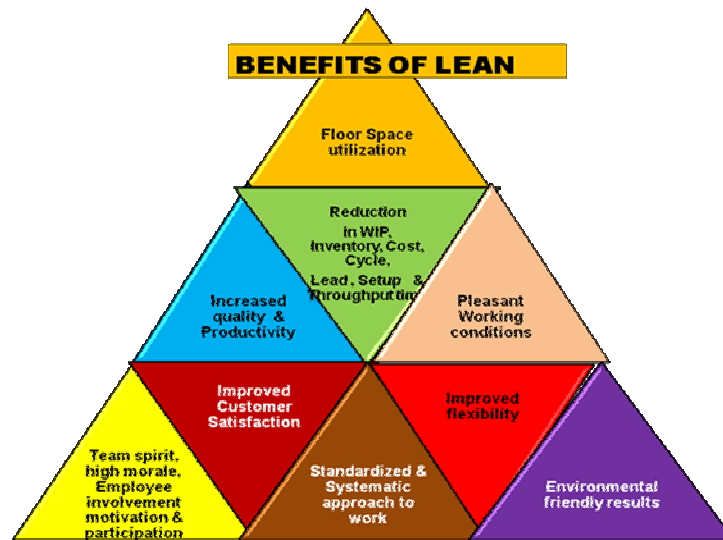


Figure 2.5. Benefits of lean. Adapted from “Lean manufacturing – The way to manufacturing excellence,” by Technopak, 2011, *Outlook*, December, p.12.

The benefits of implementing lean can be divided into three broad categories; Operational, Administrative and Strategic Improvements as follows:-

a) Operational improvements.

- i. *Reduction of defects and wastage.* Reduction of defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, and costs associated with reprocessing defective items, and unnecessary product can be achieved. It will further lead to happier customers care and a stronger reputation of the unit.
- ii. *Cycle times.* Reduced manufacturing lead times and production cycle times can be achieved by the lean implementation. It further reduces the waiting times between processing stages, as well as process preparation times and product conversion times.
- iii. *Inventory levels.* Minimized inventory levels at all stages of production, particularly works in progress between production stages is possible. It lowers the working capital requirements.
- iv. *Labour productivity.* Improved labour productivity can be achieved both by reducing the idle and work time of the workers and using their efforts as

productively as possible. Elimination of unnecessary tasks or unnecessary motions helps the unit in the enhancement of productivity.

- v. *Flexibility*. It enhances the ability of the manufacturing unit to produce a more flexible range of products with minimum changeover costs and changeover time.
- vi. *Output*. Increased labour productivity, elimination of bottlenecks and machine downtime can lead to high output from the existing facilities.
- vii. *Utilization of floor space*. Equipment and manufacturing space can be used more efficiently by eliminating the bottlenecks and maximizing the rate of production through the existing equipment, while minimizing the machine downtime. Lean manufacturing can often lead to the floor space reduction from 35-50%. This additional area saved can be used to expand the business and may even eliminate the need for a plant expansion (Epply & Nagengast, 2008; Karekatti, 2013a).
- viii. *Reduces cost*. Cost reductions of goods can be achieved by labor productivity savings, reduced total material expenditures and comprehensive elimination of unnecessary costs such as premium freight, overtime expense; rework labor and material scrap costs. Interest expenses can also be reduced through increased inventory turnover (Ana, 2008). With the money saved, manufacturing units can reinvest to grow its business, reduce their debt if any, and add to the bottom line profits. Lean implementation will provide larger returns on the investment in the manufacturing of their products.

b) Administrative improvements.

- i. Reduction in order processing errors.
- ii. Streamlining of customer service functions so that customers are no longer placed on hold.
- iii. Reduction of paperwork in office areas.

- iv. Reduced staffing demands, allowing the same number of office staff to handle larger numbers of orders.
- v. Documentation and streamlining of processing steps which enables the outsourcing of non-critical functions, allowing the company to focus their efforts on the customers' needs.
- vi. Reduction of turnover and the reducing attrition costs.
- vii. The implementation of job standards and pre-employment profiling ensures the hiring of only "above average" performers – envision the benefit to the organization if, everyone performs as well as the top by 20 %!(Kilpatrick, 2003).

c) Strategic improvements.

- i. *Full Capacity production.* Increased utilization of space, time, personnel, plant and equipment assets doesn't allow any wastage (Ana, 2008; Venita & Oberholster, n.d.).
- ii. *Culture of continuous improvement.* It creates a robust inter-dependent support system for all components of operations, and imparts a better control over day to day activities.
- iii. *Increased Sales.* Sales can dramatically increase due to the notorious word-of-mouth marketing, further leading to a higher percentage of sales from new customers along with the loyalty from existing customers.
- iv. *Happier Work Force.* The employees become happier with their jobs and a productive workforce get formed which enables to identify and eliminate wastes, produce quality products and solve problems (Venita & Oberholster,n.d.).
- v. *Promotes environment friendly practices.*
- vi. *Implements socially answerable techniques.*
- vii. *Improvement of the communication* and cooperation between management and employees.

- viii. *Closer customer relationships.*
- ix. *Robust product lines.*
- x. *More efficient new product development processes.*
- xi. *Increased market share.*
- xii. *Improving cash flow* (Kilpatrick, 2003; Kovacheva, 2010; Nayas, 2012).

Lean is not just production methodology, nor, is it just a mere strategy, but it is a long term philosophy which needs to be embedded in the organization with the belief that men have to do everything. It is more of a working culture and without the active involvement of the workers and management; no Lean program can be successfully implemented. Hence, transformation of the manufacturing facility to 'lean structure' brings about integration of people, process and technology to build a successful future.

2.1.5 Wastes.

“Waste is anything other than the minimum amount of equipment, materials, parts, space, and worker’s time which are absolutely essential to add value to the product.”

Taiichi Ohno (as cited in “Stimulation and the Lean Enterprise,”n.d.)

The organization’s success is dependent on the integrated working of men, method, material and machine at the worksite. Wastes are prevalent all over the organization, but as one lives with it or works around it, it gets hidden. Lean identifies series of wasteful activities in the processes and adds value to them by the thorough and continuous elimination of waste. Value is said to be added, when the product is physically changed towards what the customer is intending to purchase. It is added, when a service is provided for which the customer is willing to pay. Monden(1993) classifies activities in garment production into following three types.

a) *Non-value adding (NVA).*

These are pure wastes and involve unnecessary actions which should be eliminated completely as they are invisible to the customer. The customer is

not willing to pay for them. For example-waiting time, double handling and so forth.

b) ***Necessary but non-value adding (NNVA).***

These activities may be wasteful but are necessary under the current operating procedures, hence, are called ‘incidental waste’. The customer does not find value in these activities and does not want to pay for them but still these are required due to the process limitations, current technology and government regulations. For example-walking long distances to pick up parts, unpacking deliveries and transferring a tool from one hand to another, quality check and so forth.

c) ***Value adding (VA).***

These activities transform the nature, shape or characteristics of an information or product in line with the customer requirements. Customer values these activities, are willing to pay for it and they will know, if this activity is removed. For example- joining parts of collar, embroidering garment and so forth.

In order to add the value to the product, value added activities are retained, non-value added are eliminated and required non -value added are trimmed as shown in Figure 2.6.

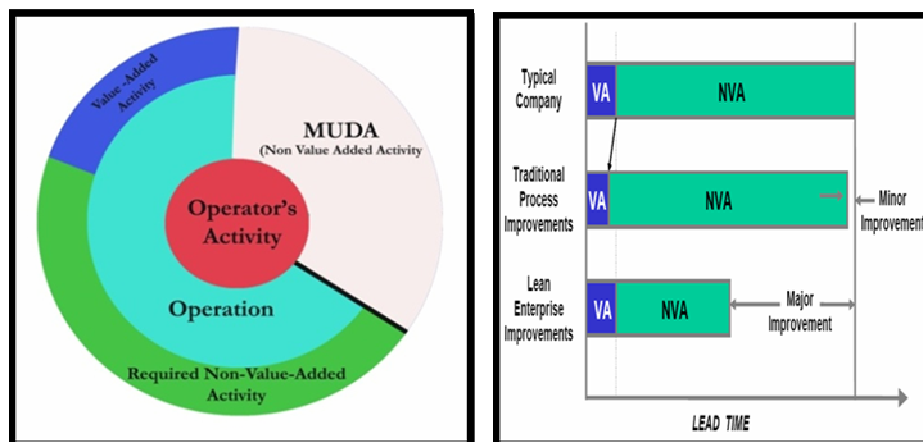


Figure 2.6. Types of activities and delivery of value to your customer. Adapted from “Toyota production system and lean management,” by PTU’s Gian Jyoti School of TQM & Entrepreneurship, 2010, p.32.

There are three forms of waste at work namely Muri, Mura and Muda. These words are interconnected and are often used together and referred to as the three M's in Japan. Mura means ‘unevenness’, and Muri means ‘overburden’ or “excess” and Muda means ‘waste’ as shown in Figure 2.7 (Schonberger,1982). Relationship between these three types of wastes is depicted in Figure 2.8.

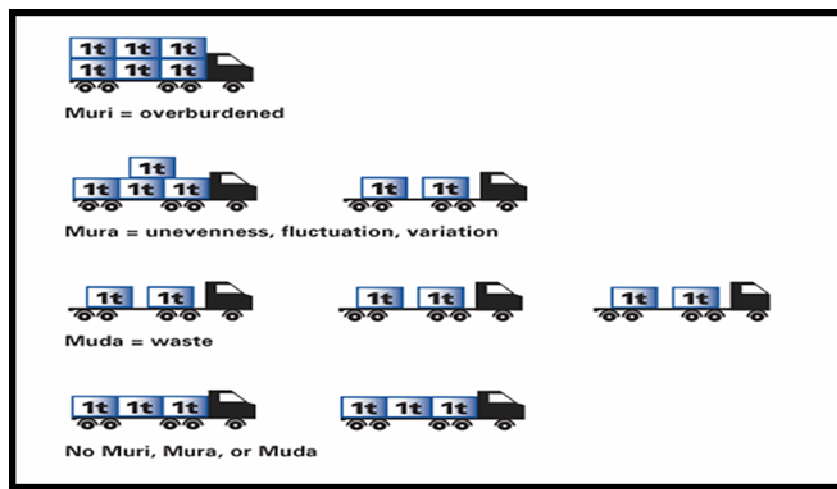


Figure 2.7. Mura, Muda and Muri. Adapted from “Glossario-Muda-Muri-Mura,” (2010).

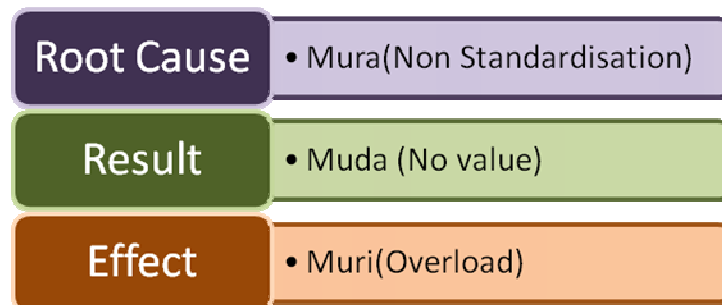


Figure 2.8. Relationship between Muri, Mura and Muda.

a) Muri. The term ‘Muri’ in Japanese stands for excessive or overburdening of the people, facilities and equipment which has a direct impact on the employee’s morale in a negative manner. It includes bad working conditions and pushing a

machine or a person beyond its natural limits, leading to work stress. When the employee is forced to take too many decisions during the times of stress, it too ends up being a waste of fruitful labour such as carrying heavy weights, operating computerized knitting machine without the safety cover in order to work significantly faster than usual and so forth.

- b) **Mura.** The term 'Mura' in Japanese stands for unevenness, irregularity, variation and inconsistency in terms of quality and the volume in the operation of a process in the production system. It is not caused by the end customers, but caused by up and down in the demand or irregular production schedule or fluctuating production problems. As it involves uneven production, it becomes necessary to have extra material, equipment, and operation on hand in anticipation of the highest demand, even though the average demand might be much less.
- c) **Muda.** It is a Japanese word meaning futility, uselessness, idleness, superfluity, wastage and so forth. It is a non-value added activity from customer's point of view. It is the most familiar 'M' which includes waste of time, consumable resource and dissatisfaction or incomplete satisfaction. Waste occurs when more resources are consumed than are necessary to produce the goods or provide a service that the customer actually wants. Nine types of wastes are shown in Figure 2.9 and explained below.

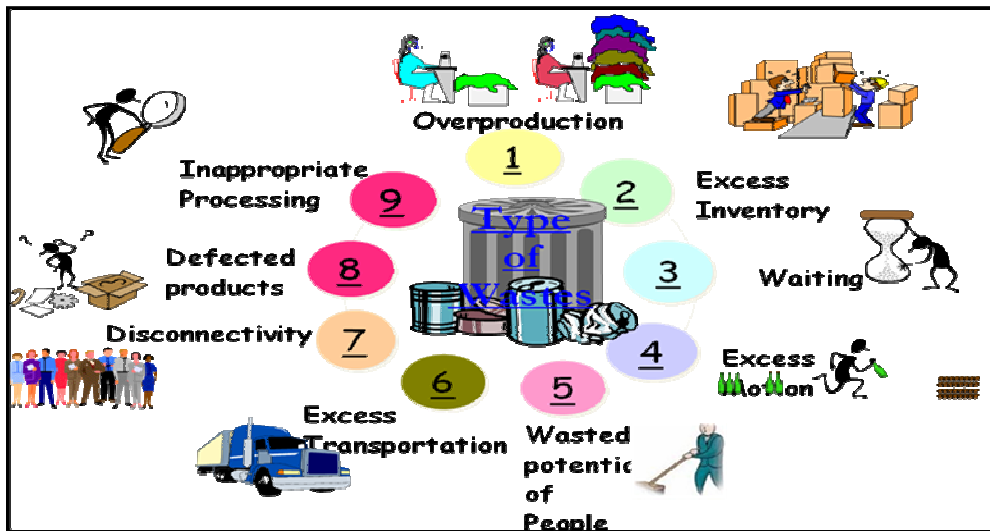


Figure 2.9. Nine types of wastes.

- i. *Overproduction*. It is referred to as the ‘just in case’ meaning producing more than the buyer’s demand or production in anticipation, rather than the actual demand. It occurs due to the production of garment before it is actually required, of which there are no orders or when rate of production is faster than consumption at a given point of time. It is regarded as the most serious, worst and fundamental waste, as; it not only leads to other wastes but also discourages a smooth flow of goods or services inhibiting quality and productivity.
- ii. *Excess inventory*. It is called a mismatch between demand and supply. Waste of inventory requires extra space for storage; time and effort; capital locked in purchased materials and material used between processes; extensive rework; damaged, obsolete and unfit inventory; larger material handling systems to move larger quantities of goods, and increase in lead time for delivery (Hines & Rich, 1997). Importance of reducing inventory is shown in Figure 2.10, where with high water level (excess inventory), the rocks (problems of production imbalances, redundancies, defects, paperwork, equipment downtime and long setup times) are hidden and management assumes everything is fine ,but, when the water level is forced down, all problems are exposed (Gomes, 2012;Johnson,n.d.). Michael Hammer (2000) describes inventory as a substitute for information: you buy them because you are not sure of the reliability of your supplier or the demand from your customer(as cited in Macmahon,2010).

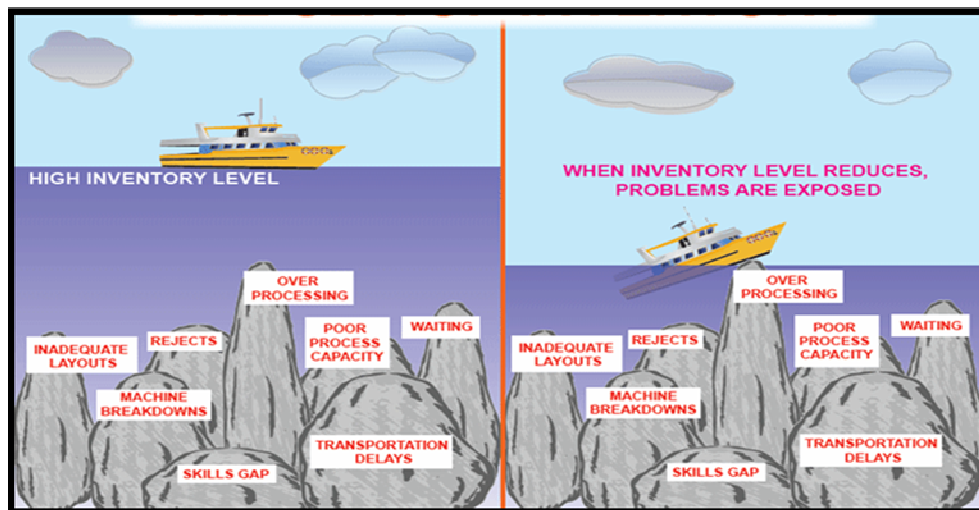


Figure 2.10. Sea of inventory. Adapted from “Sea of inventory,” n.d.

iii. *Waiting*. Queuing for anything is a waste. When the time is being used ineffectively and the goods are not moving or being worked on, then the waste of waiting occurs (Hines & Rich, 1997). In a apparel industry, waiting takes place in a number of forms as :-

- Operators waiting for material to arrive so they can work.
- Machines waiting for work, and also for operators to load and unload work pieces or other production material.
- Waiting for information from a number of sources that is supervisor, scheduling and designs.
- Waiting for equipment to complete cycle as in computerized machines.
- Waiting for inspection before performing next operation.
- Fabric waiting to be cut.
- Work in progress within cutting, sewing, finishing sections waiting to be processed either due to capacity shortfall or non receipt of trims and accessories.

iv. *Waste of excess motion*. It involves the unnecessary movements in production where the operators have to stretch, bend and pick up, and extra “busy” movements while waiting when these actions could be avoided. Such waste is tiring for the employees and is likely to lead to poor productivity and, often, to quality problems (Hines & Rich, 1997). Causes for this type of waste are faulty equipment and plant layout, lack of 5 S’s, lack of visual controls, inconsistent work methods, large batch sizes and so forth. Motion is a waste associated with both operators and equipment as follows:-

- Operator’s wasted motion includes bending, walking to get or place parts, lifting, and taking more than one step to reach or view machine interfaces.
- Equipment’s wasted motion includes long strokes, “air cut”, and other non-productive movements of machine parts.

- v. *Excess transportation.* This includes moving materials, parts, or finished goods between processes or into or out of storage. It leads to double handling, deterioration in quality, delay in communication between processes and poor quality feedback reports further delays corrective action (Hines & Rich, 1997).
- vi. *Rework.* Product defects occur when the work pieces are reprocessed or repaired due to the incapable processes, excessive variation, incapable suppliers, management decisions, insufficient training, inadequate tools or equipment, poor layouts, unnecessary handling and high inventory levels. In mass production, defects are rarely visible as they get hidden below the inventory while in continuous flow, the defects destroys the balance resulting even in a missed shipment. Consequences of product defects are additional labour, extra floor space, tools, equipment, effort, time, material, missed shipments or deliveries, lower profits and money to disassemble and reassemble defective product (Tecknopak, 2011). It becomes serious when the defective garment reaches the customer and it results in extra warranty costs, customer dissatisfaction and may also result in the loss of future business and market share (Islam, Khan, & Khan, 2013c).
- vii. *Inappropriate processing.* It is termed as ‘using a sledgehammer to crack a nut’ (Ana, 2008). It means over processing, incorrect processing and inefficient processing. Causes of this type of waste are decision making at inappropriate levels, inefficient policies and procedure, lack of customer input concerning requirements and use of expensive, large, inflexible machine , high precision equipments instead of several, small, flexible, simpler tools(Ana,2008; Hines & Rich, 1997). The two aspects of inappropriate processing are:
- Overdoing in the sense of doing too much, too soon, and beyond what is necessary. For example- reports and presentations with more information, products designed with more features than the customer needs etc.
 - Using inappropriate equipment, especially equipment that is much larger, faster, or more complicated than required. For example- Trouser or Denim pocket facing attach operation, which can be done by one machine cover stitch

machine but is planned with one over lock and one lockstitch. This adds cost to the garment without adding the value.

- viii. *Wasting potential of people.* “Our people are our greatest asset”, this proverb is true when employees develop enough understanding about value added , not - value added and then draw on their experience and creativity to find the solutions .But when people’s mental, creative, and physical abilities are not used, waste of potential of people occurs.
- ix. *Waste of disconnectivity.* This refers to waste stemming from administrative disconnection within the unit, and, between a unit and its suppliers creating barriers to creativity, innovation and knowledge sharing, when different departments of apparel unit work on their own without being connected or considering each other’s demand. For example-cutting department is cutting fabric irrespective of sewing department’s requirements hence high inventory is collected before sewing area.
- x. *Waste of excessive energy consumption.* The tenth waste is the latest inclusion in the list of wastes as it has become more and more important to rationalize the consumption of energy and energy costs to give greatest advantages for the consumer and the environment. It may be due to the use of electricity when not required, release of extra steam from boiler, and use of old inefficient machines. Hence, overutilization as well as under utilization both creates wastes.

The Toyota philosophy says that defects should be regarded as opportunities to improve rather than something to be traded off against what is ultimately poor management. In the words of Mitsuo Kinoshita, Toyota Ex. Vice President, “If we only try to achieve the results and the objectives, then results and objectives would not be sustainable. If we focus on results, we will never change, but if we focus on change, we will get the results.” (Muscat, 2008).

2.1.6. Tools and techniques of lean.

"Many people think that Lean is about cutting heads, reducing the work force or cutting inventory. Lean is really a growth strategy. It is about gaining market share and being prepared to enter in or create new markets."

Ernie Smith (as cited in "What is Lean?,"n.d.)

Lean has a set of lean 'tools' and techniques that assist in the identification and steady elimination of waste (Muda), the improvement of quality and reduction in production time and costs. The perfect lean factory represents a state of continuous flow that requires these TPS tools to operate effectively. Tools like continuous process improvement (Kaizen), the '5 Whys' and mistake proofing (poka-yoke) helps to solve the problem of waste while Kanban and Heijunka techniques are used to implementing the 'flow' or smoothness of work(IFS R&D,2004). It focuses on creating a continual improvement of culture that engages the employees in reducing the intensity of time, materials and capital necessary for meeting customer's need (Farhana & Amir, 2009a).Lean tools and techniques are given in Table 2.1.

Table 2.1

Overview of Lean Tools and Techniques

S.NO.	LEAN TOOLS AND TECHNIQUES	DESCRIPTION
1.	5S	Workplace organization and management.
2.	Visual Management(VM)	Visual Control for exceptional management.
3.	Andon	Warn of pending problems in the system.
4.	Kaizen	Continuous improvement.
5.	Kanban & Pull System	Trigger mechanism for flow and pull.
6.	Value Stream Mapping(VSM)	Optimizing Value added works.
7.	Poka Yoke	Mistake Proofing.
8.	Heijunka	Workflow levelling by volume & variety.
9.	One Piece Flow/Just In Time(JIT)	Single piece flow as per takt time
10.	Takt Time	Rate of customer demand.
11.	Total Productive Maintenance(TPM)	Preventive, predictive & autonomous.
12.	Cellular manufacturing	Group of workstations, machines & equipment efficiently arranged with people being central.
13.	Single Minute Exchange of Dies(SMED)	Quick changeover & setup reduction.
14.	Team Work & Workforce Empowerment	Working together as team, and using their knowledge to solve problems.
15.	Problem Solving Techniques	Root cause analysis through ishikawa ,5 whys and so forth.
16.	Standard Operating Procedure(SOP)	Use of stable, repeatable methods.
17.	Jidoka	Problems identified and eliminated at the source.

Note. Adapted from Bannari & Dhanakodi(2010);Hallam(2003); and Mekong Capital(2004).

Lean tools and techniques are considered important for the successful implementation of the lean system in the apparel manufacturing unit. There are 33 lean practices which are described in detail below, grouped in seven bundles as per the similarity in their purpose and objectives:-

a) Leadership and culture.

Leadership and culture is based on Lean business strategy, Management support and Culture.

i. Lean business strategy.

"Lean has got to be a strategy for GROWTH."

William (Bill) Parr (as cited in "Lean manufacturing quotes," n.d.)

Formal lean strategy is an important element of the lean transformation. It also includes proper implementation based on the real data on profits, volume and competitive advantage. It defines the cost reduction and help in realizing long term goals in terms of profits at market based competitive selling price. Lean organizational effectiveness is related to the goals of the company. These strategic goals for any organization could be delivery on time, price, profit, quality and cost. Meaning of developing a business strategy is rightly summed by Kenneth E. Kirby, "What are my core competencies and What do I hope to achieve by undergoing the change." as ("Lean manufacturing quotes," n.d.).

ii. Management support.

"...Management must awaken to the challenge, must learn their responsibilities, and take on leadership for change. . . ."

Cully, W.C. (1998, p.11)

In a lean setup, top management is not be just a manager but it also takes on the task of guiding, inspiring and motivating people. While carrying out transformation in the organization, top management demonstrates himself and sets his own example in action of the desirable value which is expected from the employees

at all level (Chary, 2007). Commitment of management improves the bottom line (Epply & Nagengast, 2008). Management understands the lean concepts, fosters a lean environment and participates in all the improvement activities in an organization. Acknowledgement of top management to the fact that lean manufacturing is a long term philosophy and provides the desired goals is of utmost important. Firm demonstration of seriousness to embed lean thinking in the culture whenever newness of the lean gimmick dies down, truly leads to the continuous development in the manufacturing unit (Kachru, 2007).

iii. Culture.

“...the lean approach percolates into ever wider circles of operations; it ceases to be about best practice and starts to become a part of the fabric of doing business.”

Corbett (2007,p.96)

Cultural change is the base of the lean, where the good true lean leaders can be developed who reinforces and leads the cultural change. Active improvement of manufacturing unit's core value streams, supported by committed leaders ultimately reinforces cultural change within the whole unit (Liker, 2004). The TPS view of culture is like an iceberg. The people look at its surface which shows the surface features like Kanban, high employee suggestion rates, clean floors, lot of charts and visuals, cells and teams. But, below the surface, there is cultural change which is only attained by continuous participation of people in improvements and elimination of wastes.

Lean culture is described in three ways. First is, involving the people to 'perceive, think and feel' in relation to problems. "Genchi Genbutsu" which means recognizing the waste and systematic decision making forms the basis of lean. Secondly, lean is invented, discovered and developed so that it becomes part of the culture of an organization. Thirdly, lean thinking is to be taught to the new workers through action in day-to-day work, where, leaders model the way. Organizations continuously adapt its culture to local conditions. So, it becomes part of their way. In order to bring about cultural change, it is important to create an environment for change through continuous trainings throughout the year. Job security should be provided so that employees fear could be removed that with the improvements, fewer

people will be needed. Trust should be built between the management and the workers (PTU's Gian Jyoti School of TQM & Entrepreneurship, 2010).

b) Employee orientation.

Until senior management gets their ego out of the way and goes to the whole team and leads them all together.... Senior management will continue to miss out on the brain power and extra ordinary capabilities of the employees. At Toyota, we simply place the highest value on our team members and do the best we can to listen to them and incorporate their ideas into the planning process.

Alex Warren (as cited in Liker, 2004, p.171)

Lean has a strong human resources management component as it fully utilizes the creative talents of employees, suppliers, sub-contractors, and others who contribute to the company's improvement (Dilworth, 1992). Employees orientation consists of the following 6 elements :-

- i. *Employee awareness.* All the employees are made aware of the need of throwing out the old system and adopting a new one.
- ii. *Team work.* It is a group effort where all operations of one garment are done by a small group of multi-skilled operators, where, benefits of division of labour and special machinery and infrastructure are optimally utilized (Jana, 2010). Here the team work becomes a management style and permanent attitude in the lean environment, so that, each person works together to improve the company. They are encouraged to think about ways to improve methods and give suggestions which are further quickly considered and if worth gets implemented (Dilworth, 1992). Deming describes it as "Break down barriers between departments (as cited in Neave, 1987). People in research, design, sales, and the production must work as a team to foresee the problems of production and while in use that may be encountered with the product or service." The 'no blame concept' is promoted with the belief that no one comes to work with the intention of deliberately doing a poor quality job.
- iii. *Communication among employees.* All the employees have a two way communication within themselves as well as with the management. Everyone is

motivated enough to help others, when a problem occurs as they are aligned towards the same goal of continuous improvement. Employees can present their innovative ideas before the management without fear and the management should also implement it, if, it is worth. It is rightly quoted by Deming “Encourage effective two-way communication and other means to drive out fear throughout the organization so that everybody may work effectively and more productively for the company” (Stanleigh, n.d., para 8).

- iv. *Commitment of employees.* All the employees are totally committed towards their work in the organization, as the lean organization provides the security to the operators in return of their commitment.
- v. *Training and development.* Trainings create a sense of belongingness among the workers. In order to embark a journey towards world class manufacturing, more internal growth opportunities are offered to the workers. Comprehensive training schedules covering technical, managerial and soft skills are practiced as an on – going process. Trainings also include sessions which educate the operators, of the advantage of staying put with a company in terms of accrued benefits. Besides incentives and other related benefits, workforce is informed regularly of the company’s overall direction and other major developments. It also includes the conducting counseling sessions to resolve work related domestic issues (Karekatti, 2013a).
- vi. *Operator flexibility.* All the operators are multi-skilled and multi-functioning so that the adjustments in the sewing line become easy with change in demand. Skill matrix is maintained and up-gradation of skills takes place through the training throughout the year.

People with the right perspective and attitude towards lean manufacturing are the soul of lean process, crucial to the success of lean transformation (Nordin, 2010a). Convis has rightly stated that basically people do what upper management wants them to do (Liker, 2004). In lean organization, people are managed from their hearts and not from their heads. In the words of Taiichi Ohno, “The slower but consistent tortoise causes less waste and is much more desirable than the speedy hare that races ahead and then stops occasionally to doze. The Toyota Production system can be realized only when all the workers become tortoises” (p.115).

c) 5S.

“5S is a way to help people gets more done by working half as hard so that the company can make more money.”

Larry Simmons (as cited in Sakthivel et al., 2012, p.63)

It is rightly said, “You never get a second chance to make the first impression!” 5S is a programme of 'industrial housekeeping', which has originated from the Japanese housekeeping concept in the later part of 20th century guiding the organizations to increased levels of cleanliness, organization, and efficiency. This concept is embedded in Japanese culture and has formed a base for setting up a successful lean enterprise such as Toyota. It is the least complex lean tool to practically implement, but requires the soft skills development in the employees. It is more than a ‘standardized cleanup.’ Five S is a method to organize and manage the workspace and work flow with the intent of improving efficiency by eliminating waste, improving work flow and reducing process inefficiencies.

5S is a 5–step program that is executed in a sequential order and can take time anywhere from 6 months to 2 years to be fully implemented. Meaning and the spirit of 5S is described in the Table 2.2.

Table 2.2

Composition of 5S

S.No.	Japanese Term	Japanese Term	Meaning	Description	English Translations	Waste Reduction/Improvement
1.	Seiri	整理	"When in doubt, throw it out"	Organize -Separate out all the things which are not needed , eliminate them & keep what is needed	Sort, Sift, Separate	Elimination of finding, Reduction of errors & Cost, Enhanced Quality
2.	Seiton	整頓	"A place for everything, and everything in its place"	Proper Arrangement-Place things in order so that they can be easily accessed whenever needed.	Set in order & place	Elimination of finding, motion, non-conformances, Reduction of errors& Cost, Enhanced Quality
3.	Seiso	清掃	"The best cleaning is to no need of cleaning"	Clean-Keep things clean and polished so no trash or dirt is in the workplace.	Sanitize, Sweep	Increased equipment knowledge, Enhanced Quality Preventive maintenance

4.	Seiketsu	清潔	"See and recognize what needs to be done"	Purity –Develop systems & procedures to maintain cleanliness and monitor the 1st three of 5S's.	Standardize	Increased equipment life, morale, Clean environment, Enhanced Quality Increase visibility of non-conformances
5.	Shitsuke	躰	"The less self-discipline you need, the better"	Commitment- Creating a habit, discipline or commitment to maintain correct procedures in all processes of continuous improvement.	Sustain	Consistency delivery of Product
6.	Safety	Added by some Companies		Respect Workplace & Employee		Eliminates unsafe conditions

i. *Seri (sort).*

It is the first step towards improvement by separating the things which are necessary for the job from those that are not and keeping the number of the necessary ones as low as possible and at a convenient location (Ho, 2002).A summary of criterion for organising things is given in Table 2.3. It includes sorting by using coloured- red, yellow and green tags to different items as given in Figure 2.11. Before and after photos are taken so that comparison could be made.

Table 2.3

Criterion for Organization Things

Usage	Degree Of Need	Storage Method
Low	- Things not used in past year - Things not used once in the last 6-12 months	- Throw them out - Store at a distance
Average	- Things used only once in the last 2-6 months - Things used more than once in a month	Store in central place in the workplace
High	- Things used once a week - Things used every day - Things used hourly	Store near the month site or carry by the person

Note. Adapted from “TQM: An integrated approach,” by Ho, 2002, p.65.



Figure 2.11.Sorting by use of red, yellow and green tags. Adapted from “Toyota production system and lean management,” by PTU’s Gian Jyoti School of TQM & Entrepreneurship, 2010, p.99.

ii. *Seiton (Set in order).*

Seiton is arranging items in the work area after establishing guidelines by placing each item in a designated area with specified maximum levels of inventory example- labelling of drawer, use of shadow boards, and signboard. It act as a strategy which identifies what (what specific items go in those places), where (location) and how many (amount) tools are be placed. It is focussed on the need to quickly search for the things one needs and also how fast it could be kept back.

iii. *Seiso (Shine).*

It is linked with a Japanese belief that it leads to the feeling of freshness , mind cleaning and also that cleaning is the responsibility of all, whether the management or the worker(Ho, 2002). Andersson (2007) describes it as visually sweeping the working environment to identify and correct the repeated problems, tools out of place, manuals out of sequence, inventory in incorrect area. It is more than just cleaning, it is also inspection. It builds a sense of pride in the employees, improves the work environment, provides for a safer workplace, and helps maintain equipment value (Hirano, 1996).

iv. *Seiketsu (Standardize).*

Seiketsu means standardization, which happens when the first three S's are properly implemented and maintained (Ho, 2002). It means that racking, painting colors, colour coding, labeling, and designing operational layouts in a standardized fashion. Display of standard activity charts turns the unit into a visual factory, so that everything is in place and everyone knows exactly what they are responsible for; and exactly when, where, and, how to do it.

v. *Shitsuke(Sustain)*.

It is a method of discipline leading to instilling the ability of doing things the way they are supposed to be done and making everything available, visible and clearly marked (Bhatt & Raj, 2006). The emphasis here is on creating a workplace with good habits. Bad habits are broken and good ones are created. Hence it is like a mirror reflecting attitudes and behavior patterns of the employees (Ho, 2002). The litmus test for 5S successful integration in the organisation is to search an item or tool in 30 seconds. If the time is found within the specific timeframe, it means 5S is properly implemented. Figure 2.12 describes the various dimensions of 5S.

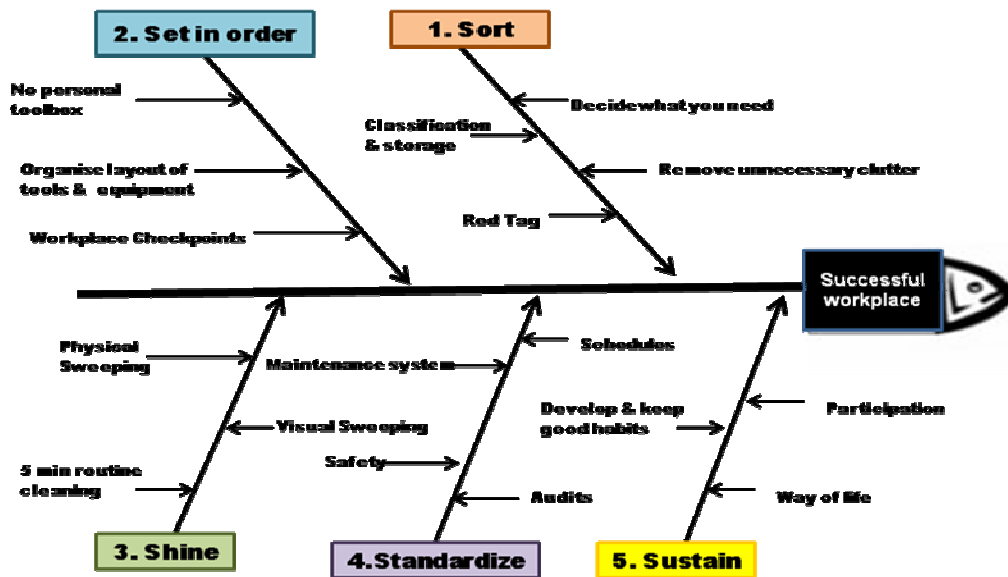


Figure 2.12. Fish bone diagram of 5S.

vi. *Safety*.

The sixth 'S' is added by some companies emphasising the safety of the workplace, identifying unsafe conditions and acts, ergonomic wise difficult tasks, and opportunities. Its main aim is to put creativity before the capital and the safety first (Andersson 2007). It also involves activities keeping the operators safe by means of wearing proper working clothes, safety glasses, gloves and shoes, masks, and not smoking in the workplace as well as maintaining a clean healthy working environment. Different precautions like non slippery, large stairways; separating spot-cleaning operations from the main production area; personal protective equipment (PPE) to avoid exposing workers to dangerous substances (dyes ,chemicals etc); safety guards in machines to prevent serious injuries to workers, belt guards and needle installation in sewing machines; use of fire safety equipment; regular check and maintenance of all safety equipments can be taken in apparel unit for the implementation of 6th S.

5S fits with the implementation of other tools and leads to proper utilization of space and establishment of convenient work practices and pleasant environment other than enhancing operational benefits. It empowers the employees to take responsibility, raises their morale, self-discipline, stronger communication, involvement and strengthens their pride in their work. It further leads to the development of Kaizen mind which brings about improvement in thinking process as well as quicker identification of problems (PTU's Gian Jyoti School of TQM & Entrepreneurship ,2010; Sakthivel et al., 2012).

d) Visual management.

“Visual management is a workplace that is a self-ordering, self-explaining, self-regulating and self-improving environment where what is suppose to happen does, on time, every time because of visual solutions.”

G. D. Galsworth (2005, p.10)

Visual Management means “Management by eyes”, which allows the lean principles to come to life more easily. It includes communication devices used in the work environment which make the abnormal condition in the 4Ms (Man, Machine, Material & Method) processes visible and understandable in one look and comparable with standards. This range of tools turns a conventional manufacturing setting into

‘visual factories.’ It works on the philosophy that ‘what gets measured and displayed gets done’, meaning, if something is clearly visible or in plain sight, it is easy to remember and kept at the forefront of mind. The principle of visual management is shown in Figure 2.13.

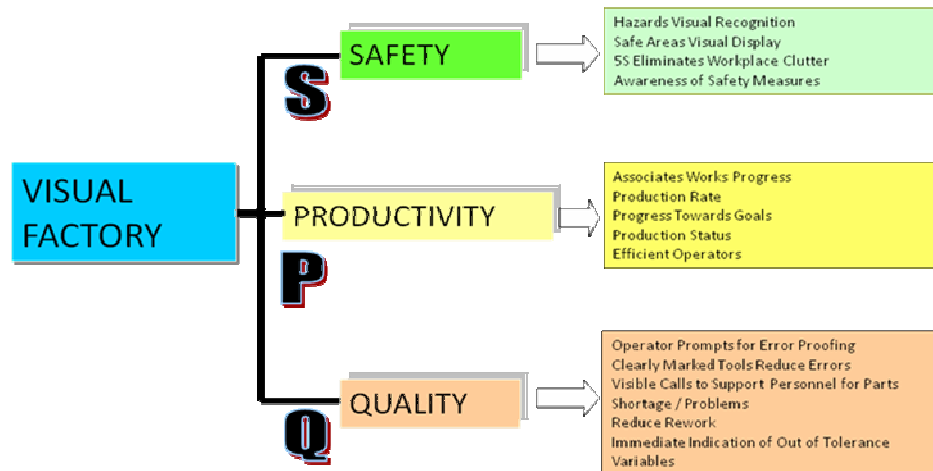


Figure 2.13.Principles of Visual Management.

Different types of Visual Management tools are-

- i. *Visual displays.* These are passive displays and the people may not notice them or respond to them. So their power level is low. These can be in the form of area information, boundaries, standard work instructions (SOP of every sewing operation) ; product ,process and work instructions; product boundary, performance status ; garment specification sheet; maintenance schedules; shadow boards; sequence instructions for checkers, colored diagram for threading of a machine ;sample of finished garment; key metrics ; Heijunka boards (showing the status of daily schedules) ;marking of light and fan switches; trend chart of yield performance, % variation of defect rate, month-to-date shipping volume status and so forth. Ten foot three second rule is adopted under which a trained person can tell what is going on by looking at the visual control in an area for three seconds from a distance of ten feet.
- ii. *Visual communication methods.* These are used in the lean production environment to provide fast communication between teams and co-workers in the form of charts, diagrams and Andon (Russell & Taylor, 2003). These are used by the team to indicate the target values and update their current

performance in terms of production information, efficiency, downtime, safety performance, quality performance and output or any other aspect that they monitor. Production board reports provide target information to everyone on large LED displays and marquees.

- iii. *Visual Signals.* These signals grab attention with visual or audible alarms, as they have medium power level. These are visible from at least 1.5m and should be in accordance with international standards, code of practice, up-to-date, well known to, and easily understood by employees, visitors and the general public. For example- traffic lights, street signs, encouraging quotes on boards, auto fuel low indicator, shift change hooter, announcements, warning lights, emergency exits etc. Tool cutouts or silhouetting, not only display needed tools for the task but also helps in locating missing tools at a glance.
- iv. *Visual process indicators.* These communicate the correct production processes or flow of materials (Mekong Capital ,2004) as follows:-
 - Footprint marks on the floor or work area act as a code. It includes aisle markings in the industry for walking and machines.
 - Color coding is such a simple organizational tool which is a fast, easy way to separate different items and to visually determine if something is misplaced and is effective in minimizing material handling mistakes. They can be in the form of dustbins, pipes, critical operations and so forth. Dustbins are coloured green, yellow, and red on the basis of biodegradable and non-biodegradable segregated and thrown garbage. Other examples include light blue colour for raw material, black for finished parts, red for non-conforming material, white for other material and yellow for border of work area.
- v. *Visual controls.* It is a technique employed in many places and contexts whereby control of an activity or process is made easier or more effective by the deliberate use of visual signals. It limits the behavior through strong visual messages or physical restrictions as an action takes place. Hence the power level is high. Example- traffic lights, Andon signal, and training matrix or skill chart. It guides the action of staff members through sign boards, dos and don'ts signs. Standards are set for every direct action to significantly reduce or remove waste and defects

in the process and they are constantly communicated back to team members (Bannari & Dhanakodi,2010).Two well-known types of Visual Controls are Andon lights and Kanbans are described below-

- *Andon* - An Andon system is referred to as an alarm (light, signal, buzzer etc.) to be raised when the defect occurs and is physically designed into the production system. Andon in English is a loanword from a Japanese word for a 'paper lantern'. It can be in the form of lights, bulbs, boards, text, graphics, cord, audio alarms, various alerts, or pre-recorded verbal messages. Industries have adopted some form of Andon practice leading to continuous improvement and uninterrupted flow. In apparel industry, Andon boards are the illuminated devices having signboard incorporating signal lights to indicate which machine or station has a problem and the signal lights are material, connected to each workstation in front so whenever there is a problem, light shines on machine. Supervisor is able to identify immediately where the problem is and reach there on time. The problem can be of poor quality, or lack of a parts which cannot be resolved without preventing a stoppage. The signal is triggered by pushing a button or a cord, or even by the equipment itself.

Andon boards represent another form of visual display (Russell & Taylor, 2003) where different colour lights are used to signal different messages. For example, a white light signal that the process is running behind schedule, whilst a green light indicates that the process and machine is running well. Amber light shows that a supervisor is needed in the area. A red light is accompanied by an audible alarm indicates that production has stopped and assistance is immediately required. A blue light signals that parts are needed or that parts may be picked up. Andon light systems are commonly used in lean production factories to monitor the work site status. It is a two way communication device. For example when indicator returns to green; this tells everybody it's back to normal. Now a days , new types of impact Andon boards with LED backlit panels and/or numeric fields to display the machine status or line states offers a historic summary report showing change, daily, weekly performance, targets, rejects and lower-occasions (Botha, 2006). Andon activation is shown in Figure 2.14.

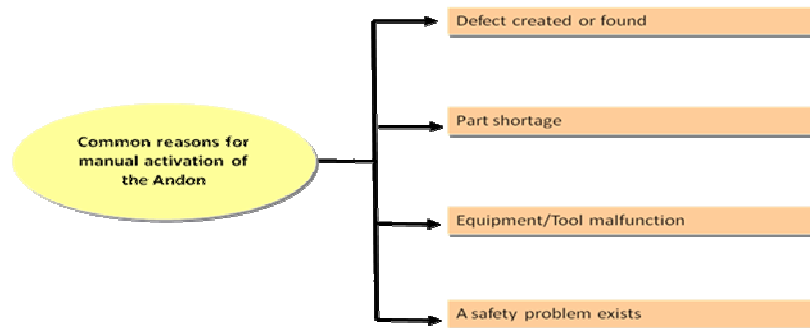


Figure 2.14. Andon activation.

- **Kanban**- It is used to limit the amount of inventory tied up in work in progress on a manufacturing floor. An empty container can be a visual signal for the previous operator to replenish it. If there is no Kanban card asking to be filled on a bin, then the bin should not be there. The filled bin without a Kanban card is a visual signal of overproduction.

Visual controls not only heighten focus on the process but also provide the foundation for a far greater level of employee involvement than any other reporting system. Visual management makes information accessible for all staff and leads to improvement in sharing information and communication, enabling quick response and recovery. It also exposes abnormalities emphasising the need of improvement and brings about pride of ownership among employees in the contribution to the company. In the visual workplace, anyone will easily know: who, what, when, where, why, and how of an area within 5 minutes. This self explanatory visual information is important for process improvement system. Lean manufacturing uses an integrated set of visual controls or a visual control system designed to create a transparent and waste-free environment (Liker, 2004).

e) Total Productive Maintenance (TPM).

“If you are going to achieve excellence in big things, you develop the habit in little matters, Excellence is not an exception, It is a prevailing attitude.”

Colin Powell (2003) (as cited in Harari, 2004, p.31)

The concept of TPM has been developed in Japan by Nakajima to maximize the overall effectiveness of production equipment. It is a plant improvement

methodology, which enables continuous and rapid improvement of the manufacturing process by the regular maintenance of machines preventing its deterioration and malfunctioning. All functions related to process of maintenance, repairs and changes are assigned to the workers operating the machines (Ho, 2002). This frees up the technicians or maintenance team for finding the root causes of breakdowns to prevent similar problems in the future such as: equipment improvement and overhauls, training, etc. In 'just as in safety', the target is zero incidences. In TPM the target is zero breakdowns (Nakajimi, 1988; Pieterse, 2005).

It is considered a personal health care insurance of all the manufacturing machine and tools in a lean environment which are required to effectively run in order to produce the apparel as per the customer demand. The cost of regular TPM is very small when it is compared to the cost of a major breakdown. Moreover in lean environment, if the machine breakdown occurs, it causes the line to come to a standstill. TPM including a set of tools to ensure machine availability and reliability in the production process are demonstrated in Figure 2.15.

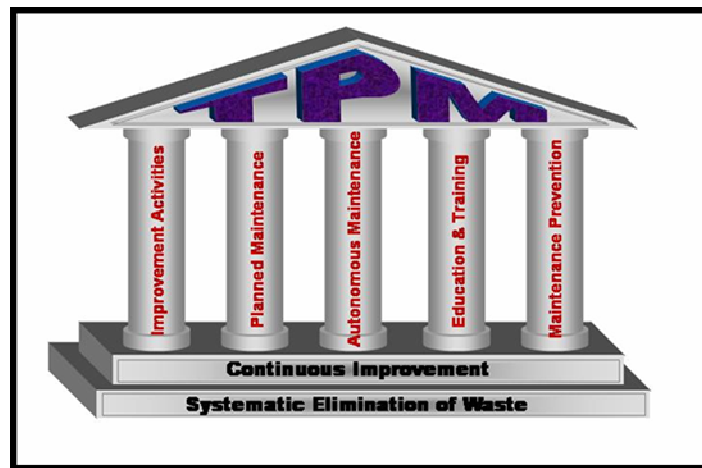


Figure 2.15. Five pillars of Total Productive Maintenance. Adapted from “What is Total Productive Maintenance (TPM),”n.d.

Aspects of TPM

- i. *Preventive maintenance.* In this type of maintenance, regular checks are made on machines to ascertain their proper functioning. A defined colour-coded maintenance chart or checklist is used for maintaining record, and is attached on the machine and filled at predefined intervals.

- ii. *Corrective maintenance.* This type of TPM quickly repairs equipment after the breakdown occurs, wait until a failure occurs and then remedy the situation as quickly as possible. Machines with easier maintenance are purchased and used in the unit.
- iii. *Maintenance prevention.* It includes designing and installing such right equipment and machines that needs little or no maintenance (Tiwari & Wanjari,2010).
- iv. *Predictive maintenance.* Rather than looking at a calendar and assessing what attention the equipment needs, operator should examine ‘the vital signs’ and infer what the equipment is trying to tell.
- v. *Defective Maintenance.* It applies to the types of devices that only need to work when required and do not tell us when they are in the failed state. For example- a fire alarm or smoke detectors. They require a periodic functional check to ascertain that they are still working (Bhatt & Raj, 2006).
- vi. *Autonomous maintenance.* It acts as a key aspect of TPM as it trains and focuses workers to take care of the equipment and machines with which they work. It has led to a change from “I operate, you fix, to I operate, I fix”. The involvement of production workers in the day to day general maintenance of machines like cleaning, and lubricating not only saves the time of skilled maintenance person but also production workers become more responsible to their machines(Paneru,2011).

The proper implementation of TPM leads to quick response, zero breakdowns, lower unplanned downtime and zero product defects, which further optimize the manufacturing processes to deliver performance, higher overall equipment effectiveness, and new efficient products and effectively manage safety and environmental issues (Ho, 2002).

f) Total Quality Management (TQM).

“Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.”

William W. Scherkenbach (1886,p.25)

TQM is a generic management term used to describe both philosophy about the quality in the organization and also a family of tools and approaches. Total means ‘the responsibility on quality lies on all’; Quality means ‘deliver the right product at the agreed time, place and price as per the customer needs’; and Management means “communication of organizational values and vision to all employees by the top management to maintain continuous improvement culture”. The simple objective of TQM is “Do the Right things right, the first time, every time” meaning that quality should be built into the production process in such a way that defects are unlikely to occur in the first place – or in so far as they do occur, they will be immediately detected .It focuses on 100% customer satisfaction irrespective of whether the customer is internal or external and zero effects.TQM is a mixture of quality culture, strategy, improvement and tools(Bhatt & Raj,2006)as shown in Figure 2.16.

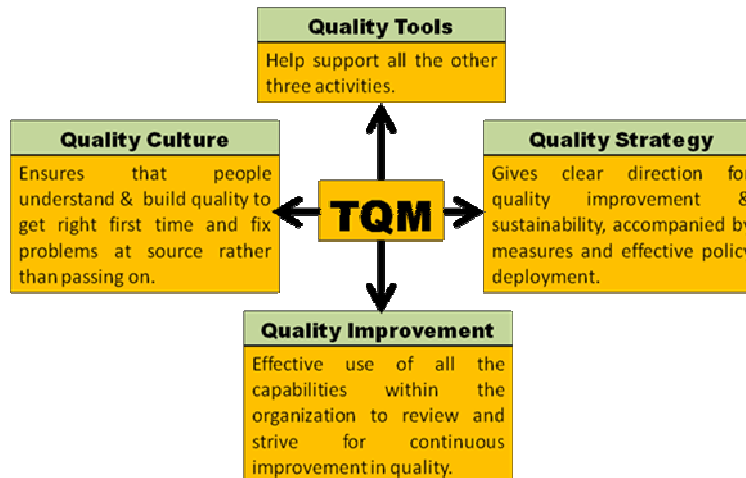


Figure 2.16.Components of Total Quality Management. Adapted from “*Quality management systems: Concept , strategies and requirements,*” by Bhatt & Raj, 2006,p.60.

Success of TQM depends on following factors-

i. Shop floor and monthly meetings.

Daily and monthly meetings are the best option for information sharing, decision making meetings, or idea-generating. Lean culture believes that everyone must work towards the same aim, be open with each other, not have hidden agenda and undertake the work they agree to in the timescale agreed. With this aim, regular meetings are organized. Shop floor meetings take place every morning standing for

few minutes, but for pre-production and monthly meetings, an agenda with timings must be circulated. This helps in developing a culture of preparation, before meeting and involving all the people involved. Precaution needs to be taken so that rather than arguing over a topic, main points should be discussed with no phone distractions. Action plan must be chalked out with dates and people allocated to the tasks.

ii. Inline and Source inspections.

The main responsibility for quality inspection lies with the workers themselves and not on separate quality inspectors. All the operators are trained in quality principles and testing procedures. They inspect their own work to ensure that they do not send defective items to their immediate customers (next person who uses or further processes the item or information) (Dilworth, 1992). This provides fastest feedback. Self checks using poka-yoke devices to allow workers to assess the quality of their own work. Because they check every unit produced; operators may be able to recognize what conditions that caused the last unit to be defective. This insight is used to prevent further defects (PTU's Gian Jyoti School of TQM & Entrepreneurship, 2010).

iii. Quality circles.

"It's the quality of the ordinary, the straight, the square, that accounts for the great stability and success. It's a quality to be proud of. But it's a quality that many people seem to have neglected."

Gerald R Ford (as cited in "New president: A man for this season," 1974)

It is a philosophy of worker's direct involvement in solving the problems that affect their work, their work output and their work place. Its main focus is to significantly affect the efficiencies in an organization's operations by capturing the creative and innovative power that lies within the workforce. This collective effort helps in human resource development by nurturing and bringing out the human potential. A group of workers meet for an hour informally in employee's home or workplace, each week to discuss their problems and recommend solutions and take corrective actions. Worker's volunteers to be a member of a circle, receives training and work in a systematic way to solve problems together with the whole team (Adam

& Ebert,1992; Bhatt & Raj,2006; Chary,2007).The problem addressed are not limited to quality alone but also deal with all technical problem that affect productivity.

iv. *Kaizen*.

“If you are content with the best you have done, you will never do the best you can do.”

Ho (2002, p.56)

Kaizen means small, continuous improvements with zero investment (Mahajan, 2008). It comes from the Japanese words “Kai” meaning school, continuous or change and “Zen” meaning wisdom, improvement which collectively means “approach to work” where workers are committed towards two types of tasks in exchange of security of their job. One is to sincerely perform the job assigned to them, and the second is to make an effort to continuously improve it (Pieterse, 2005). More formally it was developed by Ohno and Shigeo as a practice, implying choice and practices of the techniques the team has agreed to try, until it is mastered and standardized, experimented to find a better way and repeat forever. Kaizen is regarded as a conceptual umbrella consisting of a collection of Japanese practices as shown in Figure 2.17.



Figure 2.17 . Kaizen umbrella. Adapted from “Kaizen. Encyclopedia of Management,” by Mleczkowska,2013.

Kaizen is considered to be the "building block" of all lean production methods (Brown, Collins, & McCombs, 2006). *Kaizen* requires the continuous questioning of the basic workings of an operation. The continuous identification and solution of

problems by involving and empowering the workers creates a culture of ongoing continual improvement with an organization. Two methods by which involvement can be increased are the 'Kaizen circles' and 'Suggestion programs'. In Kaizen circles, 6-8 workers in a group are formed which generate ideas for solving particular problems. Typically a Kaizen Circle will meet for around one hour per week for 6-8 weeks, and at the end of that period will present some proposals to their managers on how to solve the particular problems. While in Suggestion programs, people are strongly encouraged to make suggestions and rewards are awarded for successfully implementing the suggestions (Mekong Capital, 2004). It improves quality, safety, cost structures, environments, and customer service. Each improvement may be small but the cumulative effort is tremendous (PTU's Gian Jyoti School of TQM & Entrepreneurship, 2010).

v. *Value Stream Mapping (VSM).*

"Whenever there is a product for a customer, there is a value stream. The challenge lies in seeing it."

Rother & Shook (1999,p.3)

The value of a process is expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price and at a specific time (Womack & Jones, 1996). It is the adaptive form of 'Material and Information Flow Mapping' which is a visualization tool to describe the current and ideal (future) state of a unit or process in order to develop or establish the lean System. It is a visual representation of what happens to a product as it physically moves through the production process (Bowes, 2010). Manos stated that "Pictorial representations of VSM are easy ways to learn a language that anyone in the organization can understand—a key element when communicating with process maps" (2006, p.64). Table 2.4 gives details about the purpose of the Value Mapping Process.

Table 2.4

Purpose of the Value Stream Mapping

See	Assess	Measure	Change
-----	--------	---------	--------

Documentation of the process, each transaction and making its flow-chart	Measurement and characterization of the current state process	Calculation of VSM measures- lead time, work in progress, cycle time, machine uptime etc	Identification, planning, and implementation of changes, and further measurement of improvements
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VSM brings about a deep understanding and helps convey enough information to understand the pieces, relationships and hidden wastes. It identifies and eliminates the value added and non-value added waste activities in the enterprise by gathering accurate, real-time data related to the product family or value stream”. It visualizes the whole picture of the process in one map (Tapping, Luyster, & Shuker, 2002).Hence, VSM if used correctly can prove very powerful lean tools, bringing about improvements in quality, delivery and cost of the final product.

vi. Problem solving tools

“A relentless barrage of “why’s” is the best way to prepare your mind to pierce the clouded veil of thinking caused by the status quo. Use it often.”

Shigeo Shingo (as cited in “Quotations for Lean Manufacturing,” n.d.)

Problem solving methodology is a skill that should run deep and strong at all levels of the organization from the manufacturing to the purchasing and to the sales. In lean, every problem is seen as an improvement opportunity. In most of the organizations, workers encounter very few large, few medium and many small problems. Large issues are generally addressed through the management –directed and management controlled activities .Medium and small issues should be initiated by the supervisor, the team or by an individual. Employees get involved and feel responsible as they have a reasonably good expertise in solving their daily problems. All the employees are encouraged to learn simple problem solving process techniques like brain storming, cause and effect analysis, check sheets, pareto analysis, bar charts, pie charts, histogram and process analysis (Bhatt & Raj,2006).Problem solving should be done at the actual happening place(where the problem occurs) after seeing what is happening(Genchi Genbutsu).

All the Problem Solving techniques are described below-

- *Brainstorming*- This methodology is used to encourage every worker in the group to express their opinions freely or give ideas in an open discussion. It includes listing down all problems faced by an organization, their causes and potential effect if certain suggestion is implemented (Bhatt & Raj, 2006).
- *Spaghetti diagram*- It is a simple yet powerful tool to visualize and analyze the product flow, layout of machines and the people. Time as well as distance travelled is calculated to spot opportunities to reduce the transportation and motion waste.
- *Takt time analysis*-This analysis helps in finding out whether the production is taking place as per the demand of customers. It is calculated by dividing the total working time of the customer demand. When a unit is producing more than required by the customer, overproduced garments are considered waste as it uses more resources to complete the order. When it's producing less, it will not be able to meet the rate of customer's demand as takt time. Over time needs to be given to clear the backlog. The cycle time of all the processes should be balanced under the takt time line (Rother & Harris, 2001).
- ***Five whys and one H***- Most of the problems do not require complex statistical analysis like 6 sigma but detailed thinking and analysis is required to be done. Five why is one such sophisticated technique for developing new products .It is a method for pushing people to think about the root causes that prevents a team from being satisfied with superficial solutions that won't fix the problem in the long run (George, Rowlands, Price ,& Maxey ,2005). Table 2.5 gives an example of 5why techniques used to identify the cause of the problem of not meeting the customer's orders on time.

Table 2.5

Format of 5Ws and 1H Technique

	5Why	Key Questions	Strategy
Purpose	What?	What is done?	Eliminate
	Why?	What is the purpose? Is the purpose accomplished? Why is it necessary? What if this was eliminated? What would make it unnecessary?	

Place	Where?	Where is it performed? What alternate locations are viable? Can departments be reorganized?	Combine Rearrange
Sequence	When?	What other sequence would work? Can it be combined with other even? What are the implications of other sequences?	
Person	Who?	Who performs the task? Who else could perform it?	Simplify
Means	How?	What other methods are available? What other technologies exist? Can smaller processes be used?	

Note. Adapted from “Toyota production system and lean management,” by PTU’s Gian Jyoti School of TQM & Entrepreneurship, 2010, p.53.

- *Cause-Effect Analysis (CE Analysis)*- It graphically illustrates the relationship between a problem and all the factors that influence the problem. It is also called cause & effect analysis, as it shows various causes which act as a fundamental condition or stimulus of some sort that ultimately creates a result or effect. It was developed by Ishikawa for the purpose of representing the relationship between an effect and the potential or possible causes influencing it, hence is also called Ishikawa diagram. It is demonstrated as a “fish-bone” shape, with the head of which is the effect or problem, and the ribs of which carry the categorized possible causes. It involves the use of the expert knowledge of a group of people at work to identify certain effects by brainstorming and by presenting their ideas as causes on a picture (Ho, 2002). It helps push team beyond the symptoms to uncover potential root causes and ensures that a balanced list of ideas have been generated during brainstorming or that the major possible causes are not overlooked (George et al., 2005). Basic format of cause and effect diagram is shown in Figure 2.18.

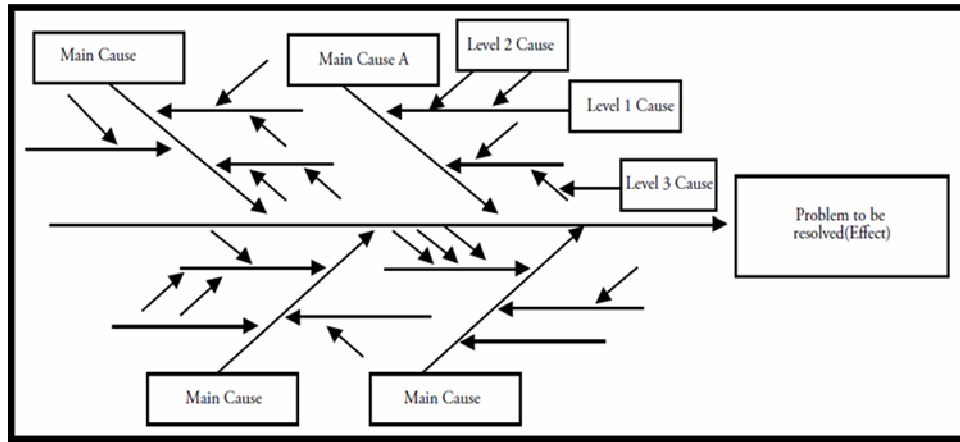


Figure 2.18. Basic format of fishbone diagram. Adapted from “Lean manufacturing - The way to manufacturing excellence,” by Tecknopak, 2011, *Outlook*, December, p.8.

- **Pareto analysis-** It is a statistical technique in the decision making that is used for the selection of a limited number of tasks that produce significant overall effect (Haughey, n.d., p.1). Dr Edward Juran applied this ‘the vital few, and the trivial many’ concept to find out the causes of quality failures. The intent of a pareto analysis is to separate the vital few from the trivial many. Thus, the pareto analysis gives a picture of the frequencies of the ‘vital few’ or important items or causes of a problem compared with the trivial many. To solve the problem, ‘vital few’ things should be targeted so as it makes a major impact on improving the performance.

vii. **Poka Yoke.**

“Poka Yoke recognizes that as humans we'll inevitable forget things, we should at least make certain we don't forget that we have forgotten.”

Shigeo Shingo(as cited in Larsson,2006, p.13)

It was based on the philosophy that the people do not intentionally make mistakes or do the work incorrectly. But these errors are the failure of the system and methods that are used to perform the work. A Poka Yoke device is any mechanism that either prevents a mistake from being made or makes obvious at a glance. It is a Japanese term referring to mistake proofing devices. These devices are often built into or interlocked with machinery or fixtures to prevent missing an operation or loading the part wrong (Fisher, 1999). Dr. Shigeo Shingo was credited with the development

of this concept. Poka Yoke are implemented so that defective materials do not get passed through the production process. In Poka-Yoke, 100% of the units are tested as part of the production process. These devices are an effective alternative to demands for greater worker diligence and exhortations to 'be more careful'.

viii. Jidoka.

In the case of machines, we build devices into them, which detects abnormalities and automatically stop the machine upon such an occurrence. In the case of humans, we give them the power to push buttons or pull cords-called andon cards-which can bring our entire assembly line to a halt. Every team member has the responsibility to stop the line every time they see something that is out of standard. That's how we put the responsibility for quality in the hands of our team members. They feel the responsibility-they feel the power. They know they count.

Alex Warren(as cited in Liker, 2004,p.129)

Jidoka is one of the pillars of Toyota Production System. Jidoka has two different meanings in Japanese, one is automation (Imai, 1986) meaning changing a manual process into a machine process and other is 'automatic control of defects' meaning incorporated the insight or mind of a human to troubleshoot and correct failures. It is 'automation with a human mind' including process or technique of detecting and correcting production defects. It always incorporates the following devices: a) a mechanism to detect abnormalities or defects, and b) a mechanism to stop the line or machine when abnormalities or defects occur.

Jidoka is a quality control process that applies the following four principles:-

- Detect the abnormality.
- Stop the line to remove the cause of the problem or when something goes a miss. This type of automation implements some supervisory functions rather than production functions. Whenever, there is an abnormal situation, the machine stops and the worker will stop the production line.
- Fix or correct the immediate condition.

- Investigate the root cause and install a countermeasure (Kachru,2007)

The first two steps can be mechanized or automated. Poka-Yoke devices are one method to allow a process to detect a problem and stop. The 3rd and 4th steps cannot be automated. They are entirely the domain of people because they require diagnosis, analysis and problem solving methods. Various problem solving techniques are used to expose the root cause and implement the remedy. These two steps help in correcting the abnormal situation so that the production can resume either by finding a temporary solution or shutting the line till the defect is corrected. It prevents the production of defective products, eliminates overproduction and focuses attention on understanding the problem and ensuring that it never recurs.

ix. Continuous Improvement (CI).

Continuous improvement is not about the things you do well - that's work. Continuous improvement is about removing the things that get in the way of your work. The headaches, the things that slow you down, that are what continuous improvement is all about.

Bruce Hamilton (as cited in Wells, 2010,p.91)

Continuous Improvement is defined as the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving the company's performance (Gersten & Riss, 2002). This continuous flow is represented in the form of spiral in Figure 2.19.

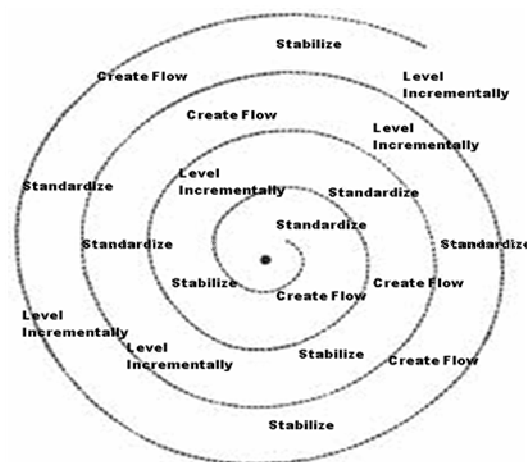


Figure 2.19. Continuous Improvement spiral. Adapted from “Toyota production system and lean management,” by PTU’s Gian Jyoti School of TQM & Entrepreneurship, 2010, p.68.

Successful CI implementation involves not only the training and development of employees in the use of tools and processes, but also the establishment of a learning environment conducive to the future continuous learning (Paneru, 2011). Its goal is to get better and better, and the way to measure a plant’s performance is to see how little WIP it requires to operate. As large inventory hides the problems and make it go unnoticed and unsolved, but, with the draining off some inventory, problems are not only found, but are also solved (Dilworth, 1992).

PDCA cycle advocates a structured methodology for continuous improvement as shown in Figure 2.20. It stands for ‘Plan Do Check Act’ and was proposed by Dr. W. Edwards Deming, hence called ‘Deming cycle’ or ‘Deming’s Wheel’ for quality improvement. In *Plan stage*, the causes are identified, data is collected and the improvement is planned collectively by the employees and management. The pilot project implementation happens in the implementation phase or the *Do phase* in PDCA cycle. In next *Check phase*, difficulties, differences and results are observed, identified and analyzed when employees try to achieve their objectives set by the plan. Lastly, in *Act phase*, the plan is actually implemented, deployed throughout the organization. The seven different kinds of continuous improvement tools (Larson, 2003) used are pareto diagram, fishbone diagram, check sheet, histogram, stratification, scatter diagram and charting. Then the results are monitored and the changes are made to make sure that the project is working according to the plan. When the necessary results are achieved, they are documented and the standards are set in order to prevent that problem coming up again. If the objectives of the plan are not achieved, it is altered slightly to facilitate the smooth operation and problem solving. This cycle is repeated again and again to continuously solve the problems in a lean organization (Ho, 2002).

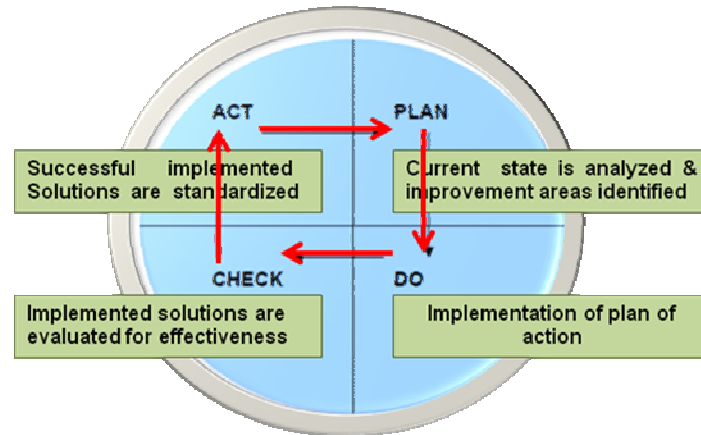


Figure 2.20. Plan Do Check Act Continuous Improvement cycle. Adapted from “Leaning the South African way: Implementing lean manufacturing in the rainbow country,” by Pieterse, 2005, p.34.

Thus, the continuous improvement is an ongoing and never ending process used to attack the inefficiencies or the wastes of the organization in its lean journey.

g) Just in Time (JIT).

“The more inventories a company has,..... the less likely they will have what they need”

Taiichi Ohno(as cited in Liker,2004,p.104)

JIT is a philosophy of manufacturing, based on the planned elimination of waste and continuous improvement of productivity by producing the right material, at the right time, at the right place and in the exact amount, without the safety net of inventory (Bannari & Dhanakodi,2010). Kiichiro devised and fine-tuned his JIT .Its importance in the lean implementation can be judged by the look at the lean house, where the first pillar is the JIT. The JIT idea is simple as shown in Figure 2.21.

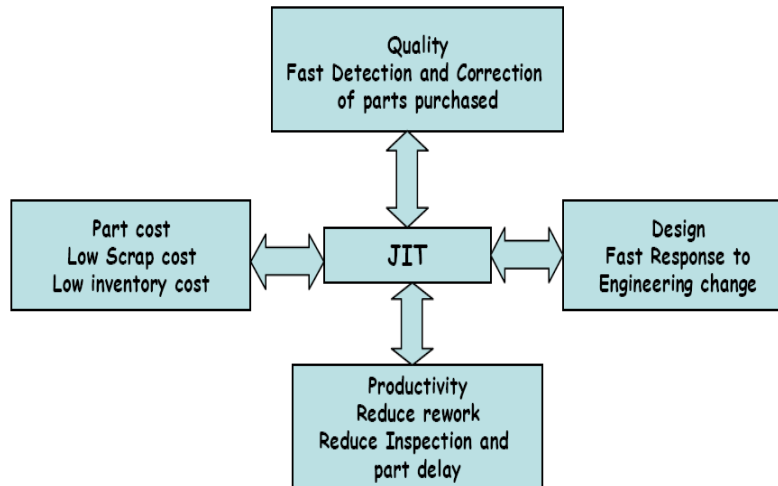


Figure 2.21. Aspects of Just in Time. Adapted from “Lean manufacturing in apparel industry,” by Tiwari & Wanjari, 2010, *Fibre2fashion*.

The Just in Time production (JIT) concept means “take one, make one” and this production mode is called “replenishment”. It is based on the concept of a “supermarket”, where, as soon as the product is picked by the customer, it is simultaneously replenished by the supermarket personnel so that it fulfills the future requirement of the customer. It is supported by leveling and signaling to produce, to keep required checks and balances, and a visual tool to accentuate ‘pull’. In apparel industry, supermarket is created between any two connected processes, where one process needs goods from the previous stage (Tecknopak, 2011).

Essential Elements of JIT.

Following are the nine essential elements of JIT:-

i. Standardized work.

Today’s standardization is the necessary foundation on which tomorrow’s improvement will be based. If you think of ‘standardization’ as the best you know today, but which is to be improved tomorrow-you get somewhere. But if you think of standards as confining, then progress stops.

Henry Ford (1926) (as cited in Liker, 2004, pp.141)

The Standard Operations Procedure (SOP) refers to the use of stable, repeatable methods everywhere to maintain the predictability, regular timing and

regular output of process. It is the foundation of flow and pull. It also acts as a key facilitator of building in the quality. Without standardization and stability of existing methods, manufacturing units cannot even assess the extent of improvement brought about by the new methods (PTU's Gian Jyoti School of TQM & Entrepreneurship, 2010). In lean manufacturing, standard work has several main elements as follows :-

- *Standard work sequence* - This is the order in which a worker must perform tasks, including motions and processes to minimize variations and therefore minimize defects.
- *Standard timing* – Manufacturing of the products are balanced with Takt time.
- *Standard in-process inventory* – This is the minimum unit of materials, undergoing processing, which are required to keep a cell or process moving at the desired rate.

Creating standardized work reduces the variations and chaos in a process and thus yields superior results forming baseline for Kaizen. It can be rightly summed by Taiichi Ohno as “without standardization, there can be no Kaizen” (Daghar, 2008; Sarkar, 2013).

ii. Production planning.

"The key is to have minimal buffers, but design them for maximum protection."
Umble and Mokshagundam (as cited in "Lean manufacturing quotes," n.d.)

In the lean setup, planning should be as per the customer demand. Ideal guiding principle which is followed while planning is “No machine should wait for material and no material should wait for the machine”. The flow of material should be as smooth and as regular as possible. Machine wait leads to permanent loss of production capacity and rise in the inventory cost. Planning of the production of a particular style prevents the irregularity of production pattern and machine material waiting ultimately leading to waste (Mahajan, 2008).

iii. Takt time.

"We're trying to create flow! Not continual "start/stop" but flow, with the ability to increase or decrease to match customer demand."

William (Bill) Parr(as cited in "Lean manufacturing," n.d.)

Takt is a German word for pace and is defined as 'the desired time between units of production output, synchronized to customer demand'. It sets the pace of production to match the rate of customer's demand. This timing mechanism is based on the monthly production schedule. The Takt time allows production of many parts of many different styles on the production schedule. It keeps the production on schedule and permits flexible response to change in sales. It is computed as available work time per day or daily required demand (parts/day)(Kachru,2007).It is very useful for stabilizing the system and further limiting the inventory and overproduction.

iv. *Heijunka.*

"If you want to manage delivery scheduling, you will need to "even out" uneven production. This is a prerequisite for Just-In-Time."

(Bhatia & Stevetuf, 2008,Defination,para 1)

Heijunka means "level scheduling" or "production smoothing" in terms of volume and product type or mix. It does not build products according to the actual flow of customer orders, which can swing up and down wildly, but takes the total volume of orders in a period and levels them out so that the same amount and mix are being made each day (Liker, 2004). According to Robert Hall, uniform load scheduling is best stated as "make a little bit of everything everyday". Doing so ties production closer to customer demand and avoids producing in large lot sizes (Adam & Ebert, 1992). Effective operation of Kanban and Pull system requires Heijunka in production system (Russell & Taylor 2003).

v. *One piece flow.*

"Make the flow through the bottleneck equal to demand from the market."

Cimorelli & Chandler (2006, p.244)

The one piece flow refers to the concept of moving one work piece at a time between operations within a work cell. Such system's flexibility changes according to the customer demand and is efficient at the same time. It originated from Ford's system of continuous material flow (PTU's Gian Jyoti School of TQM & Entrepreneurship, 2010). It is more applicable where material flow is automated. There is no need to build inventory between processes, except in case of bottle necks, where there should have more than one unit in front of it to ensure that it never stops due to lack of material to process. With cellular manufacturing, one product flow is possible by the close arrangement of the succeeding operations, eliminating excessive material handling between them and enhancing the communication and cooperation between operators (Kachru, 2007).

vi. *Cellular layout.*

Due to the set-up times, the tendency is to produce in batches that are larger than the order quantities. This supposedly utilizes the equipment more efficiently, reduces set-up costs, and reduces unit product cost. But any production in excess of immediate market demand ends up as finished-goods inventory. The result of producing these large batches in today's competitive marketplace is poor customer service despite high levels of inventory.

Umble & Srikanth. 1997(as cited in "Lean manufacturing quotes," ,n.d.)

Cellular manufacturing is not just related to physical layout, but people are considered central to the manufacturing system. It is synonymous with terms such as 'group production', 'modules', or simply 'teamwork' (Hyer & Wemmerlov, 2002). Cellular manufacturing is one such human-centric production system which is considered one of the building blocks in successful lean enterprise as shown in Figure 2.22.

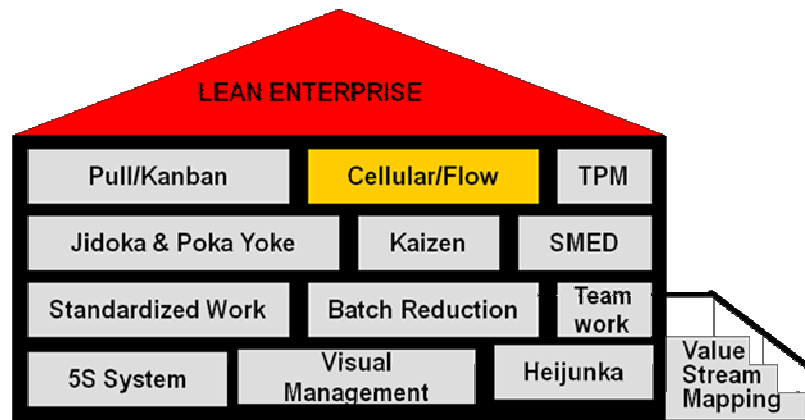


Figure 2.22. Building blocks of a successful lean enterprise.

Arranging people and equipment into the cells helps the organizations achieve two important goals of lean systems that is one-piece flow and high-variety operations. In cellular production layouts, equipment and workstations are arranged into a large number of small tightly connected cells so that many stages or all stages of a production process can occur within a single cell or a series of cells.

Table 2.6

Characteristics of Cellular Manufacturing

Characteristics	Description
Team	Specified team of workers
Products	Specified set of products & no others
Facilities	Dedicated machines / equipment
Group layout	Dedicated space
Target	Common group goal for period
Independence	Groups can reach goals independently
Size	Typically 6-15 workers

Note. Adapted from “Cellular manufacturing,” by Hicks, 2011.

Main characteristics of a typical cellular manufacturing are shown in Table 2.6. Formation of cell requires clubbing and splitting of operations with high amount of multi-tasking, resulting in self-content work cells that guarantee low levels of work in progress (Karekatti,2013a). Changing layout to cellular one in an organization increases the use of multiprocessing and multifunctional tools, cross trained workers, easy movement between work stations, smooth, sequential and balanced work flow, balanced and one-piece flow, flexibility, shared responsibility, pull-type production systems, operator's empowerment and continuous improvement .

vii. *Kanban.*

"Kanban is like the milkman. Mom didn't give the milkman a schedule. Mom didn't use MRP. She simply put the empties on the front steps and the milkman replenished them. That is the essence of a pull system."

Ernie Smith (as cited in El-Homsi & Slutsky,2010, p.84)

Kanban is referred to as the "nervous system" of lean production, as it is a key technique that determines the process production quantities, and in doing so, it facilitates JIT production and ordering systems. A Kanban is a major component of JIT production. Kanban works on the "pull" type of production system. The word is derived from the combination of two Japanese words, Kan means "visual" and "ban" means "card" or "board". Hence, it means sign board, card, electronic signals, visible plate , visual record ,standard production quantity , size of container',or, merely a communication. These cards do not constitute a Kanban system as these are employed in push system of imparting order and control. It employs a card to signal the need to deliver more parts and an identical or similar card to signal the need to produce more parts (Schonberger, 1982).Figure 2.23 shows the Kanban card containing specific information of the part.

Part Description				Part Number	
Qty		Lead Time		Order Date	
Supplier				Due Date	
Planner			Card 1 of 2		
			Location		

Figure 2.23. Kanban sample card.

Kanban is a means of signaling to the upstream workstation that the downstream workstation is ready for the upstream station to produce another batch of parts. Kanban card is a most common signal which can carry more information than a no- paper signal (Gaither & Frazier, 2004).Figure 2.24 shows the Kanban pull system.

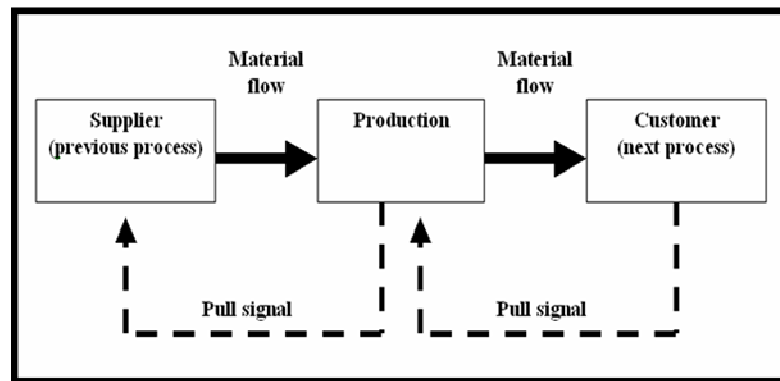


Figure 2.24. Kanban pull system.

Kanban is a system that visually indicates when the production should start and stop. Many benefits of adopting Kanban are reduction in Inventory, improved workflow, eliminates overproduction ,improves responsiveness to changes in demand, no risk of obsolete inventory and worker led process improvements .

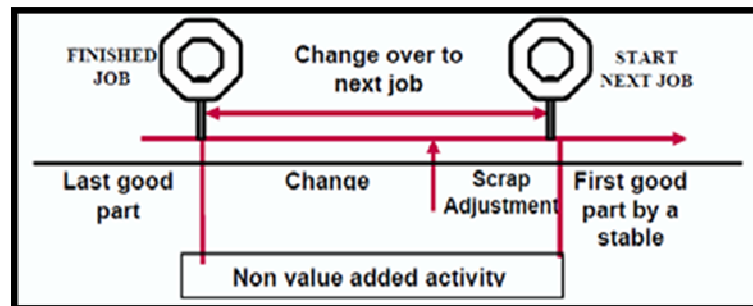
viii. *Single Minute Exchange of Minutes (SMED).*

Personally, I do believe that there are two giants who have contributed a great deal to the advancement of the manufacturing industry in Japan and who spread the victory throughout the world. And these two giants are Taiichi Ohno and Shigeo Shingo.... So every time Mr. Ohno needed some special

assistance, for example, Mr. Ohno would go to the plant and recognize that setup time must be dramatically reduced in order to meet the changing requirements. He'd go to the shop floor [gemba], tell his people that "You should change, you should reduce setup time. Now, it's taking two hours--that's too long. You should reduce it down to 10 minutes." Then the manager would say, "But how can we do it-- we don't know!" Then he would simply say, "Ask Mr. Shingo."

Masaaki Imai (as cited in "Lean manufacturing quotes," n.d.)

The SMED concept was first introduced, developed and redefined in the late 1950s and early 1960s, by Toyota. Shigeo Shingo has been considered the architect of SMED technology. It acts as a staple in the lean toolbox (Wilson, 2010). It is the process of minimizing the changeover time between two different garment styles in the production department. The phrase "single minute" does not mean that all changeovers and start-ups should take only one minute, but they should take less than 10 minutes (in other words, "single digit minute") (Shingo, 1985). The concept of SMED is diagrammatically demonstrated in Figure 2.25.



*Figure 2.25. Representation of changeover time. From "Reduction of style changeover time is critical to success," by Karekatti, 2013b, *Stitch World*, May, p.36.*

This methodology systematically reduces the time lost in production due to 'between style' machine setting from hours or hours to minutes or even less (Makhija, 2012). Shingo divided the setup operation into two parts:

- External setup time is the setup time that takes place when a process or machine is in operation, previous batch production is still running, or once the next style is underway.

- Internal set up time is the time tied to setting up the process or machine when it is not running or in production. Internal set up requires shutdown or switch off the machine for completion (Kachru,2007).

SMED aims to change all the internal setups to external ones, reduce length of internal setup, if unable to convert to external and finally reduce length of all external setups (Karekatti, 2013b). With the application of SMED, improvements noticed are substantial showing the reduction of setup time ranging from 25% to as high as 85%; expansion of production flexibility; more machine and equipment utilization; enabling small lot sizes; reducing production times, quality defects, machine adjustment times and the time that machine does not operate (Gilmore & Smith, 1996; Ulutas, 2011).

ix. Supply chain.

"It means choosing wisely those vendors that demonstrate compatibility with the company's values, cultures, and beliefs."

Yeh, Pearlson & Kozmetsky(as cited in "Lean Manufacturing,"n.d.)

In lean setup, supply chain decisions are based on the total cost of purchasing. Demand is communicated to external partners primarily through pull systems based on the customers demand. Suppliers are part or an extension of the manufacturing unit. Key supplier on time delivery percentage is more than 99%.The flow from the suppliers are pulled by the customer demand using takt time, load leveling, line balancing and single piece flow. This effective two-way communication coordinates production and delivery schedules and minimizes the inventory through all tiers of the supply chain. In a lean set up, wastes are removed in:-

- **Planning** – Sales and operations planning process.
- **Sourcing** – Procurement and the use of JIT principles including vendor managed inventory (VMI).
- **Making** – Manufacturing, assembly, and kitting.
- **Delivering** – Transportation optimization.
- **Returning** – Shipping mistakes, returns, product quality, and warranty issues.

Lean along with supporting strategies can help to give the company a competitive advantage by streamlining the supply chain and coordinating with the logistics professionals.

2.1.7. Lean implementation strategy.

Adopting Lean is to empower the worker to think, act and be ready to take quick decisions taking full responsibility for his actions. It is more a working culture and without the active involvement of the workers no Lean program can be successfully implemented.

Roshan Baid(as cited by Wickeramasinghe, 2011,p.19)

Lean can revolutionize apparel industry by empowering human-ware, which is a key business driver assisted by machinery and technology. People's participation is the core of lean implementation program. Unlike the machinery which depreciates overtime, people with innate and acquired skills develop into the long term assets of the organization, and become the core to the continuous improvement of the organization.

Lean implementation is seen as a process of adoption. The term implementation process means "progression of events" (Ahlstrom, 2000 as cited in Kovacheva, 2010, p.17). The lean implementation is defined as a process of adoption, involving the necessity of innovation and adaptation by the organization, not just following a certain sequence of steps from a preliminary designed plan as given below.

a) Precursors of lean.

Before the implementing a lean initiative, there are some major precursors or foundational issues that must be put in place in a manufacturing unit to make a lean initiative successful. The following seven precursors must be built into the lean initiative plan in the proper sequence are:-

- i. High levels of stability and quality in both the product and the processes.
- ii. Mission and vision shared created by top management and shared among the team members.
- iii. Excellent machine availability.

- iv. Talented problem solvers, with a deep understanding of variation.
- v. Mature continuous improvement philosophy.
- vi. Strong proven techniques to standardize.
- vii. Enough workers for the customer orders (Bowes, 2010; Wilson, 2010; Wong & Wong, 2011b).

b) *Steps to follow in the lean implementation.*

Various steps followed in the implementation of Lean are as follows:-

- i. *Learn about lean concepts and lean thinking.* Before implementation, it is very important to make the management aware of the concept and importance of the lean philosophy.
- ii. *Commit the management to lean.* The total commitment and support of the management helps in solving the problems which arise during the implementation of the lean production systems and is essential, for the success of the process. The leaders should always practice what they preach and lead by example so that workers under them can have a better understanding about the lean manufacturing and emulate the way leaders do things (Bowes, 2010; Wong & Wong, 2011b).
- iii. *Engaging lean expert.* Services of lean manufacturing experts should be obtained to help the units to implement the lean manufacturing systems. In particular, the shift from a push-based to a pull-based production system can potentially be quite disruptive. So, it is best to be guided by someone who has significant experience in this.
- iv. *Building awareness regarding lean.* The management should communicate the need and importance of lean implementation. Basic concept of lean must be understood by all the employees including the management. Trainings and workshops must be conducted to educate the employees about the principles and fundamentals of lean manufacturing.
- v. *Effective building of effective team.* Lean team should be built with members having qualities of openness, sincerity, respect, trust and also interdependence. Team members should accept different views and respect other people's

opinions, communicate and exchange values and beliefs pleasantly. Nevertheless, support and motivation is needed to motivate them to give more ideas for improvement (Wong & Wong, 2011b). Applying lean principles are not enough without building the human system to support lean practices and processes otherwise it collapses.

- vi. *Mapping the current state.* Value Stream Mapping should be done to carry out the baseline survey to identify wastes and non-value added operations in the processes.
- vii. *Developing the basic knowledge and skill.* Lean team members are trained to perform improvement activities related to industrial engineering and quality control.
- viii. *Designing the future Value Stream Map.* Milestones are set to form trial concept.
- ix. *Set up key performance indicators.* KPI are chosen which reflect true business improvements and related to reduction in waste.
- x. *Organize projects.* Long term projects (month long) and small (week long) Kaizen events be started to bring about process changes through PDCA, A₃ problem solving format and cause and effect analysis.
- xi. *Implement trial concept.* Units must implement lean as a test case at a small part of their operations before applying it through their entire operations, especially for the shift from a push-based to a pull-based system, since this can potentially be disruptive. It can be a single production line or a small series of processes.
- xii. *Monitor, evaluate and adjust implementation trial concept.* Review of the process should be done again and again as it is absolutely necessary.
- xiii. *Starting the change with a partial implementation of lean.* After the positive results are understood from the lean implementation, manufacturing units must initially implement only some of the lean manufacturing and gradually shift towards a more complete implementation.

- xiv. *Develop roll-out plan and follow-up.* It should be made sure that the changes brought out by the lean sticks to implementing visual management tools and working habits.
- xv. *Training and retraining along with regular audits.* Best practices should be identified and rewarded. Video and photo evidence of before and after noticing the improvements should be displayed for motivation. Surplus staff should be retained and integrated into the new production process (Bowes, 2010; Gesellschaft für Internationale Zusammenarbeit (GIZ),n.d.).Figure 2.26 describes the lean manufacturing implementation framework.

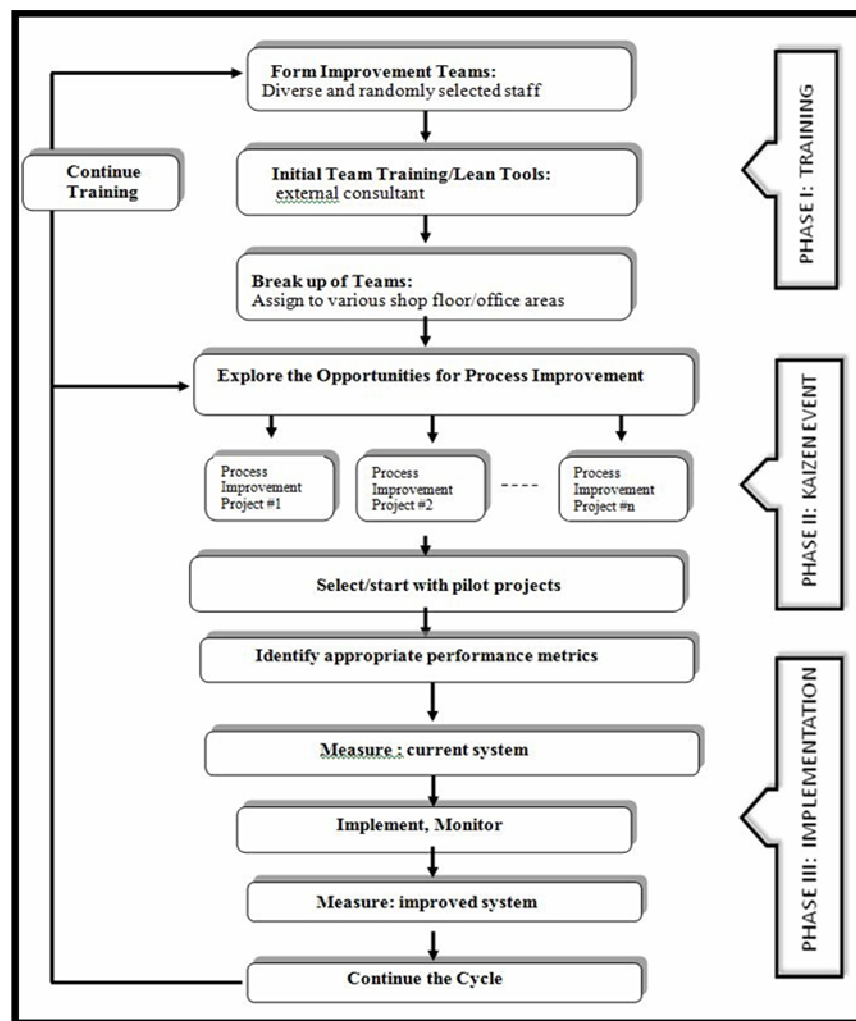


Figure 2.26. Lean manufacturing implementation framework. Adapted from “Lean Adoption in Small Manufacturing Shops: Attributes and Challenges,” by Djassemi, 2014, *The Journal of Technology, Management, and Applied Engineering*, 30(1), p.4.

c) Timeframe of lean implementation.

Lean manufacturing is a continuous process, as it gets stretched over months. As lean is a long term commitment, transformation into to a complete lean enterprise can take even 40 years. The time frame for implementing lean is described in Figure 2.27 and described below:

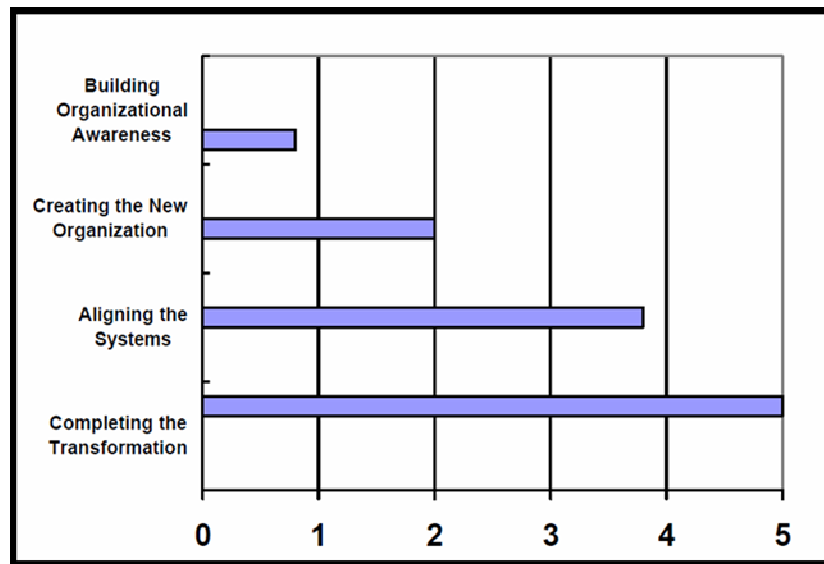


Figure 2.27. Time frame for implementing lean. Adapted from “*Lean manufacturing techniques*,” by McGivern & Stiber ,n.d.,p.3.

- i. *The first six months: Building organizational awareness.* Management should communicate the need and importance of lean implementation. Basic lean concept must be understood by all the employees including the management. It must be ensured that the lean manufacturing techniques are consistent with the organization’s long-term vision and also the organization’s readiness to make the transition to lean manufacturing. At this stage, a change agent is appointed.
- ii. *Six months to two years: Creating the new organization.* Organization must be redesigned to use lean manufacturing techniques. Training and development processes are implemented for leaders and employees to assist the transition to their new roles. Policy must also devised for excess people.
- iii. *Three years through four: Aligning the systems.* Bottom up approach must be used to bring about continuous improvement .All organizational support

systems should be in alignment and measured and the process monitoring systems should be ingrained in the new culture.

- iv. *Five years: Completing the transformation.* The transformation to lean manufacturing techniques is completed by the end of fifth year .It can be extended further with the integration of lean manufacturing techniques with suppliers .With the transformation of improvement from top-down to bottom -up, continuous improvement and organizational development becomes a way of life (McGivern & Stiber ,n.d.).

Adoption of lean has been spread inevitably beyond the auto industry, will change everything in almost every industry-choices for consumers, the nature of work, the fortune of companies and ultimately, and the fate of nations (Womack et al., 1990).

2.1.8 Performance measurement through manufacturing key performance indicators.

“It is an immutable law in business that words are words, explanations are explanations, promises are promises but only performance is reality.”

Harold Geneen(as cited in Weylman,2013,p.61)

Performance measurement is the important diagnostic tool which can be performed in terms of key performance indicators (KPI), quantifying processes for the effectiveness of the intended action. Effective assessment is very important for the timely and reliable measurement of the improvements (Andreeva, 2009).Performance of a manufacturing unit measured as KPIs are generally considered for the evaluation of the production effectiveness but it should be integrated to the company's performance measurement. The performance measurement gives feedback to managers and presents the information for the planning, monitoring and improvement of a business strategy (Shehi, Guxho, & Spahija,2012; Spahija et al.,2012; Tupa,2010). KPIs are used by an organization to evaluate its success of the activity in which it is engaged. They are the quantifiable measurements, reflecting the critical success factors of an organization. They differ depending on the organization as it reflects the organization's goals; the goals for a particular KPI may change as and

when the organization's goals change, or as it gets closer to achieving a goal (Shehi et al., 2012).

KPIs continuously help in reviewing the performance and providing feedback to users. As it captures relationship between actions and measures, the performance gap can be easily ascertained (Perera & Perera, 2012). KPI report acts as a health check on the performance of the company by providing results in some important areas. These assessments often lead to the identification of potential improvements, and as a consequence, performance indicators are routinely associated with 'performance improvement' initiatives. *By using KPIs, a company can establish the baseline figures against a number of important areas.* Some common KPIs used by an apparel unit are productivity, operators efficiency, ratio of direct operators to indirect operators, Levels of defects per hundred units (DHUs), cost of production, lead time, plant efficiency, line efficiency, work in progress, dock to dock, SQDMC (safety, quality, delivery, morale, and cost), labour productivity, through put time, floor space, workers used, labour utilization, retention time, processing time, line balancing, weekly delivery output and percentage of rework (Collyer, 2010; Gamage et al., 2012a; GTZ, n.d.; Spahija et al., 2012). Four key performance indicators selected for this study are productivity, efficiency, work in progress and quality which are described in detail below:-

a) Productivity.

"What you get out of an activity for what you put in is productivity."

Jackson Grayson (as cited by Saurabh, 1999, p.14)

Productivity is the relationship between input and output. The output in garment factories can be in the form of pieces of finished garments in sewing section, metres of fabric inspected in inspection section, cut components in cutting section, or number of garments ironed in the ironing section, whereas the input of the sections or departments within the garment factory could be in the form of man-hours, machine hours, metres of fabric consumed or electricity consumed. In simple words it is concerned with the efficient utilization of resources in producing the goods.

Therefore, Productivity= Output/Input

The output and input both can be measured in physical units or in financial terms depending on the organizational needs. Labour input is generally measured in physical units like number of operators employed, minutes, hours, days or months. Capital inputs like machines can also be measured in terms of time. In garment industry, productivity is measured in terms of number of garments produced per sewing machine per shift or per operator per shift.

There are three methods for the measurement of productivity as described below:-

i. *Physical productivity measurement method.* It uses the quantity of output and input as data for calculation.

- Labour productivity=Volume of output/Volume of labour input
- Material Productivity=Volume of output/Volume of material input
- Machine Productivity=Volume of output/Volume of machine input
- Energy Productivity= Volume of output/Volume of energy input
- Total physical productivity=Total volume of outputs/Total volume of all inputs

Average Machine productivity is 9.99 shirts /shift and total labour productivity is 7.88 shirts/shift in Indian apparel industry (Bheda, 1997) while that of the ladies blouse is 10.18 pieces/shift.

ii. *Value productivity measurement method.* It uses the value of outputs and inputs as data for calculation.

- Labour productivity=Value of output/Labour inputs
- Material Productivity=Value of output/Value of material inputs
- Capital Productivity=Value of output/Capital inputs
- Machine Productivity=Value of output/Value of machine input
- Energy Productivity= Value of output/Value of energy input

- Total physical productivity=Total value of outputs/Total value of all inputs

iii. *Value-added productivity measurement method.* This method uses the value of outputs and inputs as data for calculating, where the

Value added=Current income (before tax) +personal expenses + financial costs +rent +tax+ depreciation cost. This type of method is used where organization has diverse outputs or have expensive raw material and is as follows:-

- Labour productivity=Value Added/Labour inputs.
- Capital productivity=Value added/Capital (Bheda,2006)

Productivity acts as the basic yardstick of an organizational health and is one of the most popular metric in the industry. It is said to be high when more output is derived from the same input, or the same output is obtained from a less input (Kachru, 2007). This does give an indicative figure, but, one should refrain from comparing this figure from one factory to another unless both are producing the same garments (Ambastha, 2012).

b) Efficiency.

“Efficiency is doing things right while effectiveness is doing the right things.”

Peter Drucker(as cited in “Are You Doing Things?”,2012)

It is the comparison of what is actually produced or performed with what can be achieved with the same consumption of resources (money, time, labour, etc.).Line efficiency is defined as “percentage utilization of available time” Formula for calculating efficiency is given below:-

$$\text{Efficiency} = \text{SAM produced/Utilized minutes}$$

SAM produced = Achieved production (Garment produced) X Standard minute value

Utilized minutes =Number of Operators X Number of working hours
(Ambastha, 2012,p.32)

c) *Work in Progress (WIP).*

"The key is to have minimal buffers, but design them for maximum protection."

Umble & Srikanth(1997)(as cited in Lean manufacturing quotes,n.d.)

Work in progress is a direct result of over production and waiting. Every imperfection in the system creates a requirement for the work in progress. Therefore, work in progress is also known as the mirror of the wastes that the system has. It means that the number of garment or parts made during production in the factory at any one time. WIP of garments is expressed in the number of pieces by simply recording daily production figures between each process and accumulating the difference between sequential processes (Gibson, 2008). It is the inventory that begins the manufacturing process and it is no longer included in raw materials inventory, but it is not yet a completed product. A buffer WIP in between the operations helps to overcome the problem like machine breakdown, and bottleneck operations (constraint to throughput that limits the volume of work that can be completed in a workday).It also helps in balancing the workflow. It can be measured in the whole factory, in a production line or between two operations in terms of number of pieces or number of minutes of workload. Formula for work in progress is given below:-

Work in Progress in line = Total number of pieces in the line (pieces)

=Total number of pieces unloaded from the line- Total number of pieces loaded (Ambastha, 2012, p.26)

d) *Quality.*

“Quality is an endless journey: like walking towards the horizon-no matter how far you walk, it does not change where the horizon is.”

Bernard Fournier (as cited by Ho, 2002, p. 241)

In simple terms, quality can be interpreted as the “Customer’s expressed and implied requirement which are met fully” (Bhatt & Raj, 2006, p.3).Dr. Shigeo Shingo devised a special formula for quality control as given below:-

Quality control= Poka-Yoke techniques to correct defects + Source inspection to prevent defects = Zero”

The concept of quality has changed over the last decade. Traditional definitions have focused on conformance to standards (Kachru, 2007). Quality is stated as ‘the totality of features and characteristics of a product or service that bears on its ability to meet a stated or implied need’. It is ‘fitness for use’ and ‘conformance to the requirement’. New definitions have emerged as ‘providing extraordinary customer satisfaction’ or ‘achieving value entitlement’ (Ho, 2002,p.5). It can be measured in different ways as follows:

- i. *Defects per hundred units (DHU)*. It is the ratio of number of defects per lot or sample, expressed in percentage. It is possible that one garment may have more than one defect. Each defect is counted separately as every defect represents additional workload of repair and rework. This is a very important measure of quality on production floor and the analysis of this data can also highlight quality bottlenecks. Formula for calculation of defect hundred unit is given below:-

Defects per hundred unit = Number of defects found/Number of units inspected X

100 (Ambastha, 2012, p.31).

- ii. *Percentage defective level*. It is the basic measure of quality percentage that most factories use at the end line and in the finishing department. It is also called defect percentage. This is calculated on hourly, daily, line wise or on complete order. Factories measure defect percentage on hourly basis to continuously monitor the quality. Lesser the defect percentage, the better is the quality performance. Formula for calculation of percentage defective level is given below:-

Percentage defective level= Total defective garments/ Total garments inspected X 100

2.1.9. Studies related to lean.

“Lean is a way of thinking, not a tool, used to look at your business whether it is manufacturing, service or any other activity where you have a supplier and a customer.”

Wang & Huzzard(2011,p.2)

Georgia Tech Research Institute examined the effects of implementation of the modular manufacturing concept with the coordination of the efforts of flexible work

group on productivity in an apparel industry. For this, two different views and methods were analyzed and the most applicable method which was found effective and flexible was adopted. Teams of cross trained workers in several operations were engaged, which carried out the entire assembly processes and moved around in a group to alleviate the bottlenecks. The emphasis was laid on the group effort, employee involvement, quality assurance at the source, and short throughput time as it provided simple and efficient means for manufacturing garments on the factory floor effectively. It was found that productivity increases after the formation and working of modular cells in the production floor (Blecha et al., 1993).

The opportunities for the application of lean manufacturing tools in a high mix, low-volume traditional manufacturing factory floor setting were explored. The impact of the method of implementation, specifically the team structure and dynamics at the floor level on the success of lean was also assessed. Lean tools like Value Stream Mapping and Pareto analysis were used to investigate the impact of individual empowerment and accountability of the team on the new process sustainability and improvements. Goodson's rapid plant assessment rating sheet was used to assess the plant's use of lean manufacturing techniques. With a score of 27 out of a possible 121, a high potential to improve their use of lean manufacturing techniques was observed. Value Stream Mapping and associated analytical tools were used to explore the opportunities to streamline the flow of products on the floor with a focus on reducing the inventory and improving the quality (Dudley & Rosenfield, 1995).

With the aim to develop a well defined and categorized tool kit, for proper understanding, Hines and Rich (1997) explored various value stream tools namely process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis and physical structure mapping. These tools were derived from different fields such as industrial engineering, logistics, operations management and systems dynamics. These tools were used in a manufacturing unit to interpret the value stream. As a result these tools were found very useful for mapping work, and were used in a follow-up project for waste removal both inside and between the organizations.

A cellular manufacturing system implementation framework was created in the master's dissertation by Kilpatrick (1997) to analyze the manufacturing systems

and assess its impact on the performance of the manufacturing unit. Implementing the cellular manufacturing in the unit eliminated a large quantity of storage time ,transportation time (distance that parts travel to be processed were minimized), shipping time(moved production to the customer location) and improved the quality of products through the implementation of Poka Yoke devices(eliminated the inspection altogether).It was concluded that the cellular layout actually produced what, when the customer needed, and in the quantity the customer demanded, with less capital investment in inventory and the reduction in the customer lead time .

With the aim of examining the productivity levels achieved, factors associated and the scope for improvement by apparel manufacturers in India, a survey was conducted by Bheda in 2002. The data was collected using the interview schedules from 3000 active garment manufacturers and 36 manufacturers of domestic and regional brands from major apparel producing centers like Delhi, Mumbai, Bangalore and Chennai .Eighty eight apparel manufacturing units producing ladies woven top and having a capacity of more than 35 sewing machines were selected by judgment-cum-quota sampling method and personnel's were interviewed. The findings revealed that the performance of the apparel units was quite low. Average machine productivity was found to be 10.03 shirts per sewing machine per shift, while the labour productivity mean was 8.03 shirts per shift. The machine productivity showed a positive correlation to machine, operator and labour productivity with coefficients of 0.58, 0.58 and 0.41 respectively. The factors found associated with productivity were the product category, education level of operators, production system, payment system, presence of industrial engineering cell, rewarding creative suggestions, setting production standards and trainings. It was found that all the factors if controlled by enlightened techno-managerial team would lead to increase in productivity.

Greene (2002) in his doctorate research empirically tested the difference in the pattern of adoption between mature lean companies using a Lean Maturity model measuring from level-1(*Awareness*) to Level 2(*Sporadic Implementation*), Level 3 (*Formal Implementation*), Level 4(*Completed Implementation*) and Level 5(*Continuous Improvement*).Data was collected by sending e-mails to 400 individuals from 475 companies and 40 different countries. Results revealed that setup reduction and Total Productive Maintenance was adopted at lower-than- expected rates for all

types of value stream, while rest of the tools such as 5S, Visual Control, Kaizen, and Kanban were implemented at a high level.

The effects of three contextual factors namely plant size, plant age and unionization status on the likelihood of implementing 22 manufacturing practices in a lean production systems were examined by Shah and Ward (2002). The data was collected from the sample consisting of approximately 28,000 subscribers to Penton Media Inc.'s manufacturing-related publications. The questionnaires were mailed to the managers of plants belonging to many manufacturing firms, and 1757 completed responses were received and analyzed. Their results indicated that although the plant age had some impact on the implementation of lean practices, the direction of the effect was not always as predicted. Only three lean practices showed significant positive association with the age of plant as compared to 14 other instances. Large plants implemented 20 lean practices more extensively in comparison to small plants. There was a strong support for the influence of plant size on lean implementation, whereas, the influence of unionization was less pervasive than the conventional wisdom suggests. Four Lean bundles were formed by combining the similar practices which were found to be contributing substantially to the operating performance of plants.

In a project by Jongprasithporn and Jitjaicham (2003), the Preventive Maintenance Techniques were applied to improve the machine efficiency capacity. Problem of breakdown were also identified and preventive maintenance programs daily, weekly and monthly were undertaken to eliminate the breakdown times. The results revealed that there was an overall improvement of 11.46%, the mean time between failure increased from 62.89% to 73.99% and the mean time to repair was decreased from 19.98 hrs /breakdown to 13.38 hrs /breakdown i.e. 33.03% leading to reduction in the breakdown time.

The lean enterprise assessment tool (LESAT) by Hallam (2003) evaluated 40 criteria critical to a lean enterprise. The criteria were divided into 4 groups of 10 with each group corresponding to categories of leadership, people, infrastructure, and lean concepts. Practices included in the leadership were communication ,complexity and variability, customer-centric leadership, flexibility and ability to change, hoshin planning, metrics and performance measurement, root cause culture, social and

environmental responsibility, thriving unpredictable times and value stream organization. The practices included in people were cross training and flexibility, empowerment, leadership development, leveraging ideas, new employees and hiring, rewards and recognition, safety, succession planning, teams and work or life balance. Practices included in infrastructure were business and competitive intelligence, environment or green business, facility optimization, information systems, knowledge management, lean accounting, lean product development, lean sales and marketing, lean supply chains and quality assurance. Practices included in lean concepts were 5S or Visual controls, A3 project management, Cellular manufacturing, Kaizen and Continuous Improvement, pull manufacturing or JIT or Kanban, Quick Changeover, Standard work, Total Productive Maintenance (TPM), Training Within Industry (TWI) and Value Stream Mapping (VSM).

Various critical factors that constituted the successful lean implementation within manufacturing industries were identified by Achanga, Shehab, Roy, and Nelder, (2004). Comprehensive literature reviews and visits to 10 small and medium scale units based in the East of the UK were conducted in order to highlight the degree of lean manufacturing utilization within these companies. Leadership, management, finance, organizational culture, skills and expertise were found to be the most pertinent and critical factors for the successful adoption of lean manufacturing within SMEs environment.

A study was conducted on the utilization of the concept or principles of lean manufacturing systems to improve the effectiveness and efficiency of the production processes in the manufacturing organization. The main purpose was to see if the organization had the basic characteristics in place in order to implement lean manufacturing systems. It also identified and determined the effectiveness of the techniques in order to facilitate efficient and improved productivity along with continuous improvement. It was found that the organization had the basic elements of stability in place, prior to any of the changed initiatives. The elements associated with the concept of basic stability included – manpower, machines, materials and methods – the 4M's. Concepts of continuous improvement were clearly understood by all the employees after the lean training. Lean manufacturing was found effective to enhance the productivity (Jozaffe, 2006).

A German firm, Lean Alliance conducted a survey shedding light on the concept of lean production, tools, importance of lean philosophy and management behavior. The critical success factors for sustainable lean implementation were also investigated. A self administered online questionnaire was used to gather primary data from a number of organizations that had applied the lean principles. The sampling frame consisted of general managers of the organization which included 65 clients located in 170 different sites spread over 23 countries using the lean concepts. The main findings of the study were that the cultural and leadership aspects played a more important role than the lean tools. Employees pull and management push were the main factors identified for lean initiation. Kaizen was not found important in successful implementation of lean (Ahrens, 2006).

An article by Salem, Solomon, Genaidy, and Minkarah (2006) presented a study of a Lean construction project in which specific lean construction elements were tested. Each technique was evaluated in terms of its impact on the performance of the project. Based on the findings of the study, a new “lean assessment tool” was proposed to quantify and evaluate the results of lean implementation. The assessment tool evaluated 6 lean construction elements namely last planner, visualization, huddle meetings, first-run studies, 5S’s, and quality. Each item was rated in a linguistic scale with six values: *none* (N), *very low* (VL), *low* (L), *moderate* (M), *high* (H), and *very high* (VH).

A research was conducted to determine the impact of world-class manufacturing practices on the operational performance of small manufacturers. The survey analyses as well as the case studies methods were used to collect data. It was found that the world-class manufacturing practices had a positive impact on the operations of small manufacturers but, requires the support by the correct underlying philosophies and principles. Barriers encountered while trying to implement the practices were also identified namely untrained unskilled work force with poor work ethics, breaking down old habits, size and age of company, manpower , time, lack of interest, contract manufacturing and old-style management. It was found that the philosophies and principles guiding world-class manufacturing were more important than the individual practices. Lean manufacturing practices, supply-chain management practices, quality practices were rated on 5-point scale. Performance improvement was achieved in terms of productivity (39%) and profit (7%). It was

revealed that misapplication of practices and the poor performances often led to an attitude of cynicism and disillusionment. It was concluded that in order to achieve significant improvements in quality, lead times, inventory levels, costs, productivity, and profitability, individual practices must be implemented as components to an overall strategy specified by world-class manufacturing principles and philosophies (Johnson, n.d.).

A dissertation by McGrath (2007) was carried out to determine the extent at which the Lean principles were implemented in small numbers of Irish manufacturing companies in the South East Ireland. It also provided a theoretical framework of implementation of Lean. The case study method including in-depth interviews of the officials was used to gain more understanding of the implementation phases of lean. The results revealed that the companies complying lean had made great improvements in terms of reduction of inventory and waste. The major benefit that the companies gained after implementing lean were the continuous improvements delivering sustained value to customers and providing platform for the future growth. It was found that lean compliance acted as a strategic tool to improve competitiveness of the unit. Major barriers identified were lack of key management support, no long term vision, workers lack lustre attitude and narrow view of lean. Importance of team culture and level of support of managing director in implementing the overall lean initiative also identified.

A study by Goforth (2007) investigated the application of lean principles in the manufacturing industries to derive the most benefits of lean. It also determined the appropriateness of the implementation of lean principles in the textile industry. A road map was framed for implementing the lean in a textile firm along with the listing of common barriers to lean implementation and best practice checklist for both Value Stream Mapping and the 5S system. Information regarding best practices was collected by conducting open-ended interviews with 11 different textile companies, selected through the convenience sampling method. The implementation model proved to bring about performance benefits in a textile industry. Main barriers identified were cultural change, resistance to change, disconnect and long term benefits.

The doctorate dissertation of Achanga (2007) developed an impact assessment framework for lean manufacturing within small-to-medium sized manufacturing firms. The current level of lean manufacturing usage by 10 small and medium scale units based in the Eastern UK helped in identifying the best practices from companies who had successfully implemented the lean manufacturing within their premises. Key factors for implementing lean manufacturing were also identified. Three major factors of impact assessment were identified and were considered in the framework. Results obtained from them were then fed into the final system. The developed system visualization enabled the potential lean users to make forecasts on the relative cost of lean projects upfront, anticipate lean benefits, and realize the degree of lean readiness.

Various case studies of firms in which the Missouri Enterprise was engaged as the facilitator and consultant were presented by Fargher (2007) in his research paper. Two workshop simulation games were developed and used to orient the participants towards the lean manufacturing touching on all aspects of lean. The operations were minutely observed to identify the non -value added activities and later on the layout of the production floor was changed to reduce the material handling and decrease the distance between operations. Process operations were integrated and visibility was provided to allow operators to take decisions for the problem solving. Lean implementation in all the companies started with the Value Stream Mapping, Kaizen Blitz focusing on target areas and then collection of performance improvement data. Most companies made 35 to 75% improvements on production lead time; reduced their production costs by 10% to 25 %, increased the on time deliveries rates from 50% to 90% with lead times and increased their capacity by 20 % to 50 %.

The study by Andersson (2007) had investigated the implementation of the lean philosophy in an organization. An investigation was carried out in 4 medium scale companies in the South and Western parts of Sweden. Interviews and questionnaire methods were used and the information was collected from the managers and workers to compare the lean companies with companies that were not working with lean. The results revealed that all four companies were traditional and needed to implement lean production in order to accomplish more in their own organization with teamwork and get more engagement from the employees. With this realization, lean was implemented in same pattern in all departments and it worked quite well. Implementation started with basic lean training and appointment of

improvements teams. A pilot project was implemented in a small easy visual area and the positive results were achieved which were later extended to the whole department. Changes were observed in the employees as they felt more secure in their work with the awareness of their companies' goals, visions, current orders and economy balance with the use of lean. It created assurance among the employees that the company has a long term interest to develop the business. All the employees were found more involved with their work and work environment became much better with the introduction of lean.

In order to improve the productivity in the NCR, a survey of 10 factories was conducted under which these companies were rated and 300 people were assessed. The main aim was to analyze the current systems and advise ways to improve overall productivity. The survey was done in two parts, at first, it analyzed the factories, and, in the second, it evaluated the personnel. A comprehensive checklist was developed which covered every department and each point on the checklist and awarded a value of 1 to 5 points, 5 being considered as an International benchmark. The points awarded were added and a percentage score was calculated. The cutting department scored 48 -50%, and many weaknesses were observed in the cutting department during the survey. It was found that the staff was not sufficiently fabric conscious. Poor floor layout , unsystematic work flow, poor quality cutting tables, manual layering of fabric, more end losses, low fabric width utilization, poor remnant handling, poor positioning of numbers, no operator efficiency monitoring, no maintenance of scoreboard and improperly managed fabric reconciliation system were the few of the weaknesses identified in the survey. Thus improvements were implemented. One of the remedial measures implemented was of making the proper marker according to width, which led to saving of 10cms per garment or 9.5% of fabric. In another such intervention, when markers were remade on a wider width, a saving of 2.76% fabric was achieved. Various recommendations for improving efficiency and production in cutting department were suggested .These included accurate fabric reconciliations, establishment of standard times for each process, introduction of operator monitoring system, investigation of cutting room layout and the workflow, proper management of end pieces and remnants. Markers made were as per the fabric width, use of trolleys and other work aids for work transportation and introduction of simple laying-up aids (Methods Apparel Consultancy, 2007).

Importance of work in progress and its effects on the functioning of the factory was explored by Gibson (2008) as it is considered one of the fundamentals in building a 'lean' environment in a business. In controlling WIP, role of Fast React Systems(a global software-based solutions for the apparel industries,)which enables businesses to reduce lead times, and inventory, to improve productivity and live up to customers' demands for fast and accurate information was discussed.WIP depends on the product type, production system and subcontracting. Suggestions were given to reduce WIP which included training of workers regarding WIP concept, its measurement, planning and communication, regularly monitoring and improving. Twenty percent reduction in WIP that is reduction by 2.8 days led to further reduction of the working capital investment by \$ 157,500.

Performance assessment of apparel units in NCR was conducted with the aim to highlight the improvements required. It included analyzing the current production and management systems, investigation of the shortcomings in each department and providing recommendations for improvement. Extensive survey of 10 apparel units in NCR was conducted which had orders in excess of 2000 pieces, with 200 to 1000 operators, out of which some operators were on the company payroll and who were willing to share management cost information. The survey included the analysis of the production department, the personnel involved and potential savings in an average factory. Most of the companies had no system to measure their performance. Work Study, and finishing departments showed the lowest levels of performance, production and cutting departments scored around 52-53% and hence were unaware of their competitive status. The average assessment score of various departments varied as the work study was done, quality at 48%, fabric was at 58%, trim store at 56%, cutting at 52%, mechanics at 57%, production at 53% and finishing department was at 45%. The key problem areas identified for improvement were: reducing absenteeism, high labour turnover, WIP, throughput time, lack of innovation and technology. The recommendations given were training and development of managers, supervisors, operators, implementation of standard times and monitoring control systems in the cutting, sewing and finishing departments, conducting work study , layout improvements in cutting and finishing, introduction of SOP's and their proper use, establishment of in-house operator training schools and properly constructed management meetings. A comparison was carried out on the basis of

performance between the factories which had implemented the recommendations and those not implemented the recommendations. Positive effect on efficiency was statistically tested among the improved industries (Thomas, 2008) implementing the recommendations.

A practical study was carried out by Ramesh, Prasad, and Srinivas (2008) in a manufacturing industry with the main aim of drawing the current state Value Stream Mapping process. Various problems were identified by the Industry in terms of non-value added time. A plan of action was suggested for improving the Future State Value Stream Mapping in terms of reduction in the set up time and cycle time. Questionnaires were used to collect the data regarding the awareness, knowledge and implementation difficulties faced by the employees and the management in its effective implementation. Unnecessary or excessive human motion, inventory, and over processing, waiting waste types were the identified. The reductions in the cycle time after the implementation of Future State Value Stream Mapping was estimated, and it was suggested that a training program was required for the effective implementation and cultivation of lean thinking among workers.

One of the researches by Ramdass and Pretorius (2009) presented a case history and experiences of a South African clothing manufacturer with qualitative results of the implementation of modular manufacturing. After the successful implementation of modular manufacturing supported by upper management and committed employees, the organization benefited overall as the productivity of the line improved by 10%, while labor efficiency improved by 15% and the morale of the employees improved with education, training, open communication and above all, being treating them with dignity.

The adoption of lean manufacturing in the electrical and electronics industry in Malaysia was explored in 14 key areas of lean manufacturing namely: scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, tools and techniques. The respondents were asked to rate the extent of implementation of lean in each of these areas and it was found that most of them were “moderate-to-extensive” implementers of the lean (Wong et al., 2009).

An online survey of 117 companies by Viswanathan and Littlefield (2009) was conducted to assess the world class performance and improvement after lean implementation. It was found that 96% order delivery, 3% decrease in inventory carrying cost, 2% decrease in inventory writeoff, 4% decrease in customer lead times and 4% decrease in manufacturing cycle times were achieved by these companies. Comparative assessment was conducted on the basis of organization, process, knowledge management, technology and performance management. In order to supplement the online survey, telephonic interviews were conducted to gather information on lean strategies, experiences and results. It was found that executive leadership, lean teams, presence of centre of lean excellence in the unit, continuous improvement, demand driven manufacturing, display of real time data and right sized Kanbans and trainings provided by professionals made quite a difference in lean implementation.

Ratnayake (2009) carried out an investigation into the role of workflow fluctuation on labour performance. Data was collected from 42 garment manufacturing lines in 14 different factories of Sri Lanka. The solution was provided in the form of an algorithm to balance the production line and the sub-cells. This concept was successfully implemented in a garment manufacturing company in Sri Lanka. The evaluation of the performance indicators revealed that the production efficiency increased by more than 10%, while drastically reducing the defect percentage. The operator absenteeism was also significantly reduced. Style changeover time was another problem identified leading to low labour productivity. A newly proposed 5 step set-up quick change-over procedure was adopted, set-up activities were streamlined, average first day production efficiency of the factory was increased by over 80%, and this led to the significant reduction in the set-up times.

Another research was conducted by Ratnayake, Lanarolle, and Marsh (2009) to examine the application of cellular manufacturing techniques and its benefits in 14 garment manufacturing companies in Sri Lanka. Investigation into the low efficiencies in the manufacturing garments was carried out and the major problems identified were: WIP fluctuation, long lead-time, high percentage of rejects, low efficiency and operators de-motivation. The level of WIP and its variations were analyzed across 3 lines for each company giving a total of 42 garment manufacturing lines. The data collected revealed that the WIP fluctuation within production lines was

very high from 79.2 to 165.6%.The root cause analysis of the problems revealed that the poor line balancing was the major factor contributing to the WIP fluctuation. A lean cellular manufacturing model was then proposed as a solution to reduce work in progress. The proposed sub-cell concept led to the reduction of the WIP level and its fluctuation reduced significantly and with many advantages. The validation of the model was tested by implementing the concept into a garment manufacturing company with 20 production lines. It led to 12% increase in the production efficiency, equivalent to US\$ 1.23 million annually. The new sub-cell concept changed the organizational culture and made the production lines more flexible through the motivated cohesive team. The operators were motivated with higher earnings through higher productivity and dignity.

Puvasvaran, Megat, Hong, and Razali (2009) determined the roles of communication process in ensuring a successful implementation of leanness in the manufacturing companies. A study was conducted in a knitting section of a manufacturing industry in Malaysia. The company selected had implemented the various lean manufacturing tools, such as Continuous Improvement, 5S, Visual Management, Cellular Manufacturing, VSM, TPM and Pull Production for about two years. A 5-point scale questionnaire was used as the study instrument. This questionnaire was distributed to 45 employees working in a knitting department and also to 8 top management people. The degree of leanness (DOL) and degree of managerial commitment (DOC) was measured in terms of nine principles of lean manufacturing, worker empowerment, and training, group problem solving and quality leadership. The results indicated that both the degree of leanness and commitment of the company were moderate. Degree of the roles of communication process (CP) was also measured in terms of worker empowerment, training, group problem solving and quality leadership. The result indicated that the degree of communication of the company was moderate.

A study was conducted in Jharkhand manufacturing industries by Dalgobind and Anjani (2009) to identify and customize an implementation plan as well as to carry out the selection of the required lean tools in the light of companies long term vision, mission and corporate strategy. The data was collected from 84 small-scale industries with the help of structured questionnaire. The results revealed that the operations and performance of small manufacturers was greatly improved through the

implementation of lean manufacturing tools and techniques. It was suggested that the management should come forward through the clear understanding, and correct underlying philosophies and principles to support lean manufacturing practices. As a result the product quality and productivity was improved through the application of lean manufacturing tools and techniques in engineering industries.

A study to highlight the differences and similarities of performance between the companies of Bangladesh and other countries of the world using lean or other similar philosophies was conducted in 9 garment firms with a semi- structured questionnaire to see the extent of lean implementation and the performance improvement. Interviews were also conducted to gain a detail insight of the respondents. The results revealed that some of the organizations had several misconceptions about the lean production techniques. Their initiatives towards adopting this technique brought several improvements for the companies, that is 10%-60% improvement in productivity, 10%-60% improvement in quality, 26.7% reduction in lead time, 26.1% reduction in manufacturing cycle time, US \$1.10 reduction in per unit cost and 30.1% reduction in inventory holding time. It was concluded that lean production had brought significant performance improvements for garment manufacturers (Farhana & Amir, 2009a).

An investigation of manufacturing performance improvement through lean production in Bangladeshi garment firms indicated that the selected companies had adopted a wide variety of lean tools and techniques and gained many performance improvements. Companies that had adopted lean manufacturing as a working philosophy within their organizations had made significant improvement in terms of their operational performance even if it was in a modified format that best suited their particular business culture. It was revealed that business challenge had been the most important driving factor that led the companies to practice lean. Different changes were experienced by the firms such as the cultural change, education of workers and suppliers, empowerment of employees, commitment of top level managers, relationship with suppliers, rearranging the manufacturing process and awareness (Farhana & Amir, 2009b).

A project of implementing lean was undertaken by Daghar Consuting group in two units of NCR and results revealed that in one unit, labour productivity rose from

9.6 to 10.5% , increase in efficiency from 45% to 49%, percentage defective from 8.5% to 5% and 36% improvement in WIP from 250 pieces-160 pieces. Improvements were observed in the other unit also in terms of labour productivity from 7.1 to 8.3% with 17 % increase while 45% increase in WIP from 454pieces to 250 pieces (Dagher, 2010).

A project on total productive maintenance was conducted by Rahi, Abhishek and Sharmila (2010) in Richa Global Pvt. Ltd. with the aim to introduce TPM in the organization. The researchers not only developed the implementation framework but also prepared the implementation manual for the major elements of TPM that is Autonomous Maintenance (Jishu Hozen) and Planned Maintenance along with forms and tables to be followed for the implementation of TPM. The project helped in understanding the goals and pillars of Total Productive Maintenance. With the implementation of TPM, the morale and job satisfaction of the operators increased as they started actively participating in various activities. It also minimized the unplanned shutdown and number of machine breakdowns. The operators took care of small maintenance issues which further led to the increase in the Overall Equipment Efficiency (OEE).

Different organizational factors important in the implementation process were thoroughly examined in a theoretical thesis based on a systematic literature review of 22 articles. Key success factors that enhanced the implementation process were identified as human resource practices, management style, organizational strategic vision, organizational culture and external partnerships. Advanced lean transformation across the entire enterprise brought many positive results in regards to developing employees as problem solvers and increasing the levels of work satisfaction, changing the management culture from command and other support areas improving their activities (Kovacheva, 2010).

Lean manufacturing is a proven approach for success in manufacturing industry. As the transformation to lean manufacturing system requires radical changes involving total reshaping of purpose, system and culture of the organization, but several organizations had failed in their attempt to implement it. Keeping this in mind, an investigation was carried in 60 firms in the Malaysian automotive industry. The influence of organizational changes on the lean manufacturing transformation was

seen very clearly. The respondents were chosen from those industries who were involved directly with lean manufacturing practices such as production and quality personnel. The findings of investigation showed that the organizational change factors such as change readiness, team development, leadership and management support, effective communication, employee training, employees' empowerment and review process have significant influence on the lean manufacturing implementation (Nordin et al., 2010a).

An exploratory study of the lean manufacturing implementation in 60 Malaysian automotive industries was conducted through a questionnaire survey to explore the extent of lean manufacturing implementation. Majority of the respondent firms were classified as in-transition towards adopting lean. The main barriers identified were the lack of real understanding of lean manufacturing concept and employees' attitude (Nordin et al., 2010b).

The productivity improvement pilot projects were carried out by international consultants and Bangladesh Knitwear Manufacturers Exporters Associations (BKMEA) team in four knitwear factories. Wastes identified in the processes in the production floor were: the losses in line balancing, excess motion, absenteeism, order changes, feeding, rework and non-value added activities. The benefits gained were 85% increase in labor productivity, 51% floor space utilization, 39% reduction in production costs, 75% lead time, better utilization of labour (70% reduction in numbers of helpers per production line), higher income per worker and retention of surplus labour through upgrading of helpers to operators (Stotz, 2010).

The master's thesis by Nina (2010) mainly focused on identifying and mapping a value stream. The main purpose was to identify and evaluate tools suggested in the literature and give suggestions of suitable tools to be used to analyze a value stream with the aim of maximizing customer satisfaction and improving the financial results. The work was related to the theoretical areas of production, production systems, Toyota Production System, Lean Production, and more specifically Value Stream Mapping. It was designed as a longitudinal case study, where quantitative methods consisting of time measurements and qualitative methods focusing on observations and discussions were used for data collection and data analysis. It was found that the actual processing time was less than 18.5 minutes, out

of the production lead time which was 16.7 days. Hence, great improvements were made by implementing the true lean transformation strategy. The main problem, identified was the communication gap between management and workers when it comes to implementation of changes. Suggestions for improvements included the appointment of change agents responsible for the change management, Kanban system, and education of the employees in lean tools. The findings to some extent were applicable to all other companies too.

Another study on waste reduction was conducted by Singh and Pramanik (2010) with the aim of identifying industrial waste in apparel production in Fine Fit Garments (Pvt) Ltd, Tirupur . Suitable lean tools like 5S and Value Stream Mapping (VSM) were used to reduce the identified waste. Organized manufacturing system through standardizing material and information flow was developed and implemented in a T-shirt manufacturing sewing line. The major waste identified was waiting time. Only 2% of total time was found to be value added time. Reduction of material loss due to 5S implementation at work place not only improved the value of product but also increased the monetary profit of the unit.

The study on the best lean manufacturing practices by Rose et al.(2011)focused on the feasible lean practices which were required to be implemented in order to be successful in lean implementation in small and medium units. Main barriers identified were financial and resources constraints. Feasible lean practices were proposed, among those that require least financial investment were 5S, visual control and display, standardization of operations, Statistical Process Control (SPC) and quality circle. SMEs should apply these practices first and then follow other practices such as Kanban, and small lot sizes. Kanban practices should be implemented once the production flow is efficiently run, with the minimum machine breakdown, quality problems and parts shortage. It was concluded that piecemeal implementation of lean practices would not get full benefits, but the proposed step methodology would help SMEs to improve their performance gradually.

Paneru (2011) conducted a study in the stitching section of a shirt manufacturing company which was facing problems like the low productivity, longer production lead time, high rework and rejection, poor line balancing, and low flexibility of style changeover etc. These problems were addressed through the

implementation of lean tools like cellular manufacturing, single piece flow, work standardization, and just in time production etc. Time study method was used as research tools in the conversion of traditional batch production (long assembly line) to single piece flow (small work cells). After implementation of lean tools, results revealed that there was a reduction in production cycle time by 8%, number of operators required to produce equal amount of garments by 14%, rework level by 80%, production lead time from two days to one hour and work in progress inventory from around 500 to 1500 pieces to a maximum of 100 pieces. Apart from these tangible benefits, operator multi-skilling as well as the flexibility of style changeover was also improved.

A project was undertaken in Bangalore by Naik, Sargunamani, and Ramatal (2011) in the cutting section of a garment industry to identify the non-value added (NVA) processes so as to eliminate them for saving time, cost and improve the internal throughput time (lead time). The supplier performance was also analyzed for cost saving. Stop watch method was used to note the total time taken for each garment to complete the process of operation from fabric received in cutting till the cut audit operation. Segregations of value added and non-value added activities were done. Time wastage noticed was due to waiting, negligence of operators and no proper identification; zigzag movement due to improper lay out and no standard operation being followed by the operator. After removal of non-value added activities, again the time was noted. Average cost savings achieved was estimated to the tune of Rs 3, 41,796 per annum. It was statistically proved that by eliminating NVA activities in cutting section, cost saving as well as improvement in internal throughput time was possible.

Single Minute Exchange of Dies (SMED) was applied in a selected apparel industry by Ulutas (2011) in her project to prepare an optimal standard procedure for the changeover operations on defined machines. With this, significant time savings were achieved with minimum investment. The methodology involved the identification of current setup time, dividing the processes into internal and external activities, transferring internal activities into external ones, minimizing the internal ones and the standardization of the whole process.

An investigation was conducted by Taj and Morosan (2011) to find out the impact of practice of lean operations and designs on the Chinese manufacturing performance, using the lean assessment data from 65 plants in various industries. The associations between various factors like operations practice, production design, and operations performance were examined. The results indicated that there was a significant effect of lean manufacturing practices among different industries, with the petroleum and hi-tech industries performing relatively better than others. In addition, the garment industry also performed very well in flexibility, indicating that it not only competed just on price, but also on rapid response. These results also supported the positive impact of lean operations on the performance of the Chinese manufacturing sector.

A research was conducted by Silva, Perera, and Samarasinghe (2011a) to identify factors such as suitable methods of implementation, order of implementation, challenges, how to overcome those challenges and benefits of implementing lean manufacturing concepts in the apparel sector of Sri Lanka. Data was collected from 15 apparel manufacturers in Sri Lanka using personal interviews and observation methods. The results revealed that lean were new to most of the Sri Lankan apparel manufacturers and the full benefit was not yet being achieved by them. Hence, the industry should go forward with lean adoption.

A suitable lean model was identified for the successful implementation in apparel industry in Sri Lanka. The findings revealed that lean manufacturing can be applied to apparel industries following the mass production practices and this can create a positive mindset in the employees. As implementation of lean concepts was still in the developmental stage, the full benefit was not yet achieved. But current situation suggested that the industry can go forward with lean and capitalize on its full potential. Importance of training, experiments, employee empowerment, right leadership, and Kaizen mindset in order to develop industry's own lean system was found out. A model was proposed which could be implemented after modification to suit the global apparel industry and other industries as well (Silva, Perera, & Samarasinghe, 2011b).

Nautiyal (2011) made a critical assessment of the profitability of the adoption of lean manufacturing practices by garment manufacturing units in Delhi-NCR region

and also disseminated the compiled information to the non -lean compliant garment manufacturing units. Interviews, observation and time study method, were used to collect data. The process of implementation and effectiveness of lean manufacturing was assessed through a comparative analysis of conditions existing before and after the implementation of lean. Results revealed that the different tools of lean manufacturing were used by different units on the basis of their requirement. A Value Stream Mapping was prepared for the existing assembly line and for the projected assembly line after the implementation of lean manufacturing practices. Interventions were done keeping in mind the feasibility and elimination of waste. Reduction of wasteful activities in all individual departments led to the successful lean implementation in the units.

The extent of the practices of internal lean manufacturing at the apparel manufacturing companies in Jordan was researched by Al-jawazneh (2011). Five internal lean manufacturing practices such as Continuous flow Production, Short Set up Time, Statistical Process Control, Employee Involvement and Total Production Maintenance were chosen. A survey questionnaire was filled by 140 managers of apparel units of Jordan. The results revealed that apparel manufacturing companies in Jordan followed the internal lean manufacturing practices to a very high extent, except for the practice of employees sharing which was given almost an average rating. The employees involvement in terms of being part of problem solving teams, getting the proper cross functional training, leading the improvement efforts and driving the suggestion programs was slightly lower, but, it was at the statistically accepted level. The TPM was also applied in the apparel manufacturing companies as they were dedicating a portion of everyday to planned equipment maintenance related activities, but maintaining their equipment regularly was still far away from being excellent.

Hodge et al.(2011)in their study analyzed the appropriateness of implementation of lean principles in the textile industry through interviews, plant tours and case studies on 11 textile industry plants, primarily located in North and South Carolina, USA. Interviews, plant tours and case-studies methods were used to collect data. Tool matrix of 11 plants showed that the Visual Management and 5S was being used by 10 of the companies and Value Stream Mapping in 9. Some barriers identified for implementing lean were the resistance shown by them to change both

shop floor employees and management; shop floor employees are reluctant to offer suggestions for improvements; disconnection among marketing, sales, product and development and mindset. Benefits identified were the smaller lot sizes; reduction of raw materials; reduction in product complexity; decreased inventory (by 50% in one company), reduced changeover times, increased production (after implementing 5S, one company experienced 16% gain in 1 month); cleared space for increased production, new business; reduced finished goods inventory; increased first pass quality (from 53% to 80% in one case); and the reduction in production time. The results obtained were compiled to create a textile specific lean implementation roadmap consisting of a list of barriers, a 5S system and Value Stream Mapping best practices checklists, and a recommendation model for implementing lean tools and principles in a textile environment.

Chi (2011) focused on implementing 5S in a manufacturing unit in Taiwan with the aim of meeting the customer's demand, bringing about improvement in working environment and enhancing efficient processes. This unit was not used to a clean working environment and had difficulty in meeting the customers' demands because of time consuming, and non-efficient process flow. Thus, 5S tool was implemented in the manufacturing company to rearrange and reset the working environment making it more efficient and more productive by streamlining and enhancing the process flow. The comparison between before and after 5S was also done. 'Sort' helped to decide between used and not used items. In addition, the company got more space from that. 'Set in order' improved the time required to search for tools. 'Shine' made the working environment look better than the previous situation. 'Standardized' and 'sustained work' helped in keeping all steps going. After the implementation of 5S, improvements were observed in the unit in terms of reduction in average time consumption in manufacturing by 38%. 5S was thus used as a first step of lean transformation throughout the company.

A roadmap as well as a framework was prepared and applied for those manufacturing companies of Bangladesh who were operating significantly below their potential capacity. The procedure included the studying of existing layouts and basic lean manufacturing tools like Value Stream Mapping (VSM) and Cellular Manufacturing. These tools were used to create new layouts aimed at enhancing the production system. The common garment selected was the T-shirt style of three of

their most prominent buyers naming Puma, M&S and G-star. Productivity, product travel distance, required workers and operation times were compared between existing layouts and the proposed layouts. Later the propositions were reinforced by using a simulation software ARENA to judge the sustainability of proposal as the implementation of the recommendations were both expensive and time-consuming. The productivity improved significantly for PUMA, M&S and G-Star by 46%, 10.34% and 14.4% respectively with the use of proposed layouts. The proposed layouts not only utilized the manpower and factory floor space in a better way but also helped in to develop a good relationship among the workers and management, leading to proper coordinations and integration of the factory production with the current level of resources (Chakraborty & Paul, 2011).

Four industrial case-studies were conducted in different electrical and electronics companies in Malaysia to investigate the approach of adopting lean, the tools and techniques, the changes in the organizations, the problems encountered as well as the lessons learnt. Interviews were conducted with the key personnel and it was found that each of the organizations had developed their own unique technique and methodology as was found fit with its current production system. They had also integrated other approaches such as six-sigma and quality control practices to support their lean initiatives. The most vital part when implementing lean manufacturing lies on the people and everyone in the organization needed the right tools and support to make positive changes happen and possess the thinking to enable to identify and eliminate waste. As the lean manufacturing requires systematic problem solving methods, it was suggested that companies which want to implement lean manufacturing should continuously train their people to 'think lean' and 'act lean', and support them by giving them the right tools. (Wong & Wong, 2011a).

The practical application study of Value Stream Mapping (VSM) and Single Minute Exchange of Die (SMED) in the production floor of a selected garment export industry was carried out by Marudhamuthu, Krishnaswamy, and Pillai (2011). The researchers used VSM efficiently by modifying the production floor to improve the production process. Various forms of non-value added activities identified were the high distance between the material floor and shop floor, excess transportation, excess motion and high machine setup time which led to a low production rate and high setup time. Future Value Stream Mapping was implemented by integrating all the

floors as a single floor. It led to the reduction in load carrying capacity, travelling distance and human fatigue and increased the production rate.

In another project, Quality Management was employed to improve the performance of the existing various issues in the manufacturing industry. The problem solving process was used which started with the problem statement of high rate of rejections and goal statement to reduce defect % to minimum level. Data was collected in terms of total checked and found defective for one garment that was executive shirt. Various defects were analyzed. Various tools like pareto chart, cause and effect analysis etc were used to identify the major defects. Broken threads, rundown, cuff up and down and unevenness was the major defects identified. Therefore, training was provided in all aspects of the operator's job to them. After training the data was again collected. It was found that reduction in defects were achieved from 4.42% to 1.95%. It was suggested that trainings should be provided on continuous basis to the workers (Kumar, Naidu, & Ravindranath, 2011).

Another research by Ahsan et al., 2011 was conducted with the aim to improve the working environment. Five day Kaizen activity was planned in the Youngone Sportswear Hi-tech company limited, DEPZ, Savar, Dhaka and a particular style of NIKE top was chosen. It started with training, 5S audits, identifying top 5 defects, and taking corrective action, regular maintenance of machines and visual hourly chart display. The effects were investigated during implementation. The Kaizen implementation reduced wastes and defects. Quality improved in terms of defects per hundred units, which reduces from 134 pieces to 51 pieces. WIP reduced from 152 to 106. Continuous improvement was emphasized to continue making further improvements in readymade garments industries.

An Innovative project was conducted on the Star Cones Loom by achieving the following the benefits through application of 5S. All the processes of the industry were analyzed and the corrections were made. It resulted in the reduction of the unwanted work and the effective utilization of resources in the industry. Training of workers helped in improving their performance in their day-to-day activities. The 5S adopted by the industry changed the worker's mentality, increased the production, led to continual improvements and enhanced the profit of the organization. It was found out that many organizations were not ready to adopt the lean due to the lack of

involvement of the people, unawareness of this policy and the huge cost involvement in the implementation. After implementing the 5S in the industry, various benefits were observed namely reduction of the stoppage time of the loom, defective items, material handling time, proper utilization of floor space, improvement in employees involvement and achievement of easier and safer work environment which further increased the overall quality of product (Sakthivel et al., 2012).

An exploratory study on implementation of lean manufacturing practices was conducted in the Dewas city, the industrial town of Madhya Pradesh. Various obstacles in the implementation of lean identified were namely lack of top management's interest, lack of training, lack of interest of employees, financial constraints and lack of well trained and experienced technical staff. Results of implementation of tools revealed that Kaizen was most commonly used methodologies followed by 5S, Six Sigma, Total Quality Management (TQM) and Kanban. Wastes especially overproduction and transportation was not only identified but also eliminated most efficiently by quality control department. It was observed that the company had non-effective use of staff talent and under utilization of expertise, skills, creativity, innovation, leadership, motivation, drive. Suggestions regarding empowering and giving responsibility to manage their work areas were given and implemented with positive results (Mehta, Mehta, & Mehta, 2012).

A research focusing on the adaption of lean principles in one production line of a selected large integrated ready made garments (RMG) manufacturing unit was conducted. Forty one sewing related operations were observed in the assembly line for different styled polo T-shirts and the Value Stream Mapping (VSM) tool was used to identify the non-value added activities. The research was conducted with the ultimate aim to not only identify the non-value added time but, also to analyze the root causes, increase value added time by redesigning assembly line and finally decrease the total manpower involvement without hampering the production efficiency and productivity. Future VSM was sketched and implemented. Non-value added activities were removed using the Poka Yoka concepts, JIT, 5S and TPM. It improved the productivity of current production system by 62% and also minimized the number of workers, reduced production lead-time and lowered the work in process inventory (Haque et al., 2012).

A theoretical research on 5S implementation was conducted by Ghodrati and Zulkifli (2012), reviewing the various previous studies about the benefits of 5S implementation and its efficiency in organizations. It was found that 5S supported the objectives of the organization to achieve continuous improvement in performance and productivity. The most important barrier for implementation of 5S effectively was identified as poor communication in the industry. Poor communication in an industry caused wasting of the resources, time and money, resistance to change and lowering of morale amongst employees. Another significant barrier identified was the space between managerial level and shop floor employees, the poor training and lack of awareness of 5S. It was concluded that the key of success for 5S was the continuous training of employees as the employees on their own were not capable of activating standardization of 5S as it was the only key to change the organization's culture.

Another research addressing the implementation of lean principles in a Portuguese garment industry was conducted by Gomes in 2012. It was found that the traditionally operated garment industries were facing problems concerning low productivity, long production lead times, high rework, and poor line balancing. The concepts of lean manufacturing were understood and a description and a critical analysis to the company's productive systems were done. The problem was acknowledged. Improvement proposals were suggested related to the layout change, Visual Management, 5S, Quality Management Practices and Cellular Manufacturing. The results observed many benefits involving less movement, transportation, and material handling. Increase of 14% in productivity in one month and an increase of 60% in profits in two months were observed.

A study was conducted by Silva(2012) to identify the applicability of one of the important lean manufacturing tool 'Value Stream Mapping' in the Sri-Lankan apparel industry and to identify and propose potential avenues for improving present level of VSM. The case study approach was used and the data was collected from the leading apparel manufacturers using personal Interviews and observation methods. A garment style was chosen and a cross functional team was formed to map the process. The current Value Stream Mapping was developed after making necessary observations and calculations. It was highlighted in the study that out of the 63 total processes carried out; only 11 processes were value oriented. Later on, a future value stream map was developed after identifying the various improvement proposals based

on lean manufacturing theories or pull system. It's application led to many positive results like reduction in lead time from 23,916 to 11,951 minutes ,increase in value added ratio from 0.087% to 0.22% and reduction in work in progress or inventory .It was concluded that VSM helped in the identification of wastes generated and visualizing possibilities of eliminating and reducing it.

The study investigating the challenges of application of lean techniques in a textile knitting factory in Sri Lanka was conducted by Gamage et al.(2012a). The purpose of the study was to investigate the challenges faced in improving the productivity through lean techniques in a less labour intensive batch production environment. The case study approach was used and the data was collected using unstructured interviews from management and non-management personnel, observations and archival sources. Unnecessary transportation of goods, overproduction, inventory, defects, over-processing, waiting and motion were the different wastes identified. Value Stream Mapping revealed that value added (VA) to non-value added (NVA) ratio was 4.64% .After implementing the lean, the ratio was improved to 9.73%.The result revealed that the unit which was running at 77.74% efficiency, with the recommendations implemented, the new process was expected to run at 83.17% efficiency. Thus there was a 5.43% overall productivity improvement with no or little capital investment. Therefore, the lean was found to be an effective tool to drive the company towards continuous improvement.

Another research was carried out in an apparel manufacturing factory of Bangladesh to assess the influence of lean implementation on manufacturing performance based on the lean performance indicators and to qualitatively compare the impact on the organizational culture with that of the Toyota Production System. The initial state of performance and improvements after the lean implementation were measured through the key performance indicators (KPI), such as dock-to-dock, on-time delivery, first-time-through, and fabric utilization.The impact of lean manufacturing on the organizational culture over the period of lean implementation was analyzed through interviews and direct observations of the personnel who were directly involved with the implementation process. The results showed that the lean implementation caused a reduction in the cost of production (10%), reduction of lead time (30%), and increase in plant efficiency (20%). Based on the positive trends of qualitative and quantitative performance indicators, it was concluded that the

organizations in the bulk apparel production industry could achieve positive cultural shift and gain financial benefits through the implementation of lean manufacturing practices (Gamage et al., 2012b).

Makhija (2012) employed SMED in a garment unit with the aim of reducing the style changeover time. The process included the measurement of changeover time performance and making of graph. After identification of internal and external set up time, most of the internal factors were converted into external factors. After reducing the measured factors effectively, the line was controlled and monitored till it reached the targets with approved quality. The set up time was drastically reduced from 8 hours to 4 hours, but, it still varied between 4 hours to 48 hours depending on the complexity of the style.

Kumar and Naidu (2012a) applied the problem solving methodology to solve productivity problem due to employee absenteeism in Apple garment industry. The process started with the stating of the problem and setting the goal to reduce absenteeism percentage. After brainstorming, the data was collected department wise in terms of number of working days, number of staff and absenteeism for the last 3 months. Various tools like pareto chart, cause and effect analysis and so forth were used to identify the major defects. Various remedial actions for improvement were implemented for one month which included training, use of protective accessories, providing better working and transportation facilities, salary raise, incentives and medical help and so forth. After implementation, the absenteeism was reduced from 11.05% to 5.80% within one month. It was thus concluded that absenteeism could be controlled with the involvement of management.

A survey on the awareness of Lean manufacturing concepts in the Indian garment manufacturing units was conducted by Kumar and Naidu (2012b). A questionnaire was sent to industries situated in Bangalore, Chennai, Coimbatore, Madurai, Tirpur, Kolkata and New Delhi. The main aim of the study was to identify the status of lean practices, challenges faced by it and the benefits derived in the garment manufacturing. The results showed that the status of lean implementation in the garment sector was still in the infant stage. The reasons for low priority towards lean practices among the industries were identified, and the suitable measures were suggested to address the problems. In order to assess the extent of lean

implementation, 12 key factors for managerial executives and 25 factors for discipline were evaluated. There was low adoption of these key areas, but the degree of implementation varied among organizations. Large companies were found to have implemented the lean in few areas more rigorously as compared to medium industries. A significant positive relationship between each of the key areas of lean manufacturing and its successes was seen.

Kumar and Sampath (2012a) focused on the customized implementation of Lean tools 'Value Stream Mapping'(VSM) and 'Cellular Layout' for minimizing the work in progress (WIP), line setting time in a knitted t-shirt production industry at Tripur which in turn reduced the cost of production. It was an attempt to understand the root causes which increases the WIP between the processes .Value Stream Mapping was done for the existing product line to find out the bottlenecks. Time study and method study were conducted at the floor on each operation in the T-Shirt production line for comparison along with monitoring of hourly production between the operations as well as total production from the entire product. A future value stream mapping (VSM) was proposed for the same product by segregating similar operations together. Reduction in the WIP level, pitch time, cost of manufacturing and manufacturing lead time was achieved through the support of new cellular based layout which further led to the profit by 20-25 % in production process from the existing level.

Customized implementation of lean tools was initiated in a knitted T-shirt garment industry of Tripur to minimize the process waste such as work in progress, and the line setting time, which ultimately led to reduction of production cost. Value Stream Mapping was done to identify the hidden wastes. Main problems identified were the large inventory level (400 in number), higher production lead time (2 days to deliver the first piece), high throughput time, and the rework level. Future value stream mapping was proposed with cellular layout changes. The changes included were line balancing, removal and combination of some processes. WIP level of cellular and progressive bundle system were compared .It was found that cellular layout resulted in the reduction of WIP by 70% to 80%, pitch time, cost of manufacturing and lead time (Kumar & Sampath ,2012b).

The importance of lean manufacturing was highlighted in a garment industry to meet the global challenges by Kumar and Sampath (2012c) in their research. It provided a complete feasibility report for implementation of lean in garment manufacturing process in one selected unit 'Madura Garments'. Since the garment making process contained so much internal as well as external process variations, the customization towards the lean process enriched the productivity, and profitability. After implementation of lean system in the unit, 35% - 65% productivity improvement in the value chain was achieved with the support of a few lean implementation tools. Varieties of lean tools used were Kaizen, Cellular layout and 5S and pull system. It was also found that most of the Indian garment manufacturers were hesitant in implementing the lean manufacturing in their production process due to lack of knowledge about the lean tools, lack of direction, lack of adequate project sequencing, and the evidence of cocktail of common ingredients which were viewed as obstacles for the successful customized implementation towards garment manufacturing setup.

As waste and productivity are the two major issues in traditional RMG sector of Bangladesh industry, a research by Karim and Rahman (2012) was planned focusing on identifying and removal of waste in sewing section was conducted. The case approach was used in a selected garments industry located in Dhaka and the information as well as data was gathered through the questionnaire, observations and interviews. The main wastes identified were: overproduction , waiting , transportation, non-value-added processing and unnecessary inventory time .The methodology included identification of time loss, inventory backlog, unnecessary supplies of materials, unutilized machines and the causes of rejection of garments .Various problem solving techniques like pareto analysis, cause and effect analysis,5S analysis and workplace checklist techniques were used to get to the root cause of the problem.It was found that unnecessary elements exists in the sewing floor such as excess basket, trolley, inventory backlog, poor lighting arrangement, and unhealthy environment, which led to low labor productivity. Recommendations were given for overall improvement of the sewing section which included proper and adequate training to the inexperienced sewing operators, daily 5S housekeeping, a proper on-time maintenance system, proper simulation method or techniques and the quality check of fabric.

Performance Measurement Systems (PMS) used by lean manufacturing apparel companies in Sri Lanka were studied by Perera and Perera (2012). A sample was selected using judgmental sampling /purposeful and convenience method. Interviews with managerial level persons who were involved with the lean implementation and performance measurement development in each organization were conducted using structured interview schedule to investigate the PMS used by lean practicing apparel companies. Performance measures monitored by a lean manufacturing organization were found different from that of a non-lean organization. Hence, for performance to be monitored and the key performance indicators were set accordingly as SQDMC (safety, quality, delivery, morale, and cost). Lead time, work in progress, cost, and dock to dock. It was found that none of the units considered lean features such as elimination of zero value activities, continuous improvement, supplier integration etc. PMSs adopted by the Sri Lankan lean manufacturing organizations considered organizational objectives in setting performance objectives by the management. Manufacturing KPIs were set in line with strategic objectives of the top management and application of lean was completely omitted. As a result, these measures were found unable to identify the areas to be improved by lean to upgrade the manufacturing performance.

A research was conducted by Spahija, Shehi, and Guxho (2012) with the aim of practical application of the method for evaluating the production effectiveness of garment production companies. Various key performance indicators were identified against which data was recorded, which allowed the management of a company to make informal decisions on the ways to improve the productivity levels of their organization. The study was conducted in one of the selected export garment industry of Albania with 10 years of experience. The collection and measurement of KPIs was done for a 40 week period based on a number of useful sheets including operator performance sheets, attendance records, and skills inventory sheets. The main key indicators identified were total standard hours produced, total hours worked including overtime, number of direct operators, efficiency of direct operators, utilization of direct operators, number of indirect operators, absenteeism, labour turnover, average order size, standard hours per style, cost per standard hours, price, average defects per hundred units “in line” and average defects per hundred units “end of line”. The analysis of the weekly KPIs report highlighted the problems and their solution. These

included increase of total standard hours produced, 10% of efficiency of direct operators, improved level of absenteeism, no defects control in line and a high percentage of defects at the end of the line.

A research by Islam, Khan, and Islam(2013a) explored the applicability of lean manufacturing with the aim to visualize the different types of wastes generated in the organization and to suggest future possibilities of eliminating or reducing them. The research was conducted in two leading apparel manufacturers in Bangladesh using personal interviews, secondary data and observations. Five common garment styles with same design but colour variations were selected to produce 10,500 pieces of garments to collect the relevant data. In order to analyze the raw material, cutting, sewing and finish goods departments ,cross-functional teams with nine members were formed which were divided into three groups .Non-value added activities were recognized and SMV for each style including and excluding non-productive activities were calculated. Various wastes identified were: large inventories, over production, excess motion and waiting time. Lean tool, 5S and top strategy was implemented at raw material, cutting and numbering departments and consequence effects on overall productivity and manufacturing cost were calculated. The outcome of the observations reflected that the industry will gain higher productivity and profitability by proper application of lean manufacturing. Various recommendations were given to reduce the waste and improve the productivity by the application of lean manufacturing. These included the electronic indication method for minimizing the waiting time in all departments, re-layout of washing and drying processes, reduction of embroidery and printing lot size, use of folding boards and tools to reduce folding and packing time, establishing a visual link between cutting and production departments, reducing the number of quality checking points by implementing the self checking process and so forth .

Rework is one of the important waste and non-value added process in sewing section in a manufacturing industry. An investigation was carried out by Islam , Khan and Uddin(2013b) to eliminate wastages in order to save time, costs and lessen the internal process time. For the study, an approach based on knowledge and integrated process planning and control was adopted. The study was carried out in two garment industries in Bangladesh at sewing sections. Five styles of one garment with different colour combinations (500 in number) were selected and the time taken in

manufacturing the garments was noted down by stopwatch and the SMV was calculated. The data obtained was compared to the SMV including non-productive activities. This non-productive time was noticed due to waiting, no attention of operators, no proper identification, zigzag movement due to inappropriate lay out, no proper planning, improper machine use, sharing of working instruments, absence of operators, workers' fatigue, less experienced workers, poor machine performance, and so forth. Style-wise costs of productive and non-productive activities were also compared in sewing section. For all 80 production lines in the unit, savings obtained was estimated at \$4313088/year (80 lines x \$53913.6) and earning profit \$4313088/year. The observations reflected that an industry can gain higher productivity and profitability by eliminating non-productive activities. Various recommendations provided to reduce non-productive activities time in sewing section were: proper production planning, effective application of industrial engineering, well trained operators, proper layout plan, minimum rework, smooth running of sewing machines, proper line balancing, right time oiling to the sewing machineries, ensuring quality production, sufficient numbers of working aids, use of stickers for identification, manual counting, correct shade variation, and so forth.

A project was undertaken by Islam et al. (2013c) for the application of lean methodology in a manufacturing industry providing a framework to identify, quantify and eliminate sources of variation in an operational process, to optimize the operation variables, to improve and sustain process performance with well-executed control plans. The methodology included the study of existing quality system of the manufacturing unit, type and categorization of defects found and development of quality model inspection system, introduction of check sheets to collect defects. Inline inspection on sewing floor, trainings of quality personnel, tracking improvements and comparing them with previous situation and visual communication of performance. The defects identified were broadly classified as: seaming, sewing, placement, fabric and embroidery defects. The data was also collected in check sheets to calculate percentage defective. Using fish bone diagram, reasons for defects like measurement out of tolerance, puckering at waist, roping, uneven waistband extension, improper fly shape and fusing shining marks were thought of in terms of man, machine, method and material. Solutions were planned and applied accordingly and the reduction in defect hundred units achieved were noted down. Defect analysis was done for all

cutting, sewing and finishing sections and the SOP according to quality control system for each department was made .An audit team was employed to audit the quality system at regular intervals. It was concluded that by eliminating the non-productive activities like reworks in the apparel industries, time as well as costs were saved by ensuring quality production. The result showed that there was improvement in the process performance of the critical operational process, leading to better utilization of resources, decreasing variations and maintaining consistent quality of the process output. It also minimized the cost and improved the internal throughput time. It was concluded that an industry can gain higher productivity and profitability with improved quality product by minimizing the reworks activities.

5S being an important tool, its application in a sample section was explored in a study by Khan and Islam(2013).The main aim was to formulate the applicable solutions by application of 5S, which further saved the factory from loosing potential orders from renowned customers. Various problems identified in sample section were: weak file management, weak inventory management, dirty samples, less-skilled and inexperienced personnel. Solutions were provided by implementing the 5S system for smooth sample dispatch with quality. An excellent relation was build up with the buyer side, which led to a better scope to have more production order for the apparel industry which is highly appreciated from manufacturer's side.

Vienazindiene and Ciarniene (2013) created a model illustrating successful Lean implementation based on prior analysis of Lean implementation progress measurement and the main barriers identification. Different metrics were identified keeping in mind the progress dimensions to be measured. For continuous improvement, elimination of waste, continuous flow and pull-driven systems, multifunctional teams, different metrics and indicators were identified. Various types of barriers to lean manufacturing implementation namely people related barriers, organizational and technical barriers were highlighted. One of the major reasons of unsuccessful implementing of lean concept found was too much focus on tools and techniques instead of sufficient consideration to personally related issues.

The status and benefits of lean manufacturing competitive scheme was analyzed in detail by Gulati (2013).The presentation revealed that there were 46 clusters where lean implementation was completed, awareness programme was

conducted in 136 clusters. In 112 clusters, SPV was formed and 89 clusters had signed tri-partite agreement. Out of total 112 SPVs, 42 were in North, 15 in South, 27 were in West and 28 in South. In the Northern region, 15 were in NCR, 1 in Uttarakhand, 4 in Haryana, 2 in Himachal Pradesh, 11 in Punjab and 7 in Uttar Pradesh. There were only 8 SPV in the apparel and garments sector all over India. The results found were positive as annual savings of Rs. 90 crore and scrap value from 5S implementation of Rs.3 crore was obtained. Other benefits included 20% increase in production capacity, 10% space reclamation for productive work, 25% increase in inventory turnover, 5-30% reduction in manufacturing lead time, 15% in OEE and implementation of more than 7500 Kaizens. Other qualitative benefits obtained were capacity building among employees, opportunity to identify and solve problems, fostering team work, delegation of improvement initiatives, improved work environment, increased customer confidence, competitive spirit through internal and external benchmarking, improvement in work culture and attitude. Various critical success factors identified were commitment of owners, long term vision over short term benefits, commitment to customers, action oriented approach, competence of consultants and effective training of employees

Pakdil and Leonard (2014) developed a comprehensive tool called the leanness assessment tool using both quantitative (directly measurable and objective) and qualitative (perceptions of individuals) approaches to assess lean implementation. The tool assessed the performance using five qualitative dimensions: quality, process, customer, human resources and delivery, with 51 evaluation items and eight quantitative performance dimensions: time effectiveness, quality, process, cost, human resources, delivery, customer and inventory. The assessment method helped the managers to identify improvement needs in lean implementation, and the use of radar charts allows an immediate, comprehensive view of strong areas and those needing improvement.

A case study on application of lean manufacturing to higher productivity in the apparel industry in Gazipur, Bangladesh was conducted by Tandon, Tiwari, and Tamraka(2014).The result revealed that lean manufacturing can be effectively applied to apparel industry as the key step of waste identification by identify productive and non productive activities. Current value stream was mapped for a particular style and present level wastes were analyzed. Major wastes identified were

transport, inventory and defects, over processing, excess motion, and over production. Future value stream map was made showing the improvements in various areas and in order to continuously reduce or eliminate waste, different lean tools and techniques were applied accordingly along with adequate training to their employees. Findings were found valuable to other organizations of Bangladesh, which are expected to implement lean manufacturing in the near future

2.2 Carbon Footprint

Review was collected for the second part of the study that is Carbon footprint, which are cited below under various headings.

2.2.1. Climate change and carbon.

Climate change is a disease that has hit mother EARTH—like HIV-AIDS has humans. We don't know the disease is worsening, we refuse to believe it, we have yet to find a cure, we don't agree to a united change, and we rely on hope for our common good. Entropy prevails unless we fight our very own environmental problems, which are ours domestically.

Mr. Peuvianina Learai, (2006)

(as cited in "Questionnaire on Summary,"2007,p.12)

Climate change is a big accelerating ugly reality which the whole world has to face on account of the anthropogenic activities disturbing the composition of the atmosphere. It has resulted in higher concentration of carbon dioxide accumulation along with other green house gases (GHG) in the atmosphere, ultimately leading to increase the in the surface temperature of the Earth. Normally, earth's surface absorbs some of the sun rays and reflect most of the sun rays back into the atmosphere .The greenhouse gases present in the atmosphere act like a mirror and reflect back to the Earth some of the heat energy of the sun which would otherwise be lost in the space. The reflecting back of heat energy by the atmosphere is called the "greenhouse effect" (Gupta, 2010). The green house effect is illustrated in Figure 2.28.

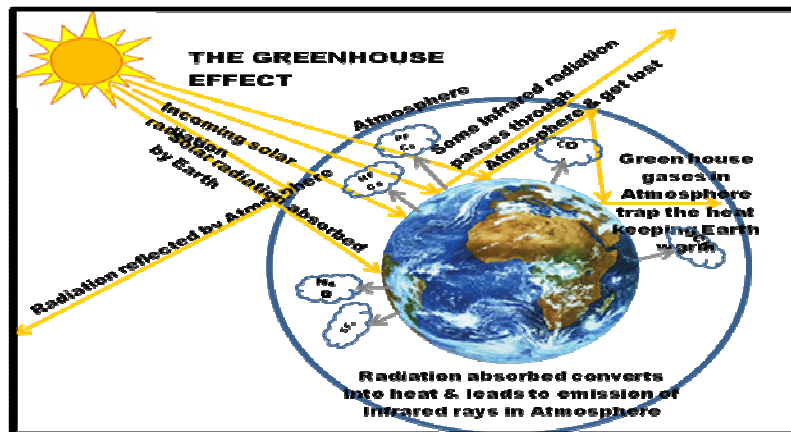


Figure 2.28. The green house effect.

The entire living organism contain carbon, and even if they decay or change, they continue to contain the element of carbon. Carbon is continuously on a move between the biosphere, atmosphere, oceans, and geosphere in various sinks, or stores, as illustrated in Figure 2.29. The values of carbon are in billion tonnes of CO_2 . An imbalance in the absorption and exchange of sun's energy by the earth's atmosphere and surface takes place due to volcanic eruptions, variations in the sun's intensity, changes in ocean current circulation or land surface and human initiated activities further leading to the increase in greenhouse gases thus disrupting the energy balance equilibrium.

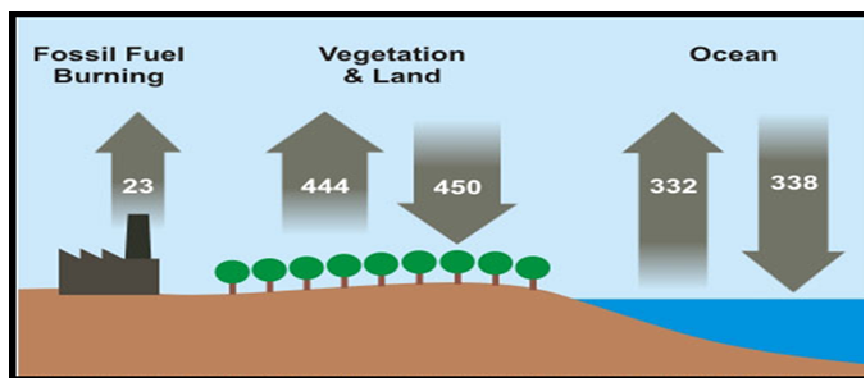


Figure 2.29. The carbon cycle. Adapted from "Complete Carbon Cycle," n.d.

Currently the carbon dioxide content present in the atmosphere stands at around 383 parts per million (ppm) and it is increasing by 2.5 ppm every year. Before the industrialization the content stood close to 260 ppm. The '550 movement' initiated by Intergovernmental Panel on Climate suggests that the upper limit of 550 ppm is the

‘red line’ that would keep Earth’s climate within ‘safe’ parameters: with ice at both poles intact though melting , and limited long-term sea-level rise for human beings as shown in Figure 2.30. It is said that the world has become 0.6°C warmer than hundred years ago and scientists have predicted that there will be a further increase in temperature by 1°C to 3°C by 2030 and 4.1°C to 5.4°C by 2100(Gupta ,2010).

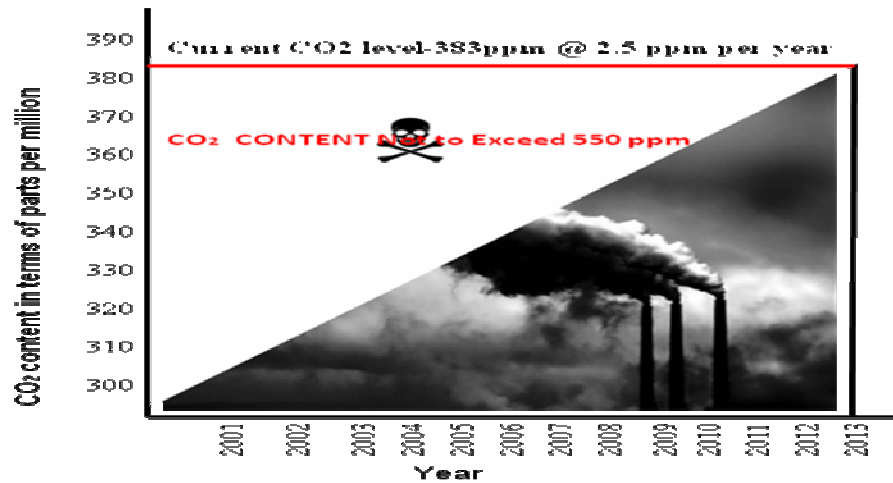


Figure 2.30. Rise in atmospheric carbon dioxide content in terms of parts per million.

Climate change has direct and indirect catastrophic impacts ranging from respiratory diseases to the extinction of species and habitat. The potential impacts of climate change are shown in Figure 2.31 (Babu & Raju, 2009).

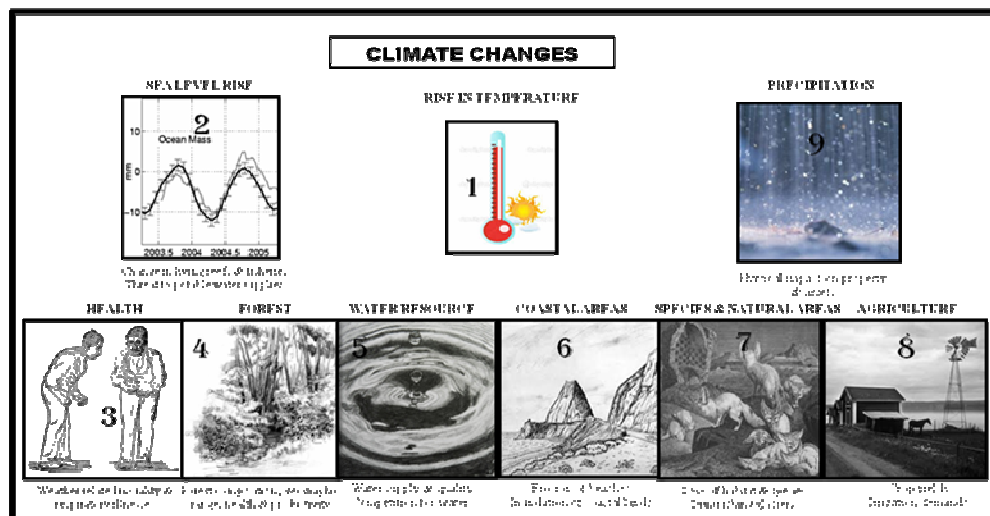


Figure 2.31. Potential impact of climate changes. Adapted from “Climate change: Consequences and repercussions,” by Lightle, 2012.

The recent years have witnessed an exponential increase in the emission of green house gases (GHG) raising the atmospheric temperature. It is reported that there was about 6% rise in GHG only in the year 2010, majority of which, was attributed to the top three pollutant countries of the world - China, the USA and India. According to the reports of the International Energy Agency, India is the third largest carbon dioxide emitter and it has pushed Russia into the fourth place. India's per capita emissions now are estimated to be in the range of 1-1.2 tonnes of carbon dioxide equivalent and are about 4% of the total global emissions (Rogers & Evans , 2011). Carbon emission rankings are shown in Table 2.7.

Table 2.7

Carbon dioxide Emissions of Different Countries

Rank	Country	2009 Total million tonnes	2009 Per capita tonnes
1.	China	7,710.50	5.83
2.	US	5,424.53	17.67
3.	India	1,602.12	1.38
4.	Russia	1,572.07	11.23
5.	Japan	1,097.96	8.64
6.	Germany	765.56	9.30
7.	Canada	540.97	16.15
8.	South Korea	528.13	10.89
9.	Iran	527.18	6.94
10.	United Kingdom	519.94	8.35

Note. Data for carbon emissions from ““World carbon dioxide emissions data by country: China speeds ahead of the rest,” by Rogers & Evans, 2011.

Greenhouse gases (GHG) are released by activities such as the burning of fossil fuels, land clearing, and agriculture. But, Industrialization is the key contributor of the carbon footprint. Nearly one third of the world’s energy consumption and 29% of the world’s green house gases emissions are contributed by the industrial sector as shown in Figure 2.32. A large number of industries are contributing to these

emissions and the textile industry is no exception to this phenomenon. This industry not only consumes a lot of energy during the manufacturing processes but also leaves very strong carbon footprint during the entire life cycle of a textile product from raw materials, manufacturing to use and disposal (Gupta, 2010).

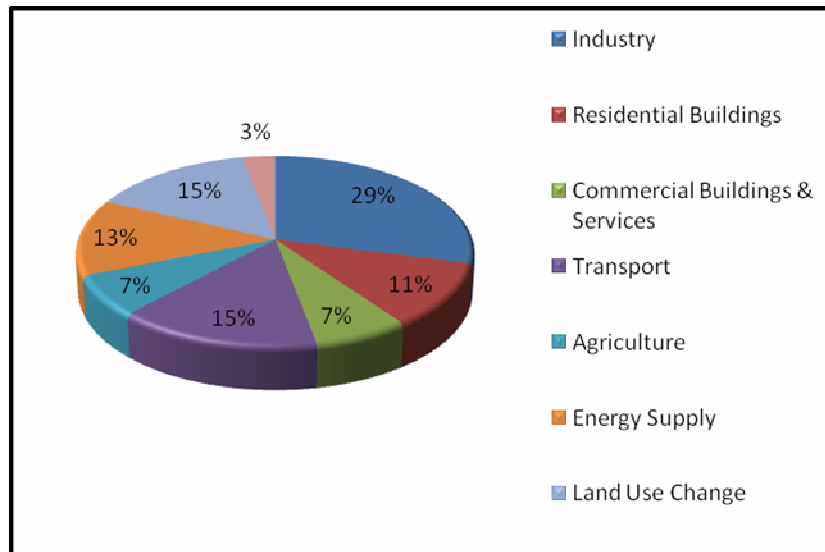


Figure 2.32. Sector wise distribution of green gas emissions. Adapted from “World GHG emission flow chart,” 2010.

The textile industry is one of the biggest GHG emitters on the Earth owing to its huge size and scope (Sivaramakrishnan, 2011). The contribution of CO₂ emissions from the textile sector to the atmosphere are shown in Figure 2.33. Many processes and products that go into the making of fibers, textiles and apparel products consume significant quantities of fossil fuels are shown in Figure 2.34. Apparel and textiles industries account for approximately 10% of the total carbon impact. The estimated consumption for an annual global production of 60 billion kilograms of fabrics uses 1 trillion kilowatt hours of electricity and up to 9 trillion liters of water (Zaffalon, 2010).

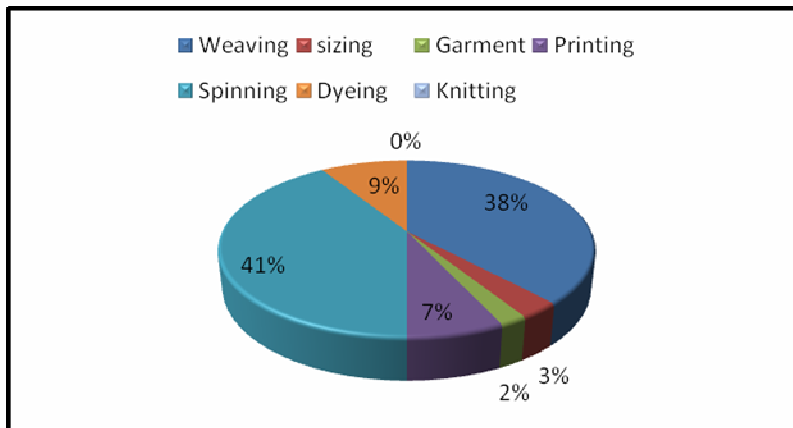


Figure 2.33. Carbon emissions from textile sector. Adapted from “Carbon credits: its role in the textile industry,” 2012, *Textile Times*, 9(10),4.

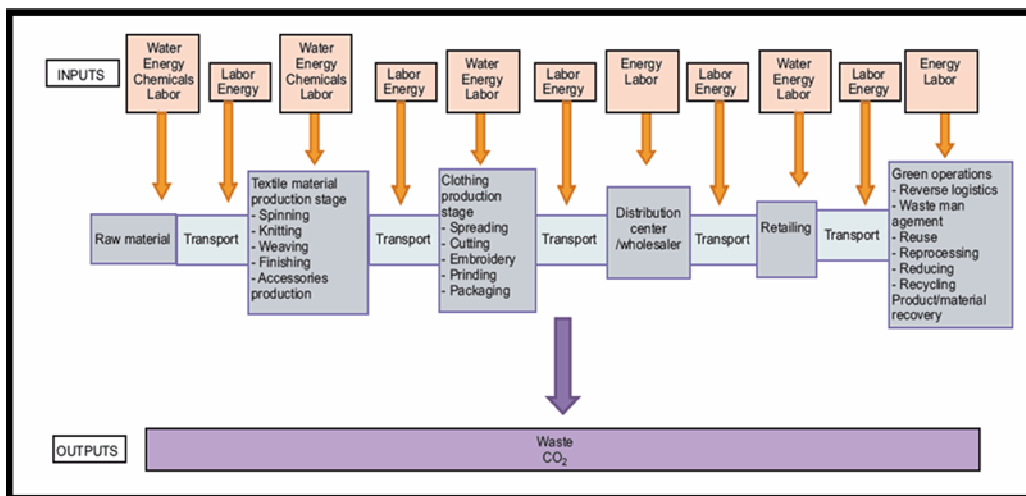


Figure 2.34. Textile product life-cycle and environmental impacts. Adapted from “Greening of the Textile and Clothing Industry,” by Eryuruk, 2012, *Fibres & Textiles in Eastern Europe*, 20(6A, 95), 23.

Garment manufacturing is a smaller portion of the overall garment environmental footprint, as it does not include fabrication, dyeing, weaving and spinning. Garment manufacturing activities comprising of cutting, sewing, ironing and packing are still significant and should be controlled and made efficient. But their impact is smaller and less chemical intensive. Carbon footprint of apparel units encompasses a wide range of green gases emissions namely CO₂, CH₄, N₂O, HFCs, PFCs and SF₆ that are directly and indirectly caused by the activities or processes such as usage of fossil fuels, water, chemicals, wastes generated or even emissions from

other organizations up and down the supply chain which are measured in terms of CO₂ equivalent or CO₂e .These excessive gaseous emissions are a great threat to the environment leading to global warming. The sources of carbon emissions in apparel manufacturing industry are shown in Figure 2.35. Figure 2.36 shows the environmental impact of a garment manufacturing process.

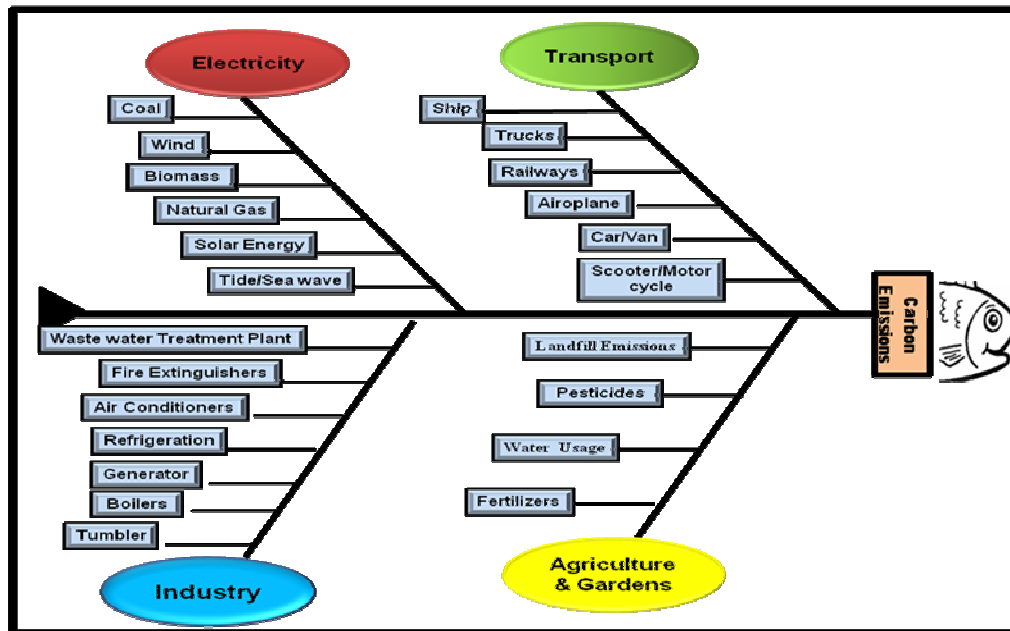


Figure 2.35.Sources of carbon emissions in an apparel manufacturing industry.

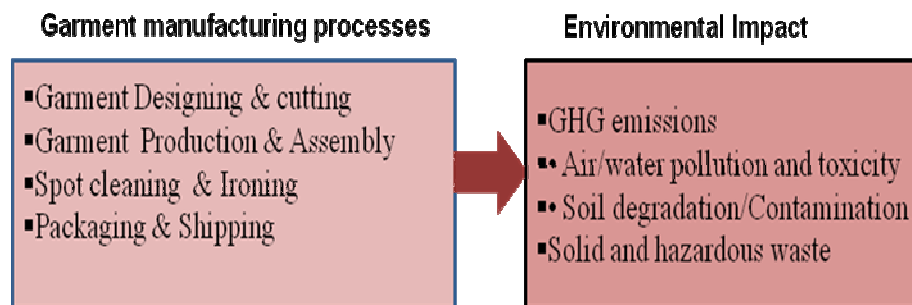


Figure 2.36 .Environmental impact of garment manufacturing processes.

2.2.2 Meaning of Carbon footprint.

"Not everything that counts can be counted and not everything that can be counted counts."

Albert Einstein (as cited in Wilkinson and Kirkup ,2009,p.1)

Carbon footprint is a more recent term for the global warming potential and it refers to the total greenhouse gas emissions associated with a product or service. The 'carbon footprint' concept has become popular over the past few years since, more or less than the year 2005 and this concept is widely accepted and used by the public and media despite its lack of scientifically accepted and universally adopted guidelines. This term is often used as the shorthand for the amount of carbon dioxide (usually in tonnes) emitted by an activity or organization. The total amount of GHG emissions produced due to the existence or production in an organization, region, event, product or a person is known as the carbon footprint of the particular parameter taken under consideration. Wright, Kemp, and Williams (2011) defined it as a measure of the total amount of carbon dioxide (CO₂) and methane (CH₄) emissions of a defined population, system or activity, considering all the relevant sources, sinks and storage within the temporal boundary of the population, system or activity of interest, calculated as carbon dioxide equivalent (CO₂e) using the relevant 100-year global warming potential (as cited in Padmavathi, 2013, p. 228-229).

The Carbon Footprint terminology phrase arose out of the debate on climate change, as a tool to measure GHG emissions. The terminology chosen was inspired by the 'Ecological Footprint' (EF), which had been introduced in the 1990s (Rees, 1992; Wackernagel & Rees, 1996). The ecological footprint is the estimation of the land requirement for energy use measured by the land area needed to sequester CO₂ emitted from burning fossil fuels. It accounts for the size and effect of the impacts that is footprints' on the earth's ecosystem made by an organization and is expressed in hectares (APO Guide, 2009; Wackernagel & Rees, 1996). The main focus of the ecological footprint was on the land requirement rather than on volume of carbon dioxide and other GHG emissions. Carbon footprint was one part of ecological footprint, but in response to the interest of governments and companies in GHG emissions and global warming, the carbon footprint became a modified, independent separate concept, expressed in terms of emitted CO₂-equivalents. It is not clear when and by whom the term carbon footprint was used for the first time, but it was found in the newspaper articles as early in the year 2000. In the publications of online letter, "Nature" by Hammond, the term carbon footprint was mentioned for the first time on January 17, 2007.

Though carbon and water footprint concepts were introduced about a decade ago simultaneously from ecological footprint, but they are independent from one

another. Ecological footprint measures the use of bio productive space in hectares; carbon footprint measures the emission of gases that contribute to heating the planet with carbon dioxide equivalents per unit of time or product, while, water carbon footprint is introduced in the field of water resources management, as a tool to measure water use in relation to the consumption patterns (Ercin & Hoekstra, 2012). Recently, the nitrogen footprint was introduced as a tool to measure the amount of nitrogen released into the environment in relation to consumption. A common property of all the footprints is that they can be related to specific activities; products and consumption patterns (Leach, Galloway, Bleeker, Erisman, Kohn, & Kitzes, 2012).Details of all four types of footprints are given in Figure 2.37.

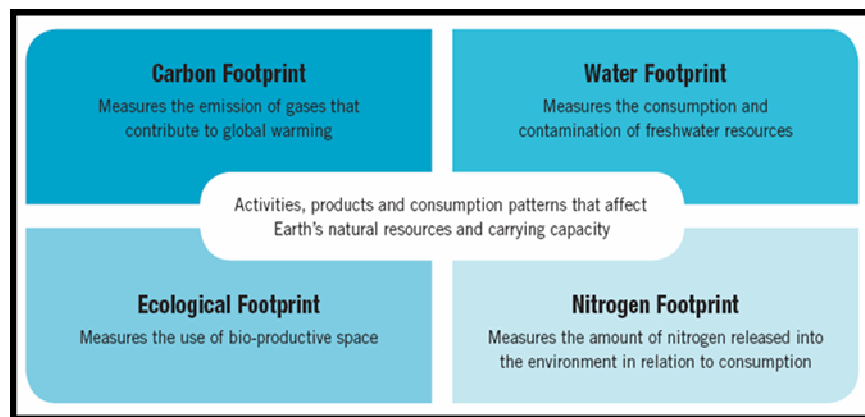


Figure 2.37. Footprint concepts. From “*Carbon and water footprints: Concepts, methodologies and policy responses*,” by Ercin & Hoekstra , 2012,p.4.

‘Carbon footprint’ has become a widely used term and concept in the public debate on the responsibility and action against the threat of global climate change. Both in science and in practice, the term is applied to different entities: single processes, whole supply chains (or all life-cycle stages) of products, individual consumers, population, companies, industry sectors, and all sorts of activities and organizations. According to Peters, "The ‘carbon footprint’ of a functional unit is the climate impact under a specified metric that considers all relevant emission sources, sinks, and storage in both consumption and production within the specified spatial and temporal system boundary."(as cited in Wu,2011,p.3).

Despite its popularity and use in commerce, there is no universally accepted definition of carbon footprint. However, with the increasing public and political

concern of climate changes, carbon footprint has developed into a separate concept with extended scope. Wiedmann & Minx(2008,p.4) gave a definition of carbon footprint as, "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."According to Larsen & Hertwich (2010,p.792), Carbon footprint is the life-cycle GHG emissions caused by the production of goods and services consumed by a geographically-defined population or activity, independent of whether the GHG emissions occur inside or outside the geographical borders of the population or activity of interest. Carbon footprint is also defined by Haq and Owen(2009) as the total amount of CO₂ emissions which results directly and indirectly from the individual use of the goods and services, covering both individuals' immediate emissions and emissions arising during the production process. A carbon footprint is "the total set of GHG emissions caused directly and indirectly by an individual, organization, event or product (Carbon Trust, 2008, p.1).

2.2.3 Types of carbon footprint.

A Persian proverb rightly describes current situation: Someone was sitting on the end of a branch while cutting the branch's stem! We are living on the blessings of nature. The wealth of biodiversity and its services are life support systems upon which we rely. But we have used every opportunity to damage these treasures under the pretext of want or need. Our existence depends on nature, yet we take every action to undermine it.

Ebtekar (2007,p.14)

Carbon footprint is caused by the emission of greenhouse gases by human activities and as it gets accumulated with the increase in its concentration in the atmosphere, it leads to global warming. There are six GHGs which are considered to be the key contributors to global warming. These are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF₆). Carbon dioxide is considered the most significant GHG in terms of its great contribution to global warming due to its increasing prevalence in the atmosphere. It accounts for nearly 80% of emissions from the industrialized countries. These GHG's are explained below:

a) Three categories of Greenhouse Gases Emissions (GHGs).

- i. *Direct GHG emissions*-These are emissions from the sources that are owned or controlled by the organizations.
- ii. *Indirect GHG emissions*-These are the emissions that are a consequence of the activities of the organization but the GHG emission occurs at sources owned or controlled by another company.
- iii. *Other Indirect emissions* from products and services (Meena, 2011,p.45).

In the ready-made garment industry, the three top carbon emitting areas are energy (both electrical and thermal), labour and materials. Electricity constitutes the largest share and is used for running the machines, computers, ventilation, refrigeration, lighting, cooling and heating systems. It has been demonstrated by some case studies that the indirect emissions constitute the majority of carbon footprint of a functional unit (Larsen & Hertwich, 2010). As indirect emissions from coal, waste, natural gas, oil etc contribute to 65% of green house gases (shown in Figure 2.38), exclusion of indirect emissions arising from the upstream supply chain as well as downstream disposal amounting to 35% GHG can bring about considerable underestimation.

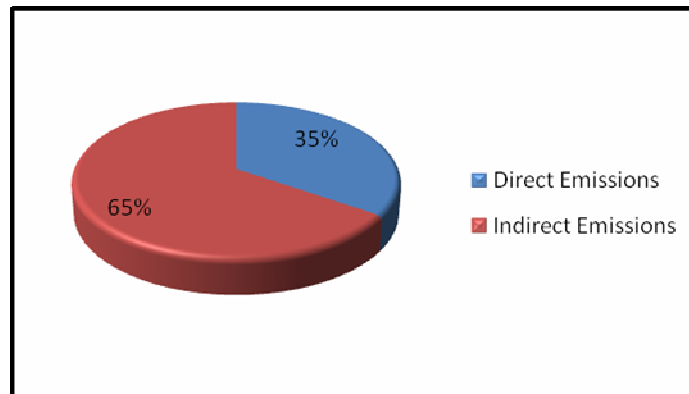


Figure 2.38. Source-wise distribution of green house gases. Adapted from “World GHG emission flow chart,”2010.

Each greenhouse gas is given a carbon dioxide rating, or global warming potential (GWP) relating to the amount of carbon dioxide required to have the same impact on the environment. The GWP reflects the atmospheric heat absorption capacity of individual greenhouse gases over a 100 year time horizon. For example,

methane's rating is 21; therefore one tonne of methane is equivalent to 21 tonnes of carbon dioxide. This allows the assessment to be undertaken based on CO₂e and further allowing comparisons between assessments. A quantity of greenhouse gas can be converted into CO₂e by multiplying its mass by its global warming potential, For example 1 kg of methane is equal to 21 kg of CO₂e. Table 2.8 outlines the GWP of some common greenhouse gases.

Table 2.8

Green Gases, Sources, and their Global Warming Potentials

S.no.	Green gases	Chemical formula	Source	Global warming potential(GWP)
1.	Carbon dioxide	CO ₂	Mobile and stationary combustion	1
2.	Methane	CH ₄	Coal mining, fuel combustion, landfills, wastewater treatment	21
3.	Nitrous oxide	N ₂ O	Fuel combustion, fertilizers	310
4.	Hydro fluorocarbons	HFCs	Refrigerants, fire suppressants, various manufacturing processes	12 – 11,700
5.	Per fluorocarbons	PFCs	Electrical equipment, various manufacturing processes, refrigerants, medicine	6,500 – 17,700
6.	Sulphur hexafluoride	SF ₆	Electrical equipment, various manufacturing processes, tracer in air modeling, medicine	23,900
7.	Hydrofluoroethers	HFes	Chemicals used in refrigeration, air conditioning, and other industrial processes.	100-500

Note. Adapted from “Greenhouse gas emissions- E₃: Eco-efficiency resources for the food processing industry,” n.d.

Figure 2.39 shows the percentage share of anthropogenic greenhouse gas emissions in the atmosphere and Figure 2.40 shows the emission distribution of carbon dioxide.

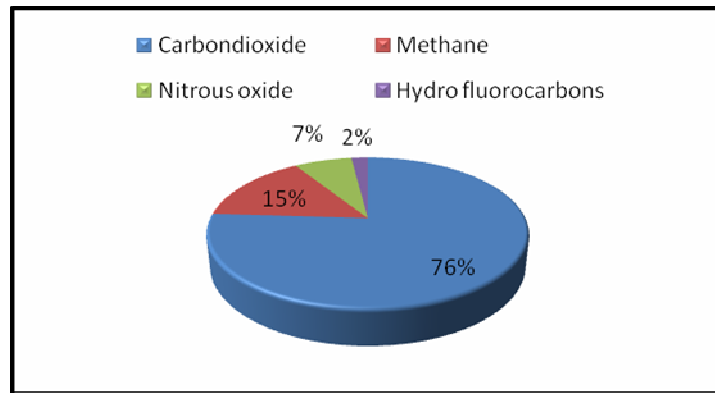


Figure 2.39. World's anthropogenic greenhouse gas emissions. Adapted from "World GHG emission flow chart," 2010.

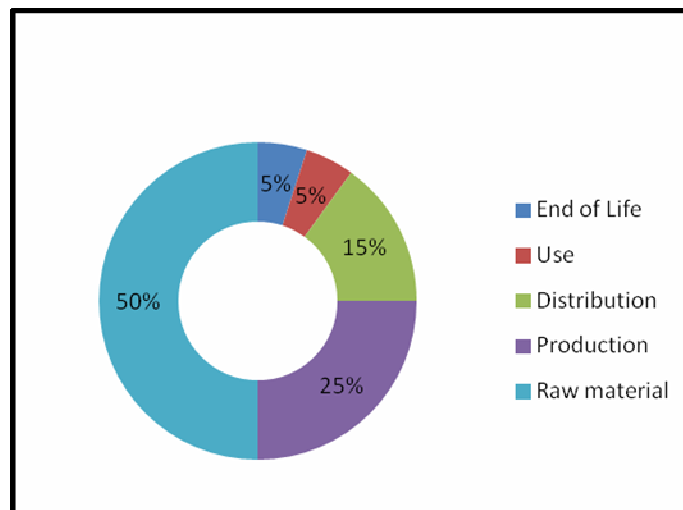


Figure 2.40. Emission distribution of carbon dioxide. Adapted from "Global warming and India, green house gas emissions from Indian industry, genesis of carbon footprint and life cycle approach," by Sharma, 2013.

b) Types of organizational carbon footprint.

The main types of carbon footprint are:

- i. *Organizational carbon footprint.* It measures the direct (primary footprint) and indirect (secondary footprint) GHG emissions from all the activities associated with an organization including the energy used in buildings, industrial processes and company vehicles. Organizational GHG inventories quantify the amount

of greenhouse gases emitted into the atmosphere and are the critical management tools for the organizations of all sizes and sectors. These inventories enable companies to identify their emission sources and track the changes over time. Information presented in an inventory can help inform corporate strategies and prioritize actions to reduce emissions, as well as, provide benchmarks against which the success of these activities can be measured (Jaye,2012)

- ii. *Product Carbon footprint.* It involves quantifying all the emissions over the whole life span associated with a product that is from “cradle to customer”. It includes all emissions from the extraction of the raw materials, processing, manufacturing, and delivery to customers, consumer use and final disposal of the product. The average total lifecycle footprint of a typical women’s short organic sleeve T-shirt is approx. 2.34 kg CO₂e, while that of a basic men's white t-shirt is approx. 6.574 kilograms (kg) of CO₂e which is around 20 times its own weight.
- iii. *Value chain carbon footprint.* It includes emissions which are outside an organization’s own operations. This represents emissions from both suppliers and consumers, including all use and end of life emissions. Boundaries of organizational and product footprint are shown in Figure 2.41.

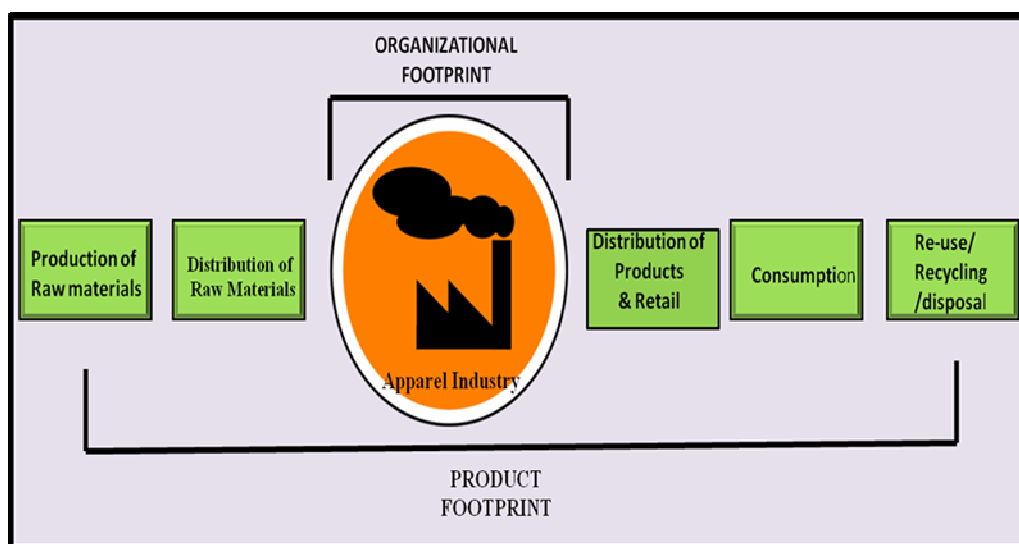


Figure 2.41. Different boundaries of organizational and product footprint.

c) *Types of individual's carbon footprint.*

An individual's or the organization's carbon footprint can be broken down into the primary and secondary footprints:-

- i. *The primary footprint.* It is a measure of the direct emissions of CO₂ from the burning of fossil fuels including energy production and transportation which can be directly controlled. For example-wood, electricity, gas, oil, coal, private and public transport. This direct footprint is straightforward to calculate or estimate.
- ii. *The secondary footprint.* It is a measure of the indirect CO₂ emissions from the whole lifecycle of products, associated with their manufacture and breakdown, For example-food and drinks, clothes, buildings and furnishings, recreation, financial services and so forth (Mahapatra,2011).It includes emissions from company-owned cars (Diesel, petrol and liquefied petroleum gas(LPG), Compressed natural gas(CNG)) vehicles and corporate jets ,emissions from purchased energy that is, electricity & heat (coal, oil & natural gas) and emissions from business travel (i.e., air travel and rental cars). This indirect footprint is little more confusing and tricky to calculate.

d) *Type of scope emissions.*

The protocols governing GHG calculations categorize emissions from an organization's operations into 3 scopes are described below:-

- i. *Scope 1.* The release of GHG emission into the atmosphere as a direct result of the activities of a 'facility' which are owned or controlled by the unit as follows:
 - *Stationary emissions*-These emissions result from the combustion of fuels in stationary sources (e.g., boilers, furnaces, turbines, and stand by generators), including CH₄ and N₂O emissions from biomass combusted for production of electricity, heat, cooling, or steam. It is usually responsible for about 70% of the greenhouse gas emissions from the energy.
 - *Mobile sources*- These emissions result from the combustion of fuels in agency-controlled mobile combustion sources (e.g., automobiles, ships, and

aircraft), including leased and agency-owned vehicles. These include CH₄ and N₂O emissions from bio-fuel combustion. It is usually responsible for one-quarter of the emissions from the energy.

- *Fugitive emissions*- These emissions result from the intentional or unintentional releases of GHGs from within the agency's organizational boundary .For example- equipment leaks from joints, seals, packing, and gaskets; landfills and wastewater treatment plants; HFC emissions from the use of refrigeration and air conditioning equipment; methane leaks from gas, transport; SF₆ emissions from leaking electrical equipment; and CH₄ emissions from agency owned and operated coal mines, helium production, venting, etc. Only a few percent of the emissions from the energy arise as fugitive emissions from extraction, transformation, and transportation of primary energy carriers (Saxena, 2009).
 - *Process emissions*- These emissions result from the manufacturing or processing of chemicals, materials and from laboratory activities.
 - *Biomass and bio-fuel combustion*- It results in the GHG emissions of CO₂, CH₄, and N₂O. CH₄ and N₂O emissions resulting from combustion of biomass and bio-fuels. Out of these emissions, CO₂ emissions are biogenic biomass or biofuel CO₂ combustion emissions, while CH₄ and N₂O emissions are not considered biogenic combustion emissions, and are treated in the same manner as emissions of these gases from the combustion of fossil fuels.
- ii. *Scope II*. It includes indirect GHG emissions into the atmosphere through off-site activities associated with the consumption of purchased or acquired electricity, steam, heating, or cooling .These emissions are a consequence of activities that take place within the organizational boundaries of the unit, but the emission release physically occurs at the facility where the electricity, steam, heating, and cooling is generated. Indirect emissions associated with transmission and distribution (T&D) losses of the unit controlled purchased electricity, purchased steam and chilled water are included in Scope II.
- iii. *Scope III*. It includes the release of GHG emissions into the atmosphere due to the consequence of the unit's activities from sources outside its organizational

boundary which are not under the direct control of the organization. It includes all other indirect emissions not included in scope II namely:

- Employee business air travel.
- Employee business ground (i.e. rail & road) travel.
- Employee commuting.
- Contracted solid waste disposal (i.e., municipal solid waste that is sent to a landfill not owned or operated by the agency).
- Contracted wastewater treatment (i.e., municipal wastewater that is sent to the wastewater treatment plant not owned or operated by the agency).
- Transmission and distribution losses associated with purchased electricity (Federal Greenhouse Gas Accounting and Reporting Guidance, 2012). Three scopes are described pictorially in Figure 2.42.

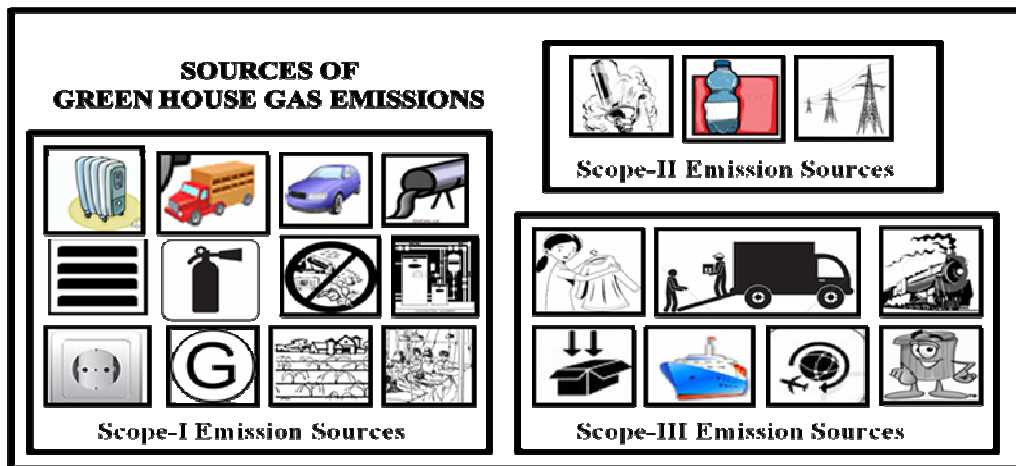


Figure 2.42. Sources of green house gas emissions.

2.2.4 Importance of carbon footprint.

The environmental reality of climate change is fast becoming an economic reality. As companies confront the demands of a low-carbon future, they face new choices, new challenges, new competitors, and – ultimately – new opportunities to reshape industries and markets around the globe.

The McKinsey Quarterly (as cited in Baumann & Kollmuss, 2010,p.3)

The increasing frequent extreme weather events, annual rise in global average rising temperatures and disruptive seasonal changes all over the world points to the increasing evidence of anthropogenic climate change. Continued reliance on outdated energy sources, coupled with the growing population and the emergence of a global middle class, is found no longer sustainable or economically viable. To achieve economic and development aspirations while also responding to the climate change, all nations of the world, businesses and citizens need to rethink current energy policies, practices and actions.

Carbon footprint calculations help to identify the effective reduction strategies being implemented and already implemented by competitors and also decide on the similar strategies their units could potentially implement in the future. Examining the carbon reduction strategies and environmental performance of other apparel manufacturing units helps to provide benchmarks and help the units to select group-wide emissions reduction targets. Calculation of organization's emissions helps in setting overall reduction target. The main reasons for calculating the carbon footprint is to manage the footprint, derive change, and, reduce costs and emissions over time; off-set emissions (to go "carbon neutral") accurately and report emissions to a third-party (for example the public).

The other benefits of calculating the carbon footprint of an organization is to derive wider changes in the supply chain, bring about reduction in the organization's emissions – by changing suppliers, choice of materials, manufacturing processes, and the product designs. It also helps gain the support of the employees, and encourage them to participate in reducing the emissions. It provides a benchmark for comparisons within an organization and within the industry identifies cost inefficiencies, carbon inefficiencies and environmental risks in the operations and/or supply chain, serves as a transparent tool to communicate environmental performance. It provides opportunities to create innovative products providing access to new markets, improve the reputation and investor's relations with the units. It also acts as an important internal and external communication tool that helps to demonstrate risks (Suneja, 2012).

Now a days, progressive apparel industries are increasingly calculating their carbon footprint in order to share the information with other organizations and to

reduce these emissions. The motives behind their public disclosure of the emissions are to:

- Meet the mandatory reporting requirements of climate change legislation.
- Report emissions as part of a corporate social responsibility programme or for the marketing purposes.
- Respond to requests from business, customers and investors for carbon emissions data.
- Participate in carbon reporting initiatives such as the Carbon Disclosure Project (CDP).
- Measure emissions levels as part of carbon reduction or offsetting strategy.

In terms of measuring the carbon footprint, India is still at a nascent stage where most of the industries are not even aware of the methodology to measure their carbon footprint, Indian apparel Industry needs to understand its personal responsibility to contribute in the world's mission to reduce CO₂ or GHG emissions and save our Mother Earth. According to official data from climate-related disasters with global CO₂ emissions, it is concluded that one person can die, starve, become sick or left homeless for every 102 tonnes of CO₂ added to the atmosphere.

Industry can take a lead in becoming the clean and fair trade industry which will help millions of workers to live a long and a life of dignity and well being. Commitment towards low carbon emissions can benefit industry in a number of ways. Adherence to environmental laws will lead to the opening of new markets and also in getting orders from international apparel buyers as they had laid out very clear guidelines of social and environmental expectations for their suppliers and manufacturers. Assessment of carbon footprint generation safeguards and the client relationships by demonstrating the environmental responsibility to customers and shareholders, hence, leading to the fulfillment of major Corporate Social Responsibility objectives. It not only helps in achieving the competitive advantage over competition but also helps in creating positive brand image and differentiation. Identification of major hotspots and activities which contributes the most to the footprint will help the industries in setting up a target for reducing emissions. It will also help to measure changes in emissions over time, and to monitor the effectiveness of reduction activities for further offsetting its emissions. This is the right time for

Indian apparel industry leaders to join this new low carbon mission's wagon which will shape and mould the future of the whole world giving new meaning to word 'profit'. Ones which will be left will lag behind and will be at a loss.

2.2.5 Carbon footprint assessment.

"Resources flow toward what is measured"

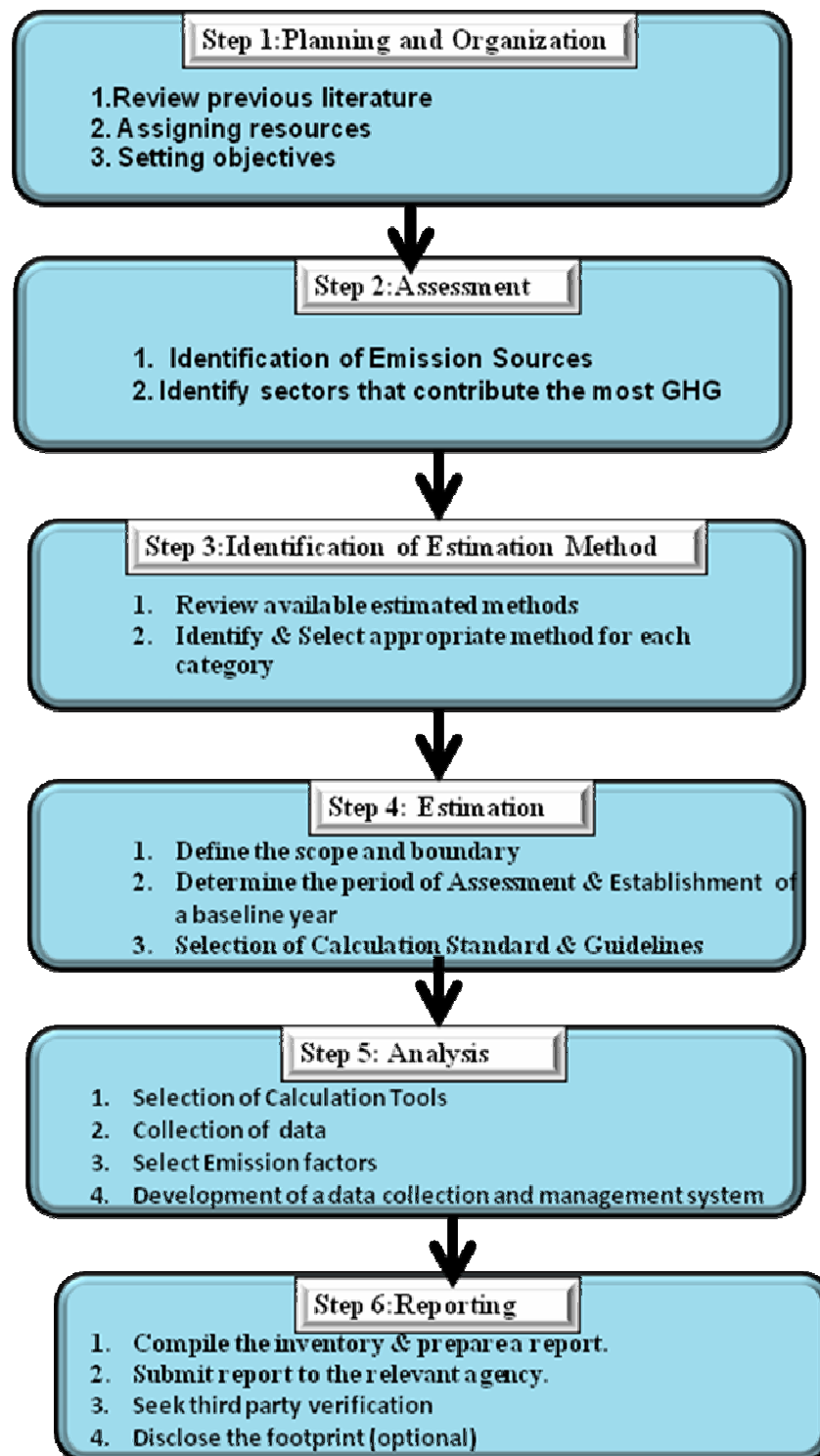
Tom Tuttle (as cited in "Lean manufacturing quotes," n.d.)

The growing awareness of environmental issues has led to the development of carbon footprinting tool with the objective of measuring the emissions of a business, production site, product, or service. To meet the ambitious carbon reduction targets that the governments are now setting for 2020 and beyond, apparel sector needs to implement the decarbonisation strategies in order to reduce its group-wide carbon footprint in response to the interests of upper management and employees, industry and customers. The longer that it takes to get onto an appropriate carbon reduction trajectory, the harder it will be to reach to achieve the targets. Many industry sectors and companies are still at an early stage in this process, analyzing their greenhouse gas (GHG) emissions and exploring options for reducing them. The old business mantra states, 'if you can't measure it, you can't manage it' (Drucker, 2008, p.19). So it is logical for a manufacturing industry to start with the detailed measurement of GHG emissions. Measuring carbon footprint of an apparel unit is the first step towards its management and improvement.

Apparel manufacturing unit's carbon footprint assessment includes a measurement of all the greenhouse gases that result from the company's operational activities such as energy use, refrigerant leakage, waste generation, employee commuting, business travel, and more. This process involves the following broad steps as shown in Figure 2.43.

a) Setting objectives and goals.

This step included establishing clear, measurable carbon reduction objectives and targets at the commencement of the process. The target often expressed as a per cent reduction within a certain timeframe, is important for planning actions and reporting on the progress of activities (Bolitho & Spence, 2010).



*Figure 2.43.*Steps in assessment of carbon footprint. Adapted from “Green gas emissions: Estimation and reduction,” by Saxena, 2009,p.17.

b) Define organizational and operational control.

Setting organizational and operational accounting boundaries is necessary to develop a consistent agency-wide GHG inventory. In a single organization, the organizational and operational boundaries are the same. But, when an organization has more than one facility, consolidation of the GHG emissions from its different facilities to produce its GHG assertion is required. Figure 2.44 shows the operational and organizational boundaries which are discussed below:-

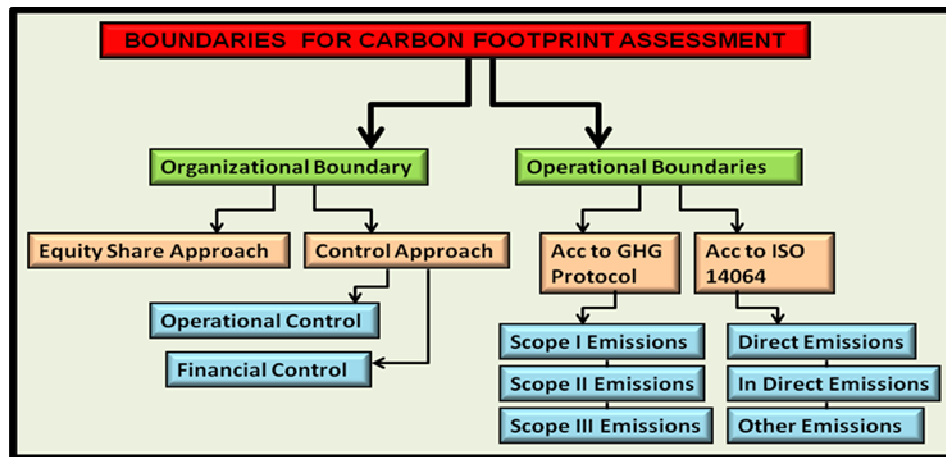


Figure 2.44. Operational and organizational boundaries.

iv. Organizational boundaries. These boundaries are defined by either the operational or financial control of entity over its various activities. There are two choices or methods to carry out the consolidation namely -equity share approach and control approach as follows:-

- *Equity share approach* – Under equity approach, an organization accounts for its portion of GHG emissions or removals from respective facilities according to its share of equity in the operation. For example Apparel unit A owns 70% interest in unit C, and unit B own 30% interest in unit C. Unit C emitted 1 million tonnes CO₂e last year. Under equity share approach, unit A was assigned 700,000 tonnes CO₂e and unit B was assigned 300,000 tonnes CO₂e.
- *Control approach* -Under the control approach, an organization accounts for all quantified GHG emissions or removals from respective facilities over which it has

the financial or operational control. It does not account for GHG emissions from the operations in which it owns an interest but has no control. For example- Apparel unit A owns 70% interest in unit C and unit B owns 30% interest in unit C. Unit-B had control over unit C's operational policy. Company C emitted 1 million tonnes CO₂e last year. Under control approach, company A was assigned 0 tonnes CO₂e and company B was assigned 1, 00,000 tonnes CO₂e. Under this approach, an organization accounts for 100% of the GHG emissions or removals from operation over which it has control. Control can be on either financial or operational terms as follows:-

- *Financial control*-An organization has the ability to direct the financial and operational policies of the operation with a view to gain benefits from its activities.
- *Operational Control*- An organization or its subsidiaries has the full authority to introduce and implement its operating policies at the operation level.

According to ISO 14064-1 a voluntary reporting standard, an organization has a right to decide at which level it defines the organization i.e. can set an organizational boundary by reporting for only one or two out of more subsidiaries but it can't represent its total emissions (Suneja, 2012).

- v. *Operational boundaries*. These are defined as the authority to introduce and implement operating policies or boundaries for each of its facilities. The establishment of operational boundaries includes identifying GHG emissions and removals associated with the organization's operations, as per ISO 14064 categorizing GHG emissions by direct and indirect GHG emissions. After the organizations determine the operations that fall within their organizational boundaries, they categorize emissions sources as per GHG Protocol as either direct (scope 1) or indirect (scope II or scope III). Table 2.9 depicts the three scopes of GHG emissions.

Table 2.9

Three Scopes of GHG Emissions

Scope	Inclusion	Type	Category	Emission source
I	Mandatory	Direct Emissions	Stationary Combustions	Fuel facilities(Boilers, Generators, Air heater, Furnace, Tumbler, LPG)
			Mobile Combustion	Fuel-own transport(Company owned Vehicles)
			Process emissions	Process emissions
			Fugitive emissions	• Air conditioning • Fire Extinguishers • Waste water treatment plan
II	Mandatory	Energy Indirect Emissions	Stationary Combustion	• Purchased Heat/cooling • Purchased Electricity • Purchased Steam
III	Optional	Other Indirect Emissions	Stationary Combustion	• Packaging • Supplier's Emission
			Mobile Combustion	• Employee travel • Third party distribution
			Process emissions	• Raw material • End of Life • Use of Product

- c) ***Selection of calculation standard and guidelines.*** Calculations for an apparel unit is done as per the standards of ISO 14064-1 and guidance of GHG Protocol Corporate Accounting and Reporting Standard developed by the World Resources Institute and the World Business Council for Sustainable Development.
- d) ***Establish a baseline.*** The organization should establish a historical base year to enable meaningful and consistent comparison of emissions over time requiring the companies to set up a performance datum with which to compare current

emissions (from the base year emissions). Base year can be fixed, multi-year or rolling year. Base year selected should have a verifiable GHG emissions or removals data .Hence the first GHG inventory period is selected as the base year (Suneja, 2012).

- e) **Establishing a methodology.** There are a number of national and international methodologies which may be used to guide participants through the carbon management process. Functional unit and scale determines which carbon footprint calculation approach is the most appropriate. Figure 2.45 shows the criteria for carbon foot printing method selection.

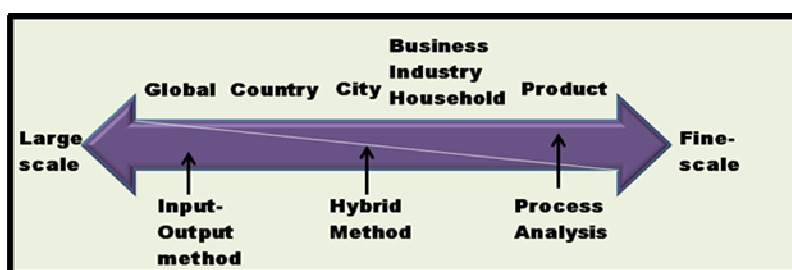


Figure 2.45. Carbon footprint methods on different scales of application. Adapted from “Carbon footprint: A case study on the municipality of Haninge,” by Wu, 2011, p.10.

Environmental Input- Output (EIO) analysis are commonly applied to CF calculation at global and national level; Hybrid -EIO-LCA method are applicable at sub-national scale, organizations or industrial sectors, while Process Analysis (PA) or Life Cycle Assessment (LCA) dominates the CF assessment of products and services (Wu,2011).

- f) **Assigning resources.** The next step includes reviewing and revising the emissions strategy of an organization annually and assigning appropriate resources and clear responsibilities for the exercise to reduce emissions.
- g) **Identification of emission sources.** It includes listing of various activities or processes in an organization leading to emission of GHG gases .These processes are as follows-

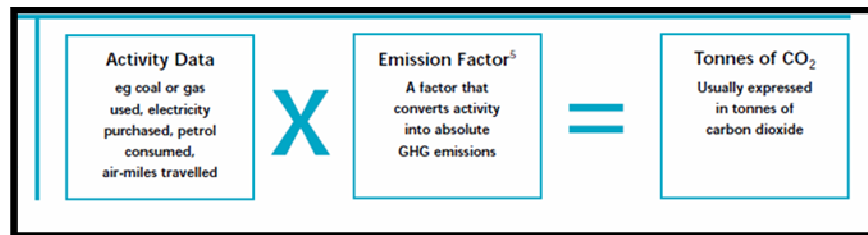
- All sources of energy consumption or direct GHG emissions related to the transformation of raw materials, which include emissions from extraction and pre-processing raw materials.
 - Emissions from distributing any energy used within the system, namely electricity and gas, should be included as also the emissions arising from consumption.
 - Emissions associated with manufacturing and service provision.
 - Operations of premises such as storage, offices and retail outlets.
 - Transport emissions including the distribution of fuel and its consumption.
 - Emissions associated with the final disposal of materials.
- h) **Select emission factors.** GHG emissions are estimated based on the developed emission factors (EFs). Various sources of emission are DEFRA, GHG Protocol tools, national government data (Suneja, 2012). Emissions of other greenhouse gases are translated into equivalent emissions data in t CO₂e, using the global warming potential factors published and are available from the Carbon Trust.
- i) **Development of a data collection and management system.** A well structured and maintained data management system can provide a uniform basis to track the emissions. Organisations must take the responsibility of GHG inventory with the appropriate training of GHG inventory team, internal audits, applicable calibration of measurement equipment and look out for opportunities to improve information management process.
- j) **Measuring emissions.** It involves multiplying the activity data by the appropriate emissions factor to determine the emissions attributed to the particular source. Online calculation tools are also available from ghgprotocol.com. According to IPCC Good Practice Guidance Guidelines, 1996, the most common simple methodological approach to calculate the GHG emissions is to combine information on the extent to which a human activity takes place (called activity data or AD) with coefficients that quantify the emissions or removals per unit activity. These are called emission factors (EF). To quantify the key information

required to calculate a basic carbon footprint, the data from sources are identified and multiplied with the emission factors. In this way, fuel, electricity and transport consumption figures are converted to CO₂ by using the standard emissions factors as shown in Figure 2.46.

$$\text{GHG emissions} = (\text{AD} * \text{EF})$$

AD=Activity Data (quantity)

EF=Emission Data (Intensity) (Suneja, 2012).



*Figure 2.46.*Carbon footprint measurement formula. From “The challenge of greenhouse gas emissions: The “why” and “how” of accounting and reporting for GHG emissions,” by NZBCSD, 2002, p.8.

While calculating an organization’s footprint, quantification of a full range of emissions sources is done in order to provide a complete picture of the organization’s impact. The total carbon footprint is calculated using CO₂ equivalent values on the basis of following the components-burning of fossil fuels, electricity consumption for lighting and production and fuel consumption for transportation. Collecting and gathering the activity data is difficult from different departments such as infrastructure and finance as it is a time consuming process. ‘Green teams’ or other cross-organizational groups must be engaged to understand where the data is available. Appropriate project planning allowances should be made to ensure that the information gathered is relevant, complete, reliable, and can be reproduced. For effective assessment of carbon footprint, gas and electricity, activity data should be collected in a variety of units, for example, KWh, liters, Kms and so forth.

Carbon CO₂ calculators are used now a day as it automatically calculates the carbon footprint of an organization after the activity data is filled in. Many countries such as Canada, the U.S., Australia, and countries of Europe have developed their

own calculators based on the IPCC guidelines. The most popular calculator is the one developed by UNEP (Saxena, 2009). Its selection varies on the basis of its suitability to the type of manufacturing firm. It provides a comprehensive excel spreadsheet for organizations to measure emissions. All this data is entered into the tabs in the spreadsheet and it does all the calculations. The spreadsheet provides the flexibility to send copies to different departments in the business or allocate responsibility to certain staff. It also allows entering new data on a fortnightly, monthly, and quarterly or on annual basis to track any changes. The calculator simply performs a conversion of the data given and is able to produce an accurate CO₂ footprint.

- k) ***Seeking third party verification.*** Verification by a third party is the next step which assesses whether the process being used is robust and is exhibiting the principles of relevance, completeness, consistency, transparency and accuracy. Such carbon footprint verification by a third party, can lend credibility to an organization's claims.
- l) ***Disclosing the footprint (optional).*** Carbon footprint after verification can be disclosed in the advertising material, in a Corporate Social Responsibility report or in other collaterals. It is important to ensure that the data is presented in a transparent manner. The following information should be clearly provided in the report:-
 - i. Methodology used.
 - ii. Boundary conditions.
 - iii. Types of emissions included and excluded.
 - iv. Data collection techniques.
 - v. Level of accuracy achieved.
 - vi. Assumptions or estimates.
 - vii. Level of verification of the results by independent third parties (Carbon Decisions, 2009).

2.2.6 Standards and guidelines.

Rethinking the future: It is a profound challenge, at the end of an era of cheap oil and materials to rethink and redesign how we produce and consume; to reshape how we live and work, or even to imagine the jobs that will be needed for transition.

Ellen MacArthur (as cited in “Sustainable Development in Government,”2010)

The assessment of the carbon footprint in the apparel industry should be made in accordance with the guidelines and reporting principles provided by the international organization as they provide an agreed and common approach to calculate the GHG emissions for the carbon assessment of supply chain. It simplifies the implementation, provides common assumptions and boundaries, supports data transfer through the supply chain and clearer understanding and improved comparability when publicly disclosed.

Standards for carbon foot print calculation.

Various standards for carbon foot printing are described below:

- a) *Intergovernmental Panel on Climate Change (IPCC) 2006* .It is an international organization comprising of 2500 scientists from all over the world, formed to conduct research, find solutions and take some concrete steps to prevent dramatic climatic changes on our planet in terms of climatic patterns. Any action on climate change are based on the findings of this body and is generally accepted on account of the representation of scientists from all countries (Cool Earth_Sustainability Services, 2012).Serious talks are organized by the United Nation Framework Convention on Climate Change (UNFCCC) every year at the ‘Conference of Parties (COP)’ where delegates in the form of environmental secretaries, ministers from various countries meet in order to deal with this thorny situation. This assist member nation on the reporting of national GHGs inventories in the UNFCCC framework, and are therefore applicable at national level.
- b) *The GHG Protocol Corporate Accounting and Reporting Standard*. It was developed by the World Resources Institute and the World Business Council for Sustainable Development and the report first was published in 2001 and has since

been continually developing. Other standards have been derived from it. It is an international accepted corporate greenhouse gas emission accounting standard inclusive, freely available and tested by diverse international companies for government and business leaders to understand, quantify, and manage greenhouse gas emissions (Gawel & Bhatia,2008). It covers the accounting and reporting of the six greenhouse gases covered by the United Nations Framework Convention on Climate Change under the Kyoto Protocol: carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, perfluorocarbons and sulfur hexafluoride. It was designed to:

- i. Help companies prepare a GHG inventory so as to represent a true and fair account of their emissions through the use of standardized approaches and principles.
- ii. Simplify and reduce the costs of compiling a GHG inventory.
- iii. Provide business with the information that can be used to build an effective strategy to manage and reduce GHG emissions.
- iv. Increase the consistency and transparency in GHG accounting and reporting among various companies and GHG programs (Greenhouse Gas Protocol, n.d.).

The GHG Protocol includes two standards:

- *GHG Protocol Corporate Accounting and Reporting Standard*- It provides a step-by-step guideline for companies to use in quantifying and reporting their GHG emissions. It simplifies and systemizes defining the boundaries. Tools and application guidance is available as a free download at www.ghgprotocol.org.
 - GHG Protocol for Project Accounting-It acts as a guide for quantifying reductions from GHG mitigation projects.
- c) *Publicly Available Specification (PAS)*. It is applied at the smallest scale among these standards, assessing life cycle emissions of products and services from "business to consumer" or "business to business"(Wu,2011).

- d) *International Local Government GHG Emissions Analysis Protocol (IEAP)*. It includes general principles and philosophy that any local government, regardless of location, should adhere to when inventorying GHGs from its government operations and community as a whole.
- e) *International Organization for Standardization (ISO 14040-14044, 14064, 14067)*. The International Standards Organization (ISO) has created an international standard for GHG accounting and reporting. ISO 14064 (2006) specifies principles and requirements at the organizational level for quantification and reporting of GHG emissions and removals. It includes requirements for the design, development, management, reporting and verification of an organization's GHG inventory. It includes specifications with guidance for use at the organizational level and the project level, as well as carries out the validation and verification of greenhouse gas assertions. The three parts of standard 14064 are:
- i. 14064-1:2006, *Part 1*- provides specification with guidance at the organizational level for the quantification and reporting of greenhouse gas emissions and removals. It contains principles and requirements for designing, developing, managing and reporting organizational or company-level GHG inventories. It includes requirements for determining organizational boundaries, GHG emission boundaries, quantifying an organization's GHG emissions and removals, and identifying specific company actions or activities aimed at improving GHG management.
 - ii. 14064-2:2006, *Part 2*- provides specification with guidance at the project level for the quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements.
 - iii. 14064-3:2006, *Part 3*- provides specification with guidance for the validation and verification of greenhouse gas assertions (Baumann & Kollmuss, 2010).

ISO 14064 was designed to work in conjunction with two other standards i.e. ISO 14065:2007 and ISO 14066:2011. ISO 14065 provides requirements for greenhouse gas validation and verification bodies for use in accreditation or other

forms of recognition, and ISO 14066 provides competence requirements for greenhouse gas validation teams and verification teams. It describes the procedures that should be followed in conducting life-cycle assessments (LCA). The objective is to promote the monitoring, reporting and tracking of progress in the mitigation of GHG emissions. Table 2.10 shows the details of the standards.

Table 2.10

The Green House Gas Standards

Type of GHG Standard	ISO	GHG Protocol
Corporate	ISO 14064-1	Corporate Accounting and Reporting Standard
		Corporate Value Chain (Scope 3) Accounting and Reporting Standard
Projects	ISO 14064-2	The GHG Protocol for Project Accounting
Products	ISO 14067	Product life cycle Accounting and reporting Standard
Verification	ISO 14064-3	No Verification Standard

Note. Adapted from “GHG inventory management,” by Suneja(2012).

All the above mentioned standards are implemented on different scales as shown in Figure 2.47.

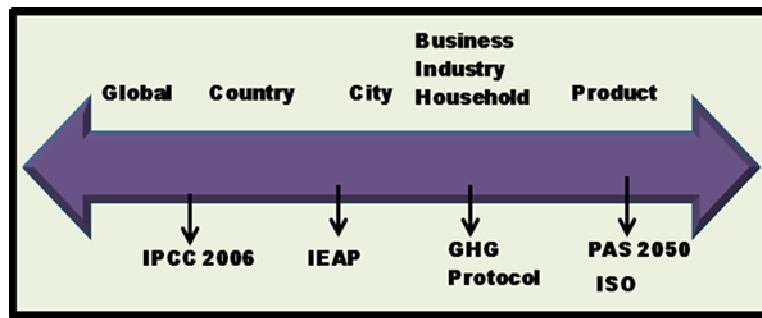


Figure 2.47. Greenhouse gas accounting standards on different scales of application. Adapted from “Carbon footprint: A case study on the municipality of Haninge,” by Wu, 2011, p.14.

“Without such practical and robust accounting systems and tools, addressing the challenge of climate change would be just unmanageable.” These words by Gawel and Bhatia (2008, p.14) best describe the importance of standards for quantifying, managing and eventually reducing their GHG emissions.

2.2.7 Performance measurement through environmental key performance indicators.

Integral to the needed transformations is a change in values – a transition to new habits of thought and a new consciousness captured well in the Earth Charter, which urges us “ to bring forth a sustainable global society founded on respect for nature, universal human rights, economic justice, and a culture of peace.

James Gustave Speth (2007, p.17)

Very few key indicators are known to evaluate the environmental effectiveness. Krajnc and Glavic (2003) had proposed a set of environmental key indicators namely input indicator including energy, water and material and output indicators including CO₂, waste and toxic as illustrated in Figure 2.48.

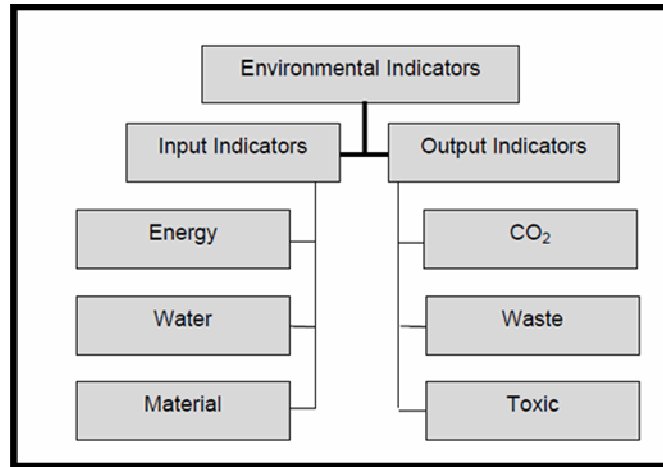


Figure 2.48. Environmental key indicators. Adapted from “Indicators of Sustainable Production,” by Krajnc & Glavic, 2003, *Clean Technologies Environmental Policy*, 5, p.280.

Kuriger et al. (2011) successfully combined sustainable production with lean in order to determine the appropriate metrics to evaluate environmental performance. The sustainability key indicators suggested were energy consumption, water consumption, material usage and CO₂ emissions. Energy consumption is the amount of energy consumed in a process or processes. Similarly, water consumption and material usage are the amount of water and material used, respectively. CO₂ emissions are the amount of carbon dioxide (CO₂) that is emitted into the atmosphere. In order to enhance its environmental performance all these key indicators should be minimized. Simons and Mason (2002) stated that carbon dioxide emissions are the primary sustainability metric used by the sustainable Value Stream Mapping in the Lean environment (as cited in Venkat and Wakeland, 2006, Introduction, para 10). There are no standard formulas for calculating these key indicators but they are easy to measure and understand. The majority of key indicators are measured using simple counts, observation, meters, utility bills, assumptions, and other means except for measuring CO₂. Various standards and guidelines are available online such as Greenhouse Gas Protocol, ISO to calculate the CO₂ emissions. Langenwalter (2006) had linked sustainability with lean operations through few key indicators namely energy used per unit of output, percent of energy from renewable resource, mass of finished goods per mass of raw material consumed, percent of raw materials reused or from recycled sources, emissions, especially greenhouse gas emissions, both total and

per unit of output, effluents discharged per unit of output, number, weight and names of toxic substances discharged in waste, or lost, both total and per unit of output.

Four environment performance indicators selected were carbon footprint emitted (tonnes) per full time employee , carbon footprint emitted(tonnes) per rupee earned, carbon footprint emitted (tonnes) per garment and carbon footprint emitted(tonnes) per sq. ft. of operation for this study, where carbon footprint of an apparel manufacturing unit is calculated in the form of CO₂ emissions released in the environment. Following formula was used to calculate the carbon footprint in tonnes CO₂ e.

- a. Carbon foot print = Activity Data x Emission Factor
- b. Carbon footprint per garment = Carbon foot print/Number of garments produced in year 2012
- c. Carbon footprint per sq. ft. of operation = Carbon foot print/Total Floor area in sq. ft
- d. Carbon footprint per rupee earned = Carbon foot print/Turnover in 2012
- e. Carbon footprint per full time employee = Carbon foot print/Total number of full time employees in 2012

2.2.8 Studies related to carbon footprint.

“The future depends on what we do in the present”

Mahatma Gandhi (as cited in “Gandhi quotes,”n.d.)

Researches on the Carbon Footprint had been conducted at various scales from national to municipal levels from industries all over the world. Very few studies are available on creation of GHG inventory of apparel industry; hence the studies of other industries were also reviewed to obtain comprehensive knowledge and better understanding relating to its concept, methodologies, calculation procedure and standards of carbon footprints. Information was collected from academic journals, scientific databases and websites of related institutions.

Life cycle assessment (LCA) of Merino Wool was conducted to prepare a detailed inventory of New Zealand merino wool production by Barber and Pellow

(2006) to determine the total energy use and carbon dioxide emissions from on-farm production of wool through to the processed wool tops being delivered to a spinning factory in China. The system boundary was expanded to encompass spinning, dyeing, apparel manufacturing, customer use, and disposal. It was found that wool production had a total energy use of 46 MJ/kg wool tops, half of which occurred in the farm. On-farm energy use was 23 MJ/kg wool tops (13 MJ/kg greasy wool). Wool processing accounted for 47% of total energy use, of which almost 90% occurred during wool scouring. Carbon dioxide emissions calculated was then very closely linked to energy use. It was found that the production of polyester fibre used 2.7 times more energy than wool. Acrylic, the fibre that most resembles wool, used 3.8 times as much energy in its production and nylon used over 5 times the energy required to produce wool.

A product carbon footprint assessment methodology was developed in order to facilitate Singapore industry to achieve sustainable manufacturing by lowering their carbon profile. Life cycle assessment (LCA) methodology was considered appropriate for assessment taking guidelines from the standards of ISO 14040 and ISO 14044. It started with the identification of raw materials, production processes, waste produced, storage and transport. The next step included the identification of the flow of the resources that is list of input and output activities, covering from the extraction and processes of raw materials to disposal of the product including packaging. Assessment boundaries or the limits of data required were set. Data was collected for the assessment and emission factors were noted. All activity data specified by quantities of resources used was multiplied by the relevant emission factor, and added together to create the final product carbon footprint. This methodology built on existing international standards, provided a clarity and certainty around critical elements that were central to the consistent assessment of carbon footprint (Rugrungruang, Chua, & Low, 2009).

A study was carried out to find out the environmental benefits of textile reuse and recycling in comparison to other disposal options. Product carbon footprint emissions were calculated for both in a textile industry. Carbon accounting methodology was followed as per the guidelines of Publicly Available Specification (PAS) 2050. DEFRA GHG conversion factors were used to calculate the emissions from energy use and transport. Results revealed that there were significant carbon emissions savings from reusing and recycling textiles. Of the parameters measured,

reuse provided greater benefits than recycling, as the emissions of new textiles were estimated to be higher than the emission rates of the functional equivalents of recycled products. It was therefore, concluded that the process of recycling textiles consumed more energy than retailing reused textiles, but retailing textiles had a more significant carbon footprint (McGill, 2009).

A survey of Small and Medium Enterprises (SMEs) on the impact of a carbon price and the challenges of operating in a carbon constrained economy was conducted by the National Centre for Sustainability (NCS) at Swinburne University of Technology from May to December 2009. Results revealed that two-thirds of the businesses had not measured their carbon footprint. They highlighted the *lack of skills and knowledge on how to identify and measure greenhouse gas emissions* as the primary barrier. *Lack of time and resources* was the second largest contributing factor. One-third of businesses who had measured their carbon footprint, 71% of them identified opportunities for cost savings (National Centre for Sustainability, 2009).

Agarwal (2010) developed the software to calculate the carbon footprint of a particular garment style in a selected apparel unit 'Orient Craft Pvt. Ltd'. Various sources of the different departments which added to the footprint were narrowed down. Methods used to calculate the footprint were analyzed and the software was developed for easy and practical data entry, with an extensive database of various equipments used, for easy selection and accurate calculations applicable to any apparel manufacturing unit. The methodology included establishing project boundaries for carbon footprint, Identification of GHG sources and sinks, defining the quantification methodologies or calculation approach and lastly software development and database for easy and accurate calculation. GHG activity product data for sample styles was collected and the carbon footprint was calculated using software which depicted that different departments, products of an AMU had varied footprints. Carbon footprint was reported and the potential areas of reduction were identified.

The Ministry of Earth Sciences (MoES) in India completed the mission mode project called System of Air Quality Forecasting and Research (SAFAR) to forecast the air quality of NCR Delhi, for the first time in the country on the occasion of Common Wealth Games-2010. A comprehensive study based on the scientific knowledge was taken up to develop the high resolution (1.67 km x 1.67 km) emission

inventory of all major air pollutants for a domain of $\sim 65 \text{ km} \times 70 \text{ km}$ ($\sim 4500 \text{ km}^2$ area) covering Delhi and its adjacent region to facilitate the accurate air quality forecasting. It was a complex process due to numerous, diverse and widely dispersed emission sources in a city like Delhi and its adjacent region and required huge amount of high resolution activity data, emission factors along with the knowledge of fundamental scientific processes. For the development of emission inventory, a bottom up approach was used. The emissions were estimated for the individual sources and for that purpose, an extensive scientific field campaign was carried out in NCR region for several months by involving more than 250 students from different colleges and university in Delhi and Pune. It inculcated the feeling of scientific temperaments in the young minds. Information related to following major activities were either generated or collected from relevant institutions regarding the quantity of fuel used, their type and daily usage: power (coal used in all thermal power plants), transport sector (CNG vehicle, diesel, petrol driven vehicles, etc), industrial (fuel used in cement, steel, bakery, chemical, metal industries, etc), slum cooking (use of kerosene, wood, coal, etc), commercial cooking (in hotels, restaurants), street vendor fuel usage survey, paved /unpaved road (dust release), industrial /shop generator sets (diesel used) and bio-fuel burning (dung, crop-residue, wood, bio-mass burning, etc). The results revealed that the transport and residential sectors were two dominant sectors responsible for the majority of pollutant emissions in Delhi region followed by industrial and power sectors. Nitrous oxide emissions were on the rise whereas black carbon emissions were quite low (Das, 2010).

A study was conducted by Central Electricity Authority of India in 2012 to assess the entire greenhouse gas emissions inventory of the Sasan Ultra Mega Power Project developed by Sasan Power Ltd (a wholly owned subsidiary of Reliance Power Limited) with appropriate emission factors. The plant was based on super critical technology, which consumed lesser coal per unit of power generation and thus produced lesser carbon-dioxide. It was found that the main greenhouse gas emissions generated in the coal fired thermal power station were carbon dioxide (CO_2 combustion) and methane (CH_4) (handling/storage of coal), nitrous oxide (N_2O) (combustion), HFCs (Air conditioners) and SF_6 (electrical systems). The CO_2 emissions from the plant were calculated as 829.43 gm/kWhr and were found less

than the National baseline data of 944 gm CO₂-e/kWh for power stations employing super critical technology (Central Electricity Authority [CEA], 2010).

Product carbon foot print of a white long-shirt whose journey started from cotton fields in Germany, manufacturing in Bangladesh and to the consumers in United States was calculated as 10.75 kg CO₂e which was 50 times of its total weight. Distribution of carbon emission sources included 12% from cotton cultivation, 28% from manufacturing, 3% from transport, 8% from distribution, 14% from catalogue, 2% from packaging, 31% from use phase and 2% from disposal. Use of fertilizers in cotton growing fields released gases which further increased CFP emissions (Global Warming Potential [GWP] of N₂O is 298) causing almost 300-time larger effect than CO₂. Total emissions comprised of 2/3rd of the carbon emissions by electricity and 1/3 by heating processes. In user phase, CFP was mainly determined by the use of washing machine, washing agent, water supply, and dryer, pressing iron and energy efficiency of machines. Similar long shirt of same size but of dark colour produced more CFP due to waste water treatment, color intensity, thickness of knit-fabric and energy sources during dyeing (Jungmichel, 2010).

Chaudhary (2010) identified different wastes generated in an ISO certified, government recognized export house, located in Faridabad and provided the suggestions to reduce its generation. Various departments like administrative, design, line development and production contributed to some amount of carbon footprint. Their work consumed electricity in the running of machines like electric cutters, sewing machines, fusing machines and steam iron sets and generated garbage like fabric scraps, papers pattern, cardboard boxes, labels, and tapes, thread cones, fusing rolls, fabric scraps and stickers. The main two sources of carbon footprint were: the transport which was used by the personnel working in the unit for traveling, and, electricity which was consumed by all the departments. The data collected for the consumption of fuel used in transport and machinery, chemicals, water and electricity was considered. The calculations of the components of carbon footprints were natural gas - 2, 81,820 kg of CO₂ eq per year, diesel - 4, 45,000 Kg of CO₂ eq per year, petrol - 1, 75,915 Kg of CO₂ eq per year, mobil oil - 3,000 Kg of CO₂ eq per year and LPG - 295.36 Kg of CO₂ eq per year. A sum total of the above values was taken and was divided by the production per year to arrive at a value of carbon footprint generated per garment and it was found to be ranging between 1.0 kg-1.5kg of Co₂ eq. Different

ways were suggested to reduce carbon footprint that is recycling of small pieces of waste fabrics into shoddy items, avoiding the usage of fusible interfacings, use of CAD and CAM systems, efficient stitching methods, use of motorized 'Energy star mark' sewing machines, regular maintenance, lubrication and upkeep of the machines, use of large baler bags for storage, use of local raw materials and so forth.

Varshney (2010) conducted a study in the Elegant Spinners (unit of Bhiwani Grasim Suitings) for the assessment of carbon footprint. Interviews were conducted to gain information regarding the wastes generated in the unit and also similar methodology was used in calculation as done by Chaudhary (2010). Carbon footprint value was found out to be 0.7 kg of CO₂e in the unit.

A project was developed by Clothing Industry Training Authority, Hongkong using appropriate methodologies to acquire knowledge, experience and best practices for factories managed by SMEs across the manufacturing sector of the Hong Kong apparel supply chain. It was carried out in order to assess and understand their product carbon footprint, effectively disclose their product carbon footprint, identify carbon emission reduction opportunities, and act against such opportunities to build their low carbon competitive advantages. A guidebook was devised for the assessment and disclosure of the carbon footprint across the manufacturing sector of the Hong Kong apparel supply chain. Information was compiled on participating factories building their low carbon competitive advantages by identifying carbon emission reduction opportunities and the ways and means of reducing product carbon emissions. Five seminars and six workshops were conducted to publicize the guidebook so as to facilitate the building of the low carbon competitive advantage of the SMEs across the manufacturing sector of the Hong Kong apparel supply chain (Clothing Industry Training Authority, n.d.).

An assessment of environmental standardization potential and needs of the Pakistani Small Medium Enterprise of textile processing sector was carried out. It aimed at the promoting the adoption of sustainable consumption and production (SCP) among small and medium sized enterprises (SMEs) in Pakistan. The interview schedule was used to collect information from 21 industries from Lahore and Faisalabad regions including inward oriented and outward oriented units. Future strategy developed including a comprehensive report on different environmental

certifications and eco labels available throughout the world which was important for the Pakistani textile sector to enhance their export market by attracting customers. Awareness seminars were organized to educate these industrial sectors about these standards and a mechanism was developed to create links between the industry and the standard organizations (“Environmental Standardization ...SMES,”n.d).

Meena (2011)reported various constituents and sources of carbon footprints in percentages that is financial services (3%), recreation and leisure (14%), household (9%), carbon in car manufacturing (7%), food and drinks (5%),holiday flights(6%),electricity(12%),coal, oil and gas(15%),private transport(10%),clothes and personal effects(1%) and share of public services(12%).Green house gases emissions were also categorized into direct emissions resulting from the activities of organizational controls as well as indirect emissions from the use of electricity and products and services.

Khurana (2011) in her research assessed the carbon foot printing in a home furnishings knitting unit in Ludhiana. Various factors contributing to carbon foot printing were listed as: usage of fossil fuel, water, chemicals and wastes generated during various processes. Methodology for calculation was found similar to as used by Chaudhary (2010).Value of carbon footprint generated per product varied from 1.75 kg-2.1kg of CO₂e in the unit. Awareness about the carbon footprint reduction among different officials of the unit was provided by conducting workshops.

Anvil Knitwear, a significant manufacturer and supplier of sustainable sportswear, engaged GHG practitioner Camco International to quantify the emissions impact associated with the production, use, and disposal of four select T-shirts: Anvil® Basic, Anvil Organic®, Anvil Recycled™, and Anvil Sustainable™. The assessment of the life cycle for each Anvil T-shirt was conducted in accordance with the guidelines and reporting principles provided by the World Business Council for Sustainable Development (WBCSD) Greenhouse Gas Protocol. In addition, the carbon footprint of the Anvil Sustainable™ T-shirt was conducted in accordance with the WBCSD/ World Resources Institute Product Life Cycle Draft Standard. Emissions data from all facilities included the production of energy, raw materials and fuels, waste disposal and transportation, purchased electricity and steam, water treatment, stationary combustion, fossil fuel production, transportation for imports &

exports, employee commuting, and business travel was collected. Each segment's overall emissions were addressed in total amount of CO₂ per t-shirt and were then compared to the values from the other t-shirts. The most energy-intensive stage associated with a t-shirt came from consumer usage. Approximately 60 % of the overall emissions were associated with how it was worn, washed, and dried over a lifetime. It was revealed that the Anvil Organic® short-sleeve, 5.0 ounce, 100 % organic t-shirt possessed the smallest carbon footprint, with 3.09 kilograms of carbon dioxide equivalent. The Anvil Sustainable™ tee showed a 15 % lower footprint than Anvil's conventional cotton tee, with each tee saved approximately 3 plastic bottles from going into a landfill. The LCA also illustrated that the majority of energy consumed during the making of a tee was expended at the textile mill, where yarn was knit into fabric, then dyed and finished (Luppino, Bonanno, Lipschitz, & Cao, 2011).

Under emission inventory improvement program, accompanied with the state tool for greenhouse gas inventory development, a user-friendly inventory spreadsheet tool was developed by U.S. EPA State, and, local climate change program. It comprised of 11 Excel®-based modules, intended to reduce the burden associated with developing a new inventory or updating an existing inventory. GHG sources category and sinks identified producing emissions were; agriculture (including manure management, enteric fermentation, agricultural soil management, rice cultivation, and agricultural residue burning), carbon dioxide from fossil fuel combustion, coal mining activities, industrial processes, land use change and forestry, methane and nitrous oxide from mobile combustion, methane and nitrous oxide from stationary combustion, municipal solid waste, natural gas and oil activities and wastewater. This tool drastically reduced the staff time and cost necessary for successful application of the inventory guidance, thereby encouraged the use of consistent emission estimation methods, facilitated state inventory development, and encouraged states to update inventories (Choate, Freed, Groth, Stanberry, & Denny, 2012).

WRAP (Waste & Resources Action Programme) conducted a life cycle carbon footprint study for UK clothing commissioned by Environmental Resources Management Limited (ERM). The objective of the research was to provide an overview of the carbon impacts of UK clothing through the clothing life cycle, identifying the most significant contributions to the carbon footprint and quantifying

opportunities for carbon footprint reduction. The system boundary included the entire life cycle of both new, and, in use UK clothing. Thus, this study was considered a full 'cradle-to-grave' or 'business-to-consumer' carbon footprint. Life cycle assessment (LCA) approach was used for assessment, following the general specifications given in PAS 2050. The lifetime of each garment type and the composition of clothing were considered. Along with it, the weighted average locations of major producers of fibres and major producers of garments were summarized. Data regarding use included washing, drying, ironing and reuse. The results revealed that the total annual carbon footprint of all garments both new and existing, in the UK in 2009 was approximately 38 million tonnes of CO₂e. Direct carbon footprint of clothing contributed approximately 2% to the UK's total direct carbon footprint. The carbon footprint of new garments was calculated by dividing the carbon footprint of both new and existing clothing by its anticipated lifetime. The carbon footprint of one tonne of garments, ranged from around 15 to 46 tonnes CO₂e, depending on the fibre type of the garment ranged from around 1 to 17 kg CO₂e. The carbon footprint per person was around 0.6 tonnes of CO₂e. It was found that 21% reduction in the carbon footprint of UK clothing was possible if all reduction measures were considered. The largest carbon footprint reductions were achieved by extending product lifetime (8%), eco-efficiency across the supply chain (4% reduction) and washing clothing less (3% reduction). The study revealed that the fibre mix of UK clothing affected the magnitude of the footprint (Thomas, Fishwick, Joyce, & Santen, 2012).

A project was taken up by the 13 units of Okhla Garment Textile Cluster (OGTC) and come up together to work on carbon emission management strategies in collaboration with GIZ and Cool Earth. OGTC became the first textile cluster to initiate such carbon footprint exercise. It started with the training of employees in various aspects of carbon management namely geo-political, corporate and scientific. Carbon footprint was calculated using 'our impacts' software. Data collection, software data entry and report generation were the three basic steps followed for the calculation of carbon footprint for these units. The results revealed that the total emissions of all the 13 units were 29,689.67 tonnes CO₂e out of which 14,953.8 tonnes CO₂e was scope 3 which was 50% of the total emissions. Scope 2 came out to be 8067.03 tonnes CO₂e(27%) and scope I was found out to be 6668.84 which was 22%. All the units were interested in reducing their impact on the planet in terms of

climate loading. These units intended to monitor and take a call on reporting of their carbon footprint to retailers and NGOs like CDP based on future requirements placed on them by international bodies (Cool Earth, India, 2013).

Research was conducted by Nigam (2013) to assess the impact of the textile industry of Rudrapur in Uttarakhand on the environment and help reduce it. Data was collected from small and medium size enterprises in Rudrapur. The study was conducted in three phases starting with the introductory awareness and motivational workshop on carbon footprint in phase I. It was followed by phase II which included technical analysis of data to determine carbon footprint. The third phase included sharing the results through workshops and providing recommendations to reduce it. The results revealed that there was limited awareness regarding carbon footprint in this textile industry and no practice of carbon footprint assessment was found. Significant reductions in carbon emissions were achieved after strategized production and technological improvements through globally acceptable methods.

Another research project on the assessment of carbon and water footprint was conducted by Batra (2013). The main objective of the study was to identify relevant functions and processes contributing to carbon and water footprint of selected apparel manufacturing units under OGTC and calculate both carbon and water footprint. Awareness was also created along with providing suggestions for its reduction and development of software for the calculation of carbon and water footprint. A sample of 11 units of Delhi was selected for the assessment. The study was carried out in three phases. The phase I included survey and interviews with managers to get information regarding concept of carbon footprint. It was followed by phase II in which data was collected from various emission sources namely fuel, water, waste, and chemicals. The phase III included conducting workshop at each unit to make them aware of the concept and give suggestions and also provide software to keep a check on regular basis. The findings revealed that garments requiring washing, drying, ironing needed the largest energy inputs. Laundering accounts for 40-80% of total life cycle of GHG emissions for each garment. Machine drying is the largest energy user and cause of GHG emissions. Use of low GHG sources such as renewable sources, use of natural fibres reduce carbon emissions was recommended. It was found that hand washed and dry cleaned garment had lower carbon footprint.

2.3 Lean and Carbon Footprint

2.3.1. Association between lean and carbon footprint.

“It is natural that the lean concept, its inherent value-stream view and its focus on the systematic elimination of waste, fits with the overall strategy of protecting the environment, which they call Environmental Lean (En-Lean).”

Sawhney, Teparakul, Aruna, and Li (2007) (as cited in Miller et al., 2010,p.14)

Lean manufacturing is often seen as a set of tools that reduce the total costs and improve the quality of manufactured products. The basic philosophy of lean is to target waste reduction in every facet of the manufacturing business, while sustainable production seeks to manufacture products in a way that uses minimum energy, releases minimum emissions, and eliminates other environmental wastes (Kuriger, Huang, & Chen, 2011). The Green, or sustainable, manufacturing is defined by Allwood as a method to “develop technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste” and is often used interchangeably with “environmentally-safe” (as cited in Miller et al., 2010, p.12). However, only recently studies have linked lean management philosophies with improving environmental sustainability. As both lean and green techniques are based on “zero-waste” practices, they tend to reduce the overall costs.

The connection between lean and green manufacturing has been well documented in the recent literature (Angel & Klassen, 1999; Sawhney et al., 2007). The common definition of Lean “The elimination of waste everywhere while adding value for customers” reveals the relationship between Lean and Green. The green does this by following the wisdom of the natural world which is both truly efficient and effective in creating value and that produces no waste at all. By eliminating all waste and adding value to customers, organizations must move towards environmental sustainability (Wills, 2009).

Teresko (2004) discussed the connection between lean and green through the Bill McDonough’s book “Cradle to Cradle” based on remaking the way we make

things. Relationship became clearer as lean by redesigning a plant layout seemed to transcend green by the reduction of pollution and efficient use of resources. Though the green wastes are different from the lean wastes as described in Table 2.11 and 2.12, but all the 8 lean wastes have environmental impacts. Lean seeks to eliminate traditional production objectives like costs or time while green is concerned with wastes that impact the environment (Miller et al., 2010). Any apparel manufacturing unit which is using lean tools to remove 8 wastes will automatically lead to reduction in energy and fuel use further leading to lowering of emissions. Table 2.13 describes the 8 types of environmental wastes targeted by Lean philosophy. The Environmental Protection Agency (EPA) had added environmental waste to the list of eight lean wastes (EPA, 2007).

Table 2.11

Eight Forms of Waste identified by Toyota

S.No.	Lean Wastes	Description
1.	Overproduction	Producing more than required or used
2.	Human Resources	Not using people's mind and getting them involved
3.	Transportation	Moving tools/materials to the point of use
4.	Inventory	Materials or information including WIP and finished goods
5.	Motion	Movement of people as well as smaller

		movements
6.	Corrections	Rework or fixing of products
7.	Over Processing	Additional work above the requirements
8.	Waiting	Time delays for materials, information or people

Note. Adapted from “A case study of lean, sustainable manufacturing,” by Miller et al., 2010, *Journal of Industrial Engineering and Management*, 3(1), p.12.

Table 2.12

Nine Forms of Waste Identified by Green Manufacturing

S.No.	Green Wastes	Description
1.	Permit Compliance	Compliance with applicable permits.
2.	Toxic Release Inventory	Over 300 chemicals subject to release.
3.	33/50 Chemicals	A Subset of TRI chemicals identified by the EPA as priority candidates for voluntary reductions by the industry.
4.	CleanAir Act Toxics	189 chemicals listed in the clean Air Act as air toxics.

5.	Risk-Weighted Releases	Toxic chemicals weighted by their relative toxicity.
6.	Waste per unit of production	Percentage of production lost as waste, generally measured by weight.
7.	Energy use	Total energy use by all aspects of corporate operations also expressed as CO ₂ .
8.	Solid Waste Generations	Total solid waste going to landfills or other disposal facilities.
9.	Product Life cycle	The total impact of a product on the environment from raw materials sourcing to ultimate disposal.

Note. Adapted from “A case study of lean, sustainable manufacturing,” by Miller et al., 2010, Journal of Industrial Engineering and Management, 3(1),p.13.

Table 2.13

Environment Impacts linked with Manufacturing Wastes

Waste Type	Examples	Environmental Impacts
Defects	Scrap, rework ,repair , replacement, inspection	• Raw materials and energy consumed in making defective products. • Defective components require recycle or disposal. • More space required for rework and repair, increasing energy use for heating, cooling and lighting.
Waiting	Delays associated with stock outs, processing delays, equipment downtime, capacity bottlenecks etc	• Potential waste spoilage or component damage leading to waste. • Wasted energy from heating, cooling and lighting during production downtime.
Unnecessary processing	Processing steps that are not required to produce the products	• Excess raw material used • Production & processing increases wastes • More energy use and emissions

Overproduction	Manufacturing items for which there are no orders	• Excess apparels go out of fashion, or get spoilt
Movement	Unnecessary human motions , and transporting long distances	• More packaging and special containers required to protect products during transportation. • More energy and emissions required for transport.
Inventory	Excess raw material, work in progress and finished products	Waste from more packaging, damage, space, energy(heat, cool & light) for stored and damaged WIP.
Unused Employee creativity	Failure to tap employees for process improvement suggestions	• Fewer suggestions of waste minimization
Complexity	More parts, process steps ,or time than necessary to meet customer needs	• More parts and raw material consumed per unit of production • Unnecessary processing increases wastes, energy use and emissions

Note. Adapted from “Using lean methodologies for economically and environmentally sustainable foundries.,” by Torielli ,Abrahams, Smillie,& Voigt, 2011, *China Foundry*,8(1), p.75.

Environmental concerns are a part of the lean concept. According to Kidwell (2006, p.18), “lean strategies” coincidentally benefit the environment. Environmental considerations can become incorporated as an inherent part of lean, without the need for special “environmental”. Emissions in air and water, as well as the generation of solid or hazardous waste, represent a waste of production which has no value to the customer. Lean tries to eliminate these wastes and along with it tries to implement 6S “Safety” by providing protective equipment such as gloves and ear plugs to the operators. Lean usually helps the environment without really intending to. Lean implementation has resulted in saving money in various organizations as well as unconsciously providing benefit to the environment. “Environmental” wastes, such as excess energy or water use, hazardous waste, or solid waste, present an untapped opportunity for the lean practitioner.

Lean’ and Green’ frequently go hand-in hand to improve both the environmental and business performance. The overall goal of lean manufacturing is to continually improve production efficiency. More efficient production means, less energy used per unit produced. It means less material resources are used per unit

produced, and materials are used or reused more efficiently. Companies usually do not consciously target “environmental” issues such as energy or water use, solid or hazardous waste, or chemical hazards, in their lean initiatives. But with the recent rise in energy and transportation costs, an increasing number of companies have begun specifically targeting energy consumption for Kaizen which is also a “environmental” wastes (Kidwell, 2007; Print City Special Report, 2010).

Rother and Shook (2003) gave 5-step process for lean transformation of any manufacturing unit based on Plan-Do-Check-Assess (PDCA) cycle. It includes finding change champion or a teacher, identifying crisis in the unit for motivation, mapping entire value stream and the removal of wastes. This methodology is similar to that of green manufacturing which is also largely dependent on PDCA cycle for deployment and assessment as described by Zandin (2007). While lean and green manufacturing strategies share similar implementation strategies, they differ in the standards to which implementation is evaluated. ISO 14001 is a standard for environmental management systems to be implemented in any business, regardless of size, location or income. The aims of this standard are to reduce the environmental footprint of a business and to decrease the pollution and waste a business produces. Lean manufacturing does not have a universally accepted standard for evaluation. Lean’s fundamental principles developed by Toyota are universally accepted and can be commonly adapted by each organization or industry.

Another connection between ‘lean and green’ reveals that the manufacturing units adopting ISO 9000 have more chance of adopting ISO 14000 as lean production minimizes waste generation, emissions and regulates costs. Adoption of ISO 9000 as a quality management standard and acts as an important step towards lean concept as it leads to the use of less waste in terms of over production, over processing, waiting, transportation and low inventory levels. Figure 2.49 clearly indicates that more an establishment engages in lean production, the lower will be its emissions. Lean adoption practices reduce the pollution which in turn lowers the barriers for the implementation of environmental standards. The cost involved in successful implementation of environmental management system gets reduced. The manufacturing apparel unit which has adopted the quality standard ISO 9000 is more likely to adopt ISO 14000 (Environmental Management Standard) which will ultimately reduce the source and emissions (King & Lenox, 2001). Technological

experience in terms of lean production and source reduction allows the firm to improve both quality and environmental performance. Lean production is complementary to environmental performance. Hence, more an establishment engages in lean, the lower will be its emissions, in other words; Lean is green (Marudhamuthu & Krishnaswamy, 2011).

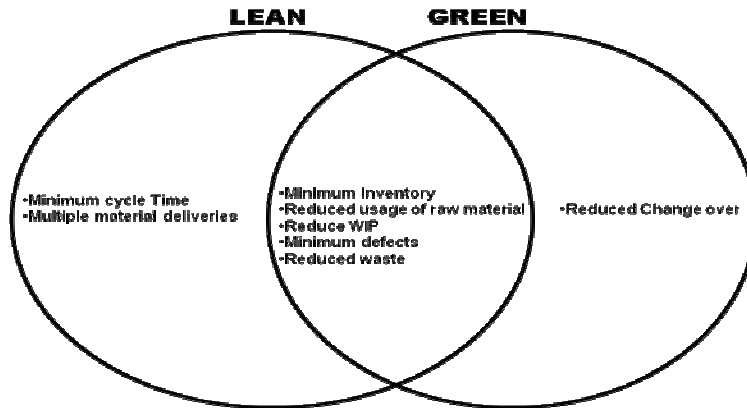


Figure 2.49. Lean and green connection. Adapted from “The development of green environment through lean implementation in a garment industry,” by Marudhamuthu & Krishnaswamy, 2011, *ARPN Journal of Engineering and Applied Sciences*, 6(9), 104-111.

Lean produces an operational and cultural environment that is highly conducive to waste minimization and pollution prevention. Lean methods focus on continually improving the resources, productivity and production efficiency, which gets translated into less material, less capital, less energy, and less waste per unit of production. It substantially reduces the footprint of production. The realignment of production around products and into cells using the right-sized equipment drives inventory requirements and movement out of the production system. It allows units to reduce by as much as 50% of their floor space requirements. This significantly further reduces the facility capital costs. For example property, buildings, as well as facility operating expenses in terms of maintenance and utilities (EPA, 2003).

Environmental concerns are a part of the lean concept. Lean can be used to support and maintain sustainable production. Many of the lean tools directly provide sustainable benefits, while others can be adapted to provide sustainable benefits. Lean metrics (total lead time, value added time or non-value added time and throughput)

should be combined with green metrics (energy consumption, water consumption, material usage and CO₂ emissions to form a lean sustainable production metrics (real time and continuous improvement) and should be implemented within a company to evaluate its effectiveness (Kuriger et al., 2011).

Lean is a philosophy and not simply a set of tools and techniques. However, some key lean tools and techniques have been proven especially effective in improving sustainability. Some tools are modified into green tools to have more impact on the lowering of the organizational footprint. These are Environmental Value Stream Mapping (EVSM), Statistical Process Improvement, 6S (Sort, Set in order, Shine, Standardize, Sustain and Safety), 7R (Reduce, Recycle, and Reuse; Remove, Renewable, Revenue, and Read) and Management Operating System (Torielli et al., 2011). “The lean and environment toolkit,” book/magazine published in January 2006, presented slightly modified visualization standard lean tools, such as EVSM and 6S, to include environmental considerations (Shahrbabaki, 2010). The ‘Toolkit’ also provides checklists and other standardized forms used during Kaizen events that provide a framework for environmental considerations. Another fairly common example is a “6S Checklist” where “safety” is included as the sixth “S” (Kidwell, 2006).

Both Green as well as Lean production has become a buzz topic in today’s arena of competition. 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, manufacturing units are starting to change their principles towards green and lean philosophies.

2.3.2. Studies related to lean and carbon footprint.

“Lean thinking must be green because it reduces the amount of energy and wasted by-products required to produce a given product. Lean’s role is a green critical enabler as the massive waste in our current practices is reduced.”

Jim Womack (as cited in Hines, 2009,p.2)

Empirical evidence of the relationship between lean and carbon footprint is sparse, though there are few individual success stories showing the link between lean and green.

Relationship between the adoption of advanced production practices as lean production, agile manufacturing, and high-performance production and innovative approaches to environmentally conscious manufacturing was examined by Florida (1996). It was stated that adoption of innovative manufacturing process creates substantial opportunity for adoption of green design and production strategies since both operate on the same underlying principles namely dedication to productivity improvement, quality, cost reduction, continuous improvement, and technological innovation. The survey was conducted and questionnaires were administered to a stratified random sample of 450 manufacturing firms. These results revealed that improving the overall industrial performance and productivity acts as an important driver of making environmentally conscious manufacturing efforts. The pursuit of zero defects and zero inventory manufacturing strategies produced spill-over benefits to the environment and created the context for innovative approaches to emission reduction and pollution prevention, which further led towards zero emission manufacturing strategies. Hence, it was assumed that lean is green.

Helper, Clifford and Rozwadowski (1997) explored the factors which would help make firms both profitable and environmentally conscious and innovators in manufacturing and leaders in emissions reduction. A number of examples were cited in which firms were simultaneously able to reduce pollution and increase efficiency by adopting innovations in manufacturing practice (lean manufacturing) and in environmental management (pollution prevention). Data for the study was collected by interviewing the production managers and environmental managers of supply firms in Northeast Ohio followed by an extensive plant tour. The firms were analyzed in respect to the two sets of practices: leanness and greenness. After every firm was assessed with respect to its leanness and its greenness, the firms were rank ordered to distinguish the leanest from the least, and the most green from the least. All the firms in the sample over the median level of 'green' were categorized as green and all the firms in the sample over the median level of 'lean' were categorized as lean. The results revealed that there was no appreciable bias across the categories of lean and green, lean, but not green, green but not lean, and neither is lean nor green.

Relation between lean production and environmental performance was explored by King and Lenox (2001). The authors were of the view that 'lean is green' as 'zero waste' was the mantra of lean production. The adoption of lean practices led inadvertently to pollution reduction as proved by the empirical analysis of 17,499 U.S. manufacturing establishments. Units that were engaged in lean production adopted formal environmental management systems that are quality standards (ISO9000 and ISO14000) which further led to reduction in inventory and hence released less toxic chemicals and wastes. It facilitated reduction in emissions through pollution prevention rather than end-of-pipe treatment.

Connection between lean manufacturing and the environmental movement was again reinstated by Sawhney et al. (2007) as he compared the environmental impact of a cellular manufacturing scenario versus a batch-style manufacturing scenario. It was reported that several green manufacturing metrics like air pollution, employee's safety and health and exposure to dangerous material were less in lean manufacturing than in batch-style manufacturing. Lean strategies implementation led to less exhausts and power consumption, optimized plant layout and elimination of unneeded material transfers.

Another study by Bergmiller and McCright (2009) found that the manufacturing units which had implemented lean manufacturing and received one of lean's most distinguished awards- "The Shingo Prize for Operational Excellence, 2009" were significantly greener than a general population of other manufacturers in 25 of 26 measures of green manufacturing. An online survey tool was used to collect the data in criteria's like status and advantages or disadvantages of environmental management system (EMS) and the environmental waste techniques was used in the manufacturing units. A strong correlation between the successful development and implementation of lean to the "greenness" of a manufacturer was found and the lean seemed to transcend green.

Qiu and Chen (2009) designed an evaluation method to visualize the environmental impacts before and after the lean production implementation in a simple way. The method was based on lean and life cycle assessment (LCA) thinking. It consisted of three steps including firstly, defining the boundary of the study. Secondly, the production performance and environmental impacts of each process to

be measured and thirdly, summarization of the production and environment performances of different processes. The evaluation method used fulfilled the criteria of visualization, comparability (between the current and future states), simplicity and practicability. The environmental impacts were categorized into energy, transports and materials for comparison before and after lean implementation. The environment performances in the three categories were measured in the common unit and presented in the VSM. The result of the comparison revealed that with the implementation of lean, the non-value added time in production process was reduced, at the same time, the environmental impacts were also reduced.

Integration of lean tools and sustainability concepts were tested by Miller et al. (2010). The principles of lean manufacturing that helps in the elimination of waste were implemented in a small furniture production company, which helped not only to increase the customers demand but also preserve the valuable resources for future generations. In one of the projects, the use of lean strategy prevented over production or under production, thus avoiding unnecessary energy consumption. Another recycling Kaizen project concerned with the solid waste disposal process, led to the recycling of a significant amount of material previously disposed of as waste. The result revealed that TPS (lean manufacturing) transcended green manufacturing, and lean transformation of the company resulted in the green transformation as well.

The lean reduced the lead time between a customer order and the shipment of the products by the elimination of all forms of waste in the production processes. Also, lean principles and methods focused on creating a continual improvement of culture that engaged employees in reducing the intensity of time, materials and capital necessary for meeting customer's need. But, the process ended only when receipt of payment was realized, since, hoarding of money at any stage was considered as a negative syndrome. Thus, the end user played a vital role in lean manufacturing. Its implementation also enhanced green or environmental performance; hence environmental savings becomes a part, even when it was not part of the financial justification for lean improvement activities (Naikwade, 2010).

A link between the Lean and green performance relationship in a garment industry was explored by Marudhamuthu & Krishnaswamy (2011). Lean tools like Value Stream Mapping (VSM) and Single Minute Exchange of Die (SMED) were

used to identify the waste and its causes. It was found that after implementing the lean tools, various waste reductions in terms of load carrying capacity, travelling distance, production rate, and material transfer were achieved in different sections on the shop floor. Adoption of lean also lowered the marginal cost of pollution source reduction. Environmental performances improved with the elimination of the wastes. Lean was proved to be associated with greater source reduction (pollution prevention) and lower emissions.

Cordeiro, Sarkis and Shaw (2012) were of the view that lean is not always green. Arguments revealed that if a firm carried too little inventory, it results in higher material as well as increased delivery frequency in the supply chain, increased number of setups and the possibility that smaller suppliers carried excess inventory. On the other hand, if it carried too much, it exposed itself to higher GHG emissions arising from higher storage and production needs, as well as possibly more waste due to inventory becoming obsolescence and also due to other factors. The overall supply chain GHG costs outweighed the benefits, if the firm carried too little or too much inventory. A U-shaped curvilinear relationship between the firm's lean inventory management and green performance of the firm's supply chain was tested by measuring GHG emissions. Primary data was collected from 559 firms, and the list compiled units of Trucost, Plc. established between 2004 to 2010. The inventory carried by that firm was used to estimate the empirical leanness indicator. The result revealed that there was no significant relationship between the firm's leanness and its own GHG emissions.

A Study was undertaken by Kakkar (2012) to identify the sources of carbon emissions in a garment manufacturing unit of Noida, employing both lean and non-lean setups. Carbon footprint was calculated and comparisons were done. Results revealed that maximum carbon footprint was generated in finishing department followed by sewing department. It was observed that carbon footprint per garment ranged from 0.191 Kg to 0.197 Kg CO₂e. The calculations revealed that the carbon foot print of non- lean lines was 0.454 Kg CO₂e compared to that of lean lines was 0.336 Kg CO₂ e. It was concluded that lean reduces the carbon footprint.

Importance of individual elements of Lean philosophy as a potential answer to the problem of increasing environmental degradation in this vibrant and

competitive market environment was highlighted by Petrovic, Slovic, & Cirovic (2013). The results revealed that Lean philosophy with its elements towards persuasion of perfection can act as a future tool to attain long term global sustainability. It not only helps business respond to the demands of environmentally aware consumers, but also helps companies to increase their efficiency with minimizing negative effect toward the environment. Environmental waste in terms of hazardous materials, green house gases, solid wastes, water usage, and energy are targeted by typical green manufacturing system leading to reduction in negative environmental impacts as a result of its activity. Implementation of best practices forms the essential core of a green manufacturing strategy linking it directly to the lean philosophy.

The matrix showing the review of related studies is given below in Table 2.14.

Table 2.14

Review Matrix

Sections	Researches	Conclusion
Exploration of Lean & Carbon footprint concept	Agbonkhese(2010); Ahrens (2006); Athalye(2012);Bolitho & Spence (2010); Goforth (2007); Hines & Rich (1997); Holweg (2007); Jozaffe (2006); Kovacheva(2010); Kumar & Sampath (2011); McGill(2009); McGrath (2007);Meena (2011); Mehta et al.(2012) ; <u>National Centre for Sustainability</u> (2009);Nina(2010);Rother & Harris(2001).	These theoretical researches shed light on the concept of lean production, tools, principles, importance of lean philosophy. Framework of implementation of Lean was also discussed to improve the effectiveness and efficiency of the production processes in the manufacturing organization. Exploratory researches dealing with the concept of carbon footprint revealed various types, sources of carbon footprints such as fuel use, holiday flights, electricity, coal, oil and gas, private transport etc; standards used to calculate, practical barriers encountered such as lack of skills and knowledge on how to identify and measure greenhouse gas emissions , Lack of time and resources etc. Various Green-House-Gas mitigation measures were also suggested which were believed to reduce Co ₂ emissions by 60%.
Lean Awareness & Practice	Achanga(2007); Andersson(2007); Dalgobind & Anjani (2009); Farhana & Amir(2009b);Hodge et al.(2011); Karim & Rahman (2012); Kumar & Naidu (2012b); Kumar & Sampath (2012c); Nayas(2012); Nordin et al. (2010b); Ramesh et al. (2008); Shah & Ward (2002); Silva et al.(2011a); Tandon et al.(2014); Vienazindiene & Ciarniene (2013); Wong & Wong(2011a).	These researches investigated the awareness level, customized approach of adopting lean tools and techniques, the changes in the organizations, the problems encountered as well as the lessons learnt in various organizations. The results revealed that lean are new to most of the organizations and the full benefit is not yet being achieved by them. There were low adoption of all lean key areas, but the degree of implementation varied among organizations Majority of the respondent firms were classified as in-transition towards adopting lean.
Success, driving & Inhibiting factors	Achanga et al.(2004); Ahrens(2006); Ghodrati & Zulkifli (2012); Goforth(2007); Johnson(n.d.); Kovacheva(2010); Kumar & Sampath (2012c); McGrath (2007); Nordin et al.(2010a); Puvanasvaran et al.(2009); Rose et al.(2011).	It was concluded from these related researches that leadership, finance, organizational culture, skills and expertise, human resource practices, management style, effective communication, employee training & empowerment ,organizational strategic vision and external partnerships were found to be the most pertinent and critical factors for the successful adoption of lean manufacturing. Employee pull and management push were the main driving factors identified for lean initiation. Various barriers encountered while trying to implement the practices were also identified namely: financial & resources constraints, untrained unskilled work force with poor work ethics, breaking down old habits, size and age of company, manpower , time, lack of interest, lack of knowledge about the Lean tools, lack of direction, lack of adequate project sequencing, lack of key management support, no long term vision, workers lack lustre attitude and narrow view of lean contract manufacturing and old-style management .

Continued

Sections	Researches	Conclusion
Assessment of Lean Initiatives	Al-jawazneh (2011); Buker Inc.(n.d.); Greene(2002); Hallam (2003); Pakdil & Leonard(2014); Salem et al.(2006); Shah & Ward (2002); Wong et al.(2009).	It was found that customized lean assessment tools were made for various industries focusing on 25 to 40 lean practices i.e. 5S, Visual controls, A3 project management, Cellular manufacturing, Kaizen & Continuous Improvement, JIT ,Kanban, SMED ,Standard work , TPM, Training Within Industry (TWI) ,VSM etc. Similar practices were combined into 4 to 8 bundles and these were evaluated in a 5 or 6 point scale and further assessment of level of adoption was done from level 1 to 5.The assessment of lean initiatives revealed that SMED and TPM were adopted at lower-than- expected level, while rest of the tools like-5S, Visual Control, Kaizen, Kanban etc were implemented at a high level.
Carbonfootprint Quantification	Agarwal (2010);Barber & Pellow(2000); Batra(2013); Central Electricity Authority (2010); Chaudhary(2010); Choate et al.(2012); Clothing Industry Training Authority(n.d.); Cool Earth, India(2013); Das(2010); Jungmichel(2010); Khurana(2011); Luppino et al.(2011). Nigam(2013);Rugrungruang, Chua, & Low(2009); Varshney(2010).	These researches assessed product and organizational carbon footprint using Life Cycle Assessment (LCA) methodology taking guidelines from the standards of ISO 14040,14044 & 14064 .Two main sources of carbon footprint identified were transport used for traveling, and, electricity consumed .
Adoption of Lean tools & practices and Manufacturing Performance improvement	Ahsan et al.(2011); Blecha et al.(1993); Brown & Rourke(2007); Chakraborty & Paul(2011); Chi (2011); Dagher(2010); Dudley & Rosenfield (1995); Farhana & Amir(2009a); Gamage et al.(2012a); Gamage et al.(2012b); Haque et al.(2012); Hines & Rich (1997); Islam et al.(2013a) ; Islam et al.(2013b) ; Islam et al. (2013c);Jongprasithporn & Jitjaicham(2003); Khan & Islam(2013);Kilpatrick(1997); Kumar & Naidu(2012a); Kumar & Sampath (2012a); Kumar & Sampath (2012b); Makhija (2012); Marudhamuthu et al. (2011); Naik et al.(2011); Nautiyal(2011); Paneru(2011); Rahi et al.(2010); Ramdass & Pretorius (2009); Ratnayake et al. (2009); Rother & Harris(2001); Sakthivel et al.(2012); Silva(2012); Singh & Pramanik(2010); Spahija et al. (2012); Stotz (2010); Taj & Morosan (2011); Ulutas(2011); Viswanathan & Littlefield (2009).	The researches focused on significant improvements after adoption of individual lean tools and practices in terms of various manufacturing key indicators. With the implementation of lean tools in various units,varied results were obtained as productivity was increased from 10-62%;labour productivity rose from 9.6 to 10.5%;production or labor efficiency improved by 12-15%;breakdown time was reduced by 33.03% ;profit increase by 7%;production lead time improved from 4 to 75% ;production costs reduced by 10% to 25 %;time deliveries rates increased by 50% to 90%;10%-60% improvement in quality; reduction in rework level by 80%;capacity increased by 20 % to 50 %.;96% order delivery; 3% decrease in inventory;4%-26.1% decrease in manufacturing cycle times; 30.1% reduction in inventory holding time; 51% floor space utilization; reduction of WIP by 10%; absenteeism reduced by 5.80%;increase in the Overall Equipment Efficiency ; and better utilization of labor. One research also highlighted the negatives of lean in terms of unintended problems in workplace, health, and safety.
Environmental Performance improvement after lean adoption	Florida (1996); Helper et al.(1997); King & Lenox (2001); Sawhney et al.(2007);Bergmiller & McCright (2009); Qiu & Chen(2009) ;Miller et al.(2010); Naikwade(2010); Marudhamuthu & Krishnaswamy(2011); Cordeiro et al.(2012) ;Kakkar (2012); Petrovic et al.(2013).	It was found in these theoretical researches that with lean adoption, pursuit of zero defects and zero inventories begins along with adoption of ISO9000 and it further unintentionally leads to zero emission and pollution prevention with adoption of ISO 14000, highlighting the fact that lean is green and lean seemed to transcend green. While other studies proved the opposite. Though there was lack of empirical data.
Impact of Lean workshop	Clothing Industry Training Authority(n.d.);Environmental Standardization ...SMES(n.d); Fargher(2007).	It was concluded from these researches that Awareness seminars and workshops were beneficial for facilitating the building of the low carbon competitive advantage and educating industrial sectors regarding lean and carbon footprint concept, measuring standards etc. Various simulation games were developed and used to orient the participants towards the lean manufacturing touching on all aspects of lean.

After going through the complete review, it was observed that lot of work has been done on the implementation of individual lean tools and practices but following were the research gaps observed by the researcher which motivated to undertake the present study-

Research Gaps:-

1. A number of studies have been conducted on lean manufacturing implementation in automobile and electrical and electronic industry but only few efforts have been made to study its implementation in the apparel export industry. The lean concept remains unexplored to the apparel sector.
2. Very few studies have been found on the lean implementation and its impact on performance improvement in Indian apparel industry as most of the apparel based researches were found to be conducted in garment industry of Taiwan, Jordan, Malaysia, Portuguese, Srilanka, Bangladesh etc.
3. A number of the studies have been conducted on single lean tool or techniques and its performance implications but there are very few studies which explores the total impact of lean initiation on the apparel industry's performance.
4. There is a lack of researched evidence regarding the impact of lean practices on the performance improvement in terms of operational key performance indicators namely production, efficiency, work in progress, and quality and carbon foot print reduction in apparel industry.
5. Very few studies have concentrated on assessment of lean initiatives and there is lack of comprehensive lean assessment schedule specific to the garment industry for assessing the status of the lean initiation.
6. Even fewer studies have explored the relationship between year of lean initiation and performance.
7. Very few studies have been found emphasizing on the empirical evidence of environmental impact of Lean manufacturing practices.
8. Only a few studies have concentrated on the issue of lack of awareness of lean manufacturing.

9. Very few researches have dealt with the methodology and quantification of green house gas inventory of an apparel manufacturing unit as most of the researches focused on product carbon footprint calculation.
10. Researches on the Carbon Footprint had been conducted at various scales from national to municipal levels from industries all over the world. Very few studies are available on creation of GHG inventory of apparel industry; hence the studies of other industries were also reviewed to obtain comprehensive knowledge and better understanding relating to its concept, methodologies, calculation procedure and standards of carbon footprints.

This research has made an attempt to bridge all the above mentioned gaps by carefully and systematically investigating the lean practices in the apparel firms and also assessing their performance improvement.