CHAPTER 4

LEAN MANUFACTURING TOOLS AND TECHNIQUES

4.1 INTRODUCTION

The purpose of this literature review is to provide a background on applicability of lean across a variety of industries. This understanding will help determine which lean principles are appropriate for implementation within the apparel industry, and how to use these concepts to bring the most benefit to an apparel company. In order to explore the concept of lean, a history of how “lean” came into existence and how it has progressed over time will be provided, as well as a brief explanation of other production approaches and many methods and tools associated with the term ‘lean. There are numbers of lean manufacturing tools which are available for industry application. If used properly, the industries will get the best results. Once the source of the waste is identified, it is easier to select the suitable lean tool to reduce or eliminate it and try to make waste free systems. Some of these tools are discussed in this chapter.

4.2 PURPOSE OF LEAN TOOLS

The objective of lean is to create the most value for the customer while consuming the least amount of resources to design, build, and sustain the product. In their 1996 book, Lean Thinking – Banish waste and create wealth in your corporation, Womack and Jones (1996) identified how Toyota’s production system is different from the traditional mass production
approach. The book explains that companies will gain improvements from lean when they redesign their value streams by applying the following principles

- Specify value from the standpoint of the customer,
- Identify the value stream for each product or service-line family,
- Make value flow toward the customer,
- Produced based on the pull of the customer, and
- Strive continually to approach perfection.

The objective of these lean principles is to create the best possible system, from concept to consumer using the current financial and resource constraints to provide the most value to the customer. Once the value stream is designed, or redesigned, improvements can be made by implementing lean tools and techniques appropriate to the particular situation (Womack and Jones 1996). Lean is concerned with eliminating all types of process wastages. Taichi Ohno identified seven types of waste in his book Toyota Production System (Ohno 1988). He explained that waste is sometimes hard to see but can be classified by overproduction, time on hand, transportation, over processing, inventory, movement, and defective products (Ohno 1988) which has been described previously in detail. All the lean tools work toward common goals of eliminating this waste, in order to bring the most value to the customer. An organization striving to be lean will want to have only the required inventory when needed, improve quality to zero defects, reduce lead time through setup time reduction, reduce queue lengths and lot sizes, incrementally revise operations, and accomplish improvements at minimum
The following lean tools are discussed briefly in the subsequent sections of this chapter such as PDCA Cycle, Visual management, 5S System, Andons, Kaizen, Kaikatu, Jidoka, Poka-yoka, Standardised work, Namawashi, Catchball, Kanban, supermarkets, cellular layout, One piece flow, Continuous improvement, Total Productivity maintenance, Value Stream Mapping (VSM).

4.3 PDCA CYCLE

PDCA requires supportive management that allows for visible current production status and compel countermeasures or improvements. PDCA also requires solid visual management, because visual systems such as report boards and line-side process reviews create a shared understanding of the production performance data with everyone involved with the production of products (Akai 1988 and Akai 1991).

![PDCA Cycle Diagram](image)

**Figure 4.1 Creating PDCA flow (Liker 2004)**

The short description of PDCA cycle is given below

**Plan** : Identify an opportunity and plan for change.

**Do** : Implement the change on a small scale.
Check : Use data to analyze the results of the change and determine whether it made a difference.

Act : If the change was successful, implement it on a wider scale and continuously assess the results. If the change did not work, begin the cycle again. Thus continuous improvement is an ongoing and never ending process. It measures only the achievements gained from the application of one process over the existing one. So while selecting the continuous improvement plan one should concentrate on the area which needs more attention and which adds more value to their products. There are seven different kinds of continuous improvement tools (Larson 2003). The use of these tools varies from case to case depending on the requirement of the process to be monitored.

4.4 VISUAL MANAGEMENT

The goal of visual management is to create a work environment that is self-explaining, self ordering, and self-improving (Greiff 1991). In his book “The Visual Factory,” Greiff illustrates this idea in a visual management triangle seen in the Figure 4.2. In this type of workplace, employees can immediately notice out of standard situations and easily take corrective actions. A vital component of visual management is the 5s organization system, which will be discussed in detail in the next section.
4.5 THE 5s SYSTEM

The 5s tool is a structural system to organize any type of business or operation, and it represents five steps such as, sort, set in order or place, shine or scrub, standardize and sustain (Hirano 1996). All these steps must be followed to have success with a 5s event or for an operation to say that they are 5s. However, the second and third step, set in order and shine, may be switched depending on the needs of the organization using 5s.

4.5.1 Sort

The first step, ‘sort’ means to simply separate what is needed and necessary in the workplace or station. Sorting reduces problems and annoyances in the workflow, improves communication between workers, increases product quality, and enhances productivity (Hirano 1996). Anything that is not used or needed in the workplace gets in the way of the actual work
being done there. An area should be set aside nearby to put these unnecessary items and the items in which there are uncertainties. Just about anything can be put into this holding area, including items that may or may not be used such as

- Machinery – sewing machines, cutting knife, ironing machine, etc.,
- Stock - Raw materials, parts, assemblies, etc.,
- Tools and Equipment – Trimmer, Screw driver, hammers, etc.,
- Facilities - Work tables, chairs, desks, etc.,
- Documents - Files, notices, awards, memos, folders, etc.,
- Stationery - Pencils, staplers, erasers, paper, etc.,
- Fittings - Nuts, bolts, wire, hooks, etc.,
- Locations - Rooms, bays, floors, shelves, etc., and
- Others-Catalogs, radios, magazines, books, etc (Hirano 1996).

This area is called a red tag area where the items in the area have red tags or the area is marked off in red. The items should be kept in this area for a short period of time, which serves as an evaluation period. A decision must be made about these red-tagged items; the items can either be held or kept in the area, relocated to another area in which they could be put to better use, or disposed off. Every business or operation will have different red tag criteria according to their needs, which are used to make the decision of what to do with the items in the holding area.
4.5.2 Set in Place

The second step, ‘set in place,’ is a storage principle in which everything in the work area has a place and is always stored there when not in use. This makes the tools easy to find and anyone should be able to find them and then replace them after use (Hirano 1996). Using or creating tools with multiple functions can eliminate a variety of tools. Properly setting things in order can eliminate a variety of waste in the workplace including motion, searching, human energy, excess inventory, unsafe working conditions, and using the wrong tools (Hirano 1996).

There are several different strategies used to set in place or order, which can be used apart or together. The signboard is a strategy, which identifies what, where and how many items should be stored. There are three main types

- Location indicators, which show where items go,
- Item indicators, which show what specific items go in those places, and
- Amount indicators, which show how many of these items, belong in those places.

Signboards can be used to identify names of work areas, inventory locations, standard procedures, machine layouts, etc. The painting strategy is used to identify locations on floors and walkways. Paint can be used or a less permanent method like plastic tape can be used. These markings are most commonly used to mark off storage areas of bigger items, which are stored on the floor, or to mark aisle traffic directions. The outlining strategy is where color-coding is used to show clearly which part and tools go in which place. For example, if certain parts are used to make a particular product, they can
all be color coded with the same color and even stored in a location that is painted in that color. In order to store items to eliminate waste according to 5s, items must be located according to their frequency of use in the workday, and items used together should be stored together and in the sequence that they will be used (Hirano 1996). These items should also be located at the point of use. The storage places should be larger than the items being stored so that they are easily removed and replaced.

4.5.3  **Shine**

The third step is ‘shine’ or ‘scrub’ to keep the work place clean by eliminating all forms of dirt, dust, grease and grime. This builds a sense of pride in the employees, improves the work environment, provides for a safer workplace, and helps maintain equipment value (Hirano 1996). Cleaning can also be used as a form of inspection. While in the process of cleaning a piece of equipment, a problem can be noticed that would not have been seen in passing. In order for shine to be effective and 5s to be maintained, cleaning must become a standard part of the everyday routine.

4.5.4  **Standardize**

The fourth step, ‘standardize,’ is where working conditions are implemented to maintain sort, set in place, and shine. Standardization creates a consistent way in which tasks and procedures are carried out so that absolutely anyone can understand the work (Hirano 1996).

4.5.5  **Sustain**

The last and fifth step is ‘sustain,’ making a habit of properly following the correct procedures and continuously repeating all the steps of the 5s process. By sustaining all of the 5s steps, many problems in the work place can be avoided including
Unneeded items piling up as soon as the sorting process is completed.

Tools being put in the wrong place after use.

No one ever cleaning equipment or picking up after themselves.

Items being left in walkways.

Dark, dirty work environments which lower morale of employees, and

Dirty machines which start to malfunction and/or produce defects (Hirano 1996).

The commitment to sustain a particular course of action is made because the reward for maintaining this course of action is greater for the individual or organization than the rewards of departing from the course of action. Commitment is needed by everyone in the organization to uphold the 5s principles. Sustain cannot be implemented as a technique or measured, because the results exist inside the minds of the workforce (Hirano, 1996).

4.6 ANDONS

Another type of visual control or management is the andon. At Toyota each assembly and machining line is equipped with call lights and an andon board (Monden 1993). The call light is used to call for a supervisor, maintenance, or general worker. Usually, there are several different colors of lights, which designate different types of assistance. The andon is the indicator board, which shows that the line has been stopped. In many cases, the andon has different colored lights to indicate the condition of the line. The board usually has five colors with the following meanings: red indicates machine trouble, white represents the end of a production run (required
materials have been produced), green means no work due to material shortage, blue means a defective unit, and yellow means set up is required (Monden 1993). The andon board and call lights are usually suspended from the ceiling so that they are easily seen and located.

4.7 KAIZEN

The term kaizen is often mentioned in the application of lean manufacturing. It simply means, “Change for the good of all” in Japanese and is used as an improvement tool. Kaizen is the starting point for all lean initiatives. Kaizen is a team approach to quickly tear down and rebuild a process layout to function more efficiently (Ortiz 2006). Quality in Toyota’s just in time manufacturing system was based on the kaizen continuous improvement concept. This approach is used to create trial and error experiences in eliminating waste and simplifying processes, and this approach is repeated over and over again to continuously look for problems and solutions (Russell and Taylor 2002). A Kaizen Blitz is a term used to describe when a process is quickly changed to eliminate activities that have no value (Russell and Taylor 2002). Kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen requires no or little investment. The principle behind is that “a very large number of small improvements are more effective in an organizational environment than a few improvements of large value.” This pillar is aimed at reducing losses in the workplace that affect our efficiencies (Kumar 2008).

4.8 KAIKAKU

Kaikaku is Japanese term for radical or rapid improvement. Like Kaizen, a Kaikaku has the goal of eliminating waste, but unlike ‘continuous improvement’ which is incremental, ‘rapid improvement’ is a onetime event to make improvements on a particular problem or issue. Kaikaku and its
application are discussed further in Womack’s Lean Thinking (Womack and Jones 1996).

4.9 JIDOKA

Jidoka is a Japanese word comprising of three Chinese characters, ji-do-ka. The first, “ji” is the worker. If there is something wrong or a defect, the worker must stop the line. “Do” refers to the motion to stop the line and the “ka” means action. Taken all together jidoka is defined by Toyota as “automation with a human mind.” This implies that workers and machines have the intelligence to identify errors and take quick countermeasures for correction (Shingo 1985). The ultimate goal of jidoka is to prevent defects. The first use of jidoka was in the textile industry in 1902 when Sakichi Toyoda, the founder of Toyota, invented a loom that would stop automatically if any threads snapped. This invention allowed for the creation of automated looms where a single operator could handle many looms at a time (Womack et al 1990). This new idea also introduced the concept that it was all right to stop production in order to find out the root cause of a defect. Shigeo Shingo developed and extended the jidoka concept, which is in contrast to W.Edwards Deming statistical process control (SPC). The difference is that SPC shows how many defects will be produced, but jidoka’s goal is to prevent defects through 100 percent inspections (Shingo 1985). To achieve this goal, Shingo developed the concept of pokayoke.

4.10 POKA-YOKE

Shingo observed that humans are the most unreliable components of complex systems. Standardized work, visual management, and 5s are lean tools discussed previously, which can be used to improve human reliability. Poka-yoke is another tool for this purpose. Poka means inadvertent error and yoke means prevention. Poka-yoke complements simple low cost mistake
proofing devices that detect abnormal situations before they occur or once they occur stop production to prevent defects (Shingo 1985). Poka-yokes reduce the physical and mental burden of constantly checking for common errors that lead to defects such as missing process steps, process errors, missing or wrong parts, improper equipment setups and so forth. A good poka-yoke must be simple and low maintenance, very reliable, low cost, and designed for the specific workplace condition. When a poka-yoke detects an error, it should either shutdown production or delivers a warning. Warning poka-yokes should be used if the stopping of the line during the middle of a process increases the potential for defects. An effective poka-yoke must inspect 100 percent of the items and provide immediate feedback for countermeasures (Shingo 1985).

4.11 STANDARDIZED WORK

Standardized work is the safest, easiest, and most effective way of doing the job that we currently know, but the purpose of standardized work is to provide a basis for improvement on that job. The goal should be to optimize the utilization of people instead of machines, because the flexibility of people provides more benefits than machine utilization (Dennis 2002). The lean system of standardized work is based on human movement. Standardized work provides many benefits such as process stability, clear stop and start points for each process, organizational learning, audit and problem solving, employee involvement, poka-yoke, and kaizen (continuous improvement). It also provides a basis for training (Dennis 2002). At Toyota, the supervisor determines the components of standardized work, but at most other companies, this determination is usually made by the Industrial Engineering staff. Toyota has set it up this way because of their belief that the supervisor has a better knowledge of the performance of workers. Toyota’s model for elements of standard operations is depicted in Figure 4.3.
Figure 4.3 Toyota’s model for elements of standard operations

In order to use standardized work, a process must be stable without continuous line stoppages and slowdowns. Standardized work involves three elements, which are the baseline against which any given process can be accessed such as cycle time, work sequence, and in-process stock. Standardized work is relayed to the operators through standard operations sheets and charts that define standard work.

4.12 NEMAWASHI OR CHANGE BY CONSENSUS

This word translates “to prepare a tree for planting,” which means nemawashi is the process of building for alignment. When using the nemawashi process, the decisions are made slowly, by consensus, considering all options thoroughly, and then the action to correct is taken rapidly. During this process, many people give their input, which generates the consensus, and by the time the proposal has reached top management for final approval, the decision is made and agreed upon (Liker 2004). Figure 4.4 shows the nemawashi decision making method as used by Toyota. The nemawashi process for decision making and policy take longer; however, the implementation process is quicker and more effective as a result (Dennis 2002).
4.13 CATCHBALL

Catchball refers to the compromises required among management levels during the planning process. The objective of ‘catchball’ is to link the vision of management and the daily activities of the operators or plant floor workers (Akai 1988 and Akai 1991). Figure 4.5, depicts the general movement of dialogue or ‘catchball,” represented by two-way arrows, used among senior management, implementation teams, and middle management to establish and agree upon the goals of the organization. Catchball is the means in which consensus dialogue of nemawashi occurs which helps enable the decision making of policy deployment.

Figure 4.4 Alternative Toyota decision making methods (Likert 2004)
4.14 KANBAN

A pull method used in lean manufacturing is kanban, which ensures that material and products are pulled through the factory when they are demanded (Lai et al. 2003). Kanban is the Japanese word for card. In a simple form, kanban is a card or device used by a customer workstation to send a signal to the preceding supplier station that it needs more parts (Slack et al. 2001). Kanban applied to lean manufacturing, is a stocking technique using containers, cards and electronic signals to make production systems respond to real needs and not predicitions and forecasts. A kanban is a major component of JIT production. Three types of kanbans are mainly used which are withdrawal kanban, production ordering kanban, and supplier kanban. A withdrawal kanban specifies the kind and quantity of a product in which the subsequent process should withdraw from the preceding process. A
production ordering kanban, sometimes called in-process or production kanban, specifies the kind and quantity of a product in which the preceding process must produce. A supplier kanban or subcontractor kanban is used for making withdrawals from a vendor like a part or materials supplier. The supplier kanban includes instructions, which requests the delivery of the supplier of product (Monden 1993). Figure 4.6 provides a visual depiction of the kanban pull system (Vatalaro and Taylor 2003).

Figure 4.6 Kanban pull system (Vatalaro and Taylor 2003)

A study accomplished by Jonsson and Mattsson (2000) showed that the use of kanban as a material planning method in manufacturing companies has increased during the last decade. Most of the companies used kanban for in-house material control. The parts are usually stored and moved into kanban trolley. However, several trolleys can be used for one card, if the parts are too big to fit into one trolley. An example of kanban card and trolley is given in Figure 4.7.
In order to achieve JIT production, Toyota specifies that certain rules with regard to the use of kanbans must be followed (Monden 1993).

**Rule 1:** The subsequent process should withdraw the necessary products from the preceding process in the necessary quantity at the necessary point in time.

- Any withdrawal without a kanban is prohibited
- Any withdrawal greater than the number of kanbans is prohibited
- A kanban should always be attached to a product

**Rule 2:** The process should produce its products in the quantities withdrawn by the subsequent process

**Rule 3:** Defective products should never be sent to the subsequent process

**Rule 4:** The number of kanbans should be minimized.

**Rule 5:** Kanbans should be used to adapt to small fluctuations in demand
In order to determine the number of kanbans needed for any given process, first, a demand analysis and a capacity analysis must be conducted (Vatalaro and Taylor 2003). Demand analysis determines the current daily demand for each process, which can be done using historical order patterns but ideally with current booked orders. Capacity analysis determines the actual capacity for the particular product. This information is used for the calculation of the actual number of kanbans

\[
\text{Number of Kanban} = \frac{\text{Daily Demand} \times \text{Order Frequency} + \text{Lead Time} - \text{Safety Time}}{\text{Container Quantity}}
\]

Daily Demand is the current quantity level of daily demand for a component. This number must be recalculated often as demand varies over time. Order frequency represents the frequency at which the consuming process will place orders to the supplying process for a component. This number is expressed in days. Lead time is an estimate of how long the consuming process will need to wait for a product once replenishment has been authorized. Safety time is allotted to compensate for the impact of waste on the supplying process. This number is also expressed in days. Container quantity is a standardized number of units of each product that a container will hold. Of all the elements of the kanban equation, the container size has the most freedom for change (Vatalaro and Taylor 2003).

Another calculation, which is needed for kanbans, is the determination of the run line. The run line is the number of kanbans that need to accumulate in order for the production of that component to be authorized. Run line is calculated as follows

\[
\text{Run Line} = \frac{\text{Daily Demand} \times \text{Order Frequency}}{\text{Container Size}}
\]

After the number of kanbans and the run line for each item has been determined, the maximum and average amount of inventory can be calculated as well as the production lot size for each item.
Maximum Inventory = Number of Kanbans × Container Quantity
Average Inventory = Daily Demand (1 / 2 Order Frequency + Safety Time)
Lot Size = Run Line Value × Container Quantity

In order to obtain these numbers used to determine the implementation strategy for kanbans, Vatalaro & Taylor suggest conducting a value stream mapping exercise (Vatalaro and Taylor 2003).

4.15 SUPERMARKETS

A ‘supermarket’ is a kanban stock point, which is noting but buffer storage area located at the end of the production process (Rother and Shook 1999). Like an actual supermarket, a small inventory is available for one or more downstream customers inside a process who come to the supermarket to pick out what they need. The upstream work center then replenishes stocks as required. Whenever the supermarket inventory is below a certain level the production process is initiated. Supermarkets are used when a one piece or continuous flow is impractical, and the upstream process must operate in batch mode. The ‘supermarket’ reduces overproduction and limits total inventory (Vatalaro and Taylor 2003).

4.16 CELLULAR MANUFACTURING

Cellular layout divides the manufacturing facilities into small groups called cells which will be exclusively utilized for specific task (Nicoletti et al 1998). A cell contains of equipment and work stations that are arranged to maintain the smooth flow of product without much of waiting time (Farwaz and Abdulmalek 2007). A cell is a combination of people, equipment and workstations organized in the order of process to flow to manufacture all or part of a production unit (Wilson 2009). Work or machines of different types performing different processing steps are organized in cells,
typically in a U-shape layout. Especially within the cells, that enables the flexible deployment of workers in a way that they can operate several machines at the same time (multi-machine working). The catenation of several cells may again exhibit a U-shape, or a L-shape. This kind of layout drastically reduces used space on the shop floor and thus enables shorter distances between single cells, which again is better for worker’s communication. Foremen and supervisors can reach stations with occurring problems in only a few moments assuring instant help, and because of the proximity of the start and end point of the work area they are responsible for, each walk about is almost a closed loop and thus contains only little idle time for them (Womack and Jones 1996). The cell layout is a graphical representation of the operator flow and material flow. It depicts the path of the overall material movement through the cell and describes the designed operator sequence and operations.

Figure 4.8 Cellular layout model
Following are the characteristics of effective cellular manufacturing practice.

1. Should have one-piece or very small lot of flow.

2. The equipment should be right-sized and very specific for the cell operations.

3. Is usually arranged in a C or U shape so the incoming raw materials and outgoing finished goods are easily monitored.

4. Should have cross-trained people within the cell for flexibility of operation.

5. Generally, the cell is arranged in C or U shape and covers less space than the long assembly lines.

There are lots of benefits of cellular manufacturing over long assembly lines. Some of them are as follows (Heizer and Render 2000).

- Reduced work in process inventory because the work cell is set up to provide a balanced flow from machine to machine.

- Reduced direct labor cost because of improved communication between employees, better material flow, and improved scheduling.

- High employee participation is achieved due to added responsibility of product quality monitored by themselves rather than separate quality persons.

- Increased use of equipment and machinery, because of better scheduling and faster material flow.

- Allows the company higher degrees of flexibility to accommodate changes in customer demand.
- Promotes continuous improvement as problems are exposed to surface due to low WIP and better communication.
- Reduces throughput time and increases velocity for customer orders from order receipt through production and shipment.
- Enhances the employee’s productive capability through multi-skilled operators.

Apart from these tangible benefits, there is the very important advantage of cellular manufacturing over the linear flow model. Due to the closed loop arrangement of machines, the operators inside the cell are familiar with each other’s operations and they understand each other better. This improves the relation between the operators and helps to improve productivity. Whereas in long assembly line one operator knows only two operators (before and after his operation in the line) and it seems that operators are working independently in the line. Typical benefits attributed to the implementation of cells included simplified material flow together with reductions in product handling, work in progress and throughput times. In addition to this, improvements are achieved in quality, schedule adherence and job satisfaction (Boughton and Arokanam 2000).

The researcher found numerous studies on the implementation of cellular manufacture. The results of implementing cellular manufacturing are described below. Hyer et al (1999) developed a model to implement cellular manufacture. Two years after the implementation the organization had achieved:

- Scrap reduced from $40,000 per month to $14,000 per month.
- Lead-time reduced from 10 - 15 days to 5 – 7 days.
- Monthly production volume of $11,000,000 increased to $20,000,000.
Da Silveira et al (2001) carried out a study on implementing cellular manufacture in a mechanical industry through a team based approach in Brazil, with the following results

- Reduction in scrap=40%
- Reduction in rework level=83%
- Percentage of improvement in product diversity =233%
- Reduction in work in progress= 92 %
- Reduction in floor space=44%

Wemmerlov and Johnson (1997) found the following average improvements from the 46 surveyed organizations that had implemented cellular manufacturing:

- Reduction in throughput time 61% average improvement
- Reduction in response time to customer orders 50% average improvement
- Reduction in WIP inventory 48% average improvement

Van der Zee (2009) cites a 44% increase in productivity and 46% reduction in order lead-time. The time workers spent on value added activities went from 74% to 92%, and required floor space was reduced by 44%. Gunasekaran et al (2001) noted an increase in inventory in some areas, but in general a reduction in WIP. They also made improvements in machine utilization, scrap levels and output performance. The advantage of this cell based layout is to achieve the single piece flow, and other benefits of implementing the cellular layout are to improve the quality of the product, minimize the WIP, reduce the throughput time, reduce the setup time and improve the productivity (Burbidge 1979).
4.17 ONE PIECE FLOW

An overriding principle of cellular manufacturing is to arrange production work stations and equipment in a sequence that creates a smooth flow of material (Witt 2006). The possibility of achieving one piece flow is another benefit of adopting cellular manufacturing (Jing-Wen and Barnes 2000). Put simply one piece flow is the process of ‘make one, check one, and move one on’ (Black 2007). It has at its heart the principle of manufacturing only to the demand of the customer. This concept of customer demand being the signal or authorization to manufacture is classed as a ‘pull system’, because the customer is ‘pulling’ the product. It is a very similar concept to JIT (Just in Time). This is very different from the traditional approach of a ‘push system’, where the company pushes product through the organisation to a forecast. One of the benefits of one piece flow is that it reduces lead times and is flexible and accommodates peaks and troughs in demand (Witt 2006) (Black 2007). To achieve one piece flow, improve productivity and performance, an organization needs to complete the process of cellular manufacturing. One piece flow is considered the ultimate and most difficult step in achieving as compared with other lean tools (Miltenburg 2001). Therefore it is logical to implement one piece flow after implementing cellular manufacturing.

4.18 CONTINUOUS IMPROVEMENT

Continuous Improvement (CI) can be defined as the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance. Activities and behaviors that facilitate and enable the development of CI include problem-solving, Plan-Do-Check-Act (PDCA) and other CI tools, policy deployment, cross-functional teams, a formal CI planning and management group, and formal systems for evaluating CI activities.
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 future continuous learning. Information about PDCA system is described in earlier titles.

**Pareto Diagram:** The Pareto diagram is a graphical overview of the process problems, in ranking order from the most frequent, down to the least frequent, in descending order from left to right. Thus, the Pareto diagram illustrates the frequency of fault types. Using a Pareto, one can decide which fault is the most serious or most frequent offender.

**Fishbone Diagram:** A framework used to identify potential root causes leading to poor quality.

**Check Sheet:** A check sheet is a structured prepared form, for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

**Histogram:** A graph of variable data providing a pictorial view of the distribution of data around a desired target value.

**Stratification:** A method of sorting data to identify whether defects are the result of a special cause, such as an individual employee or specific machine.

**Scatter Diagram:** A graph used to display the effect of changes in one input variable on the output of an operation.

**Charting:** A graph that tracks the performance of an operation over time, usually used to monitor the effectiveness of improvement programs.
4.19 TOTAL PRODUCTIVE MAINTENANCE (TPM)

Machine breakdown is one of the major headaches for people related to production. The reliability of the equipment on the shop floor is very important because if any one of the machines is down the entire shop floor productivity may be nil. The tool that takes care of these sudden breakdowns and helps maintenance as well as production workers to minimize these unplanned breakdowns is called total productive maintenance. Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to increase production, increase employee morale and job satisfaction (Bisen and Srivastava 2009). TPM is set of tools, which implemented in an organization as a whole gives the best utilization of machines with least disruption of production. This is about the involvement of production workers in the day to day general maintenance of machines like cleaning, lubricating etc. which saves the time of skilled maintenance person at the same time the production workers are made more responsible in maintaining their machines.

4.20 VALUE STREAM MAPPING (VSM)

Value Stream Mapping (VSM) is a technique that was originally developed by Toyota and then popularized (Rother and Shook 1999). Visually representing the flow of material and information in a manufacturing system, which makes it possible to see the effects that lead times, inventory levels, cycle times, and non-value-added activities have on the system as a whole. Pavanskar et al (2003) said that value stream mapping is a functional method aimed at recognizing production systems with lean vision. As per Mehmet et al (2008), value stream mapping is a visual way of representing the flow of
information and materials in the production of products. This creates simple way for managers to see the flow. A value stream is a collection of all actions, value added as well as non-value added that are required to bring a product or a group of products that use the same resources through the main flows, from raw material to the arms of customers (Rother and Shook 1999). These actions are those in the overall supply chain including both information and operation flow, which are the core of any successful lean operation. Value stream mapping is an enterprise improvement tool to assist in visualizing the entire production process, representing both material and information flow.

The goal is to identify all types of waste in the value stream and to take steps to try and eliminate them (Rother and Shook 1999). Taking the value stream viewpoint means working on the big picture and not individual processes, and improving the whole flow and not just optimizing the pieces. It creates a common language for production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al 2002). While researchers and practitioners have developed a number of tools to investigate individual firms and supply chains, most of these tools fall short in linking and visualizing the nature of the material and information flow in an individual company.

At the level of the individual firm many organizations have moved toward becoming lean by adapting different lean tools such as JIT, setup reduction, 5s, TPM, etc. In many of these cases firms have reported some benefits; however, it was apparent that there was a need to understand the entire system in order to gain maximum benefits. For example, Gelman Science, Inc., a manufacturer of micro porous membrane filtration products started their lean journey by implementing setup reduction. Some reductions were realized, but throughput stayed the same. So in order to attain
noteworthy improvements they decided to use value stream mapping to visualize the entire flow and select lean tools that yielded maximum benefits (Zayko et al 1997).

Lately, and in particular over the last few years, a number of companies have utilized value stream mapping. The application crosses over different types of industries and organizations such as automotive, aerospace, steel, and even non-manufacturing industries including information technology. One application of value stream mapping was found in steel manufacturing. A current state map was created for a steel producer, a steel service center and a first-tier component supplier (Brunt 2000). The map shows the activities from hot rolling steel through delivery to the vehicle assembler. The overall goal of the study was to improve the supply chain performance lead-time. The current state map identified huge piles of inventory and long lead-time. A future state map was then developed. On the future state map target areas were subjected to different lean tools including kanban, supermarket and continuous flow. The results obtained by implementing the future state map were reduction in lead-time from between 47 and 65 days to 11.5 days, and a reduction of cycle time from 7262 sec to 6902 sec (Brunt 2000).

Another application of value stream mapping is in aircraft manufacturing (Abbett and Payne 1999). Current and future state maps were developed with the objective of reducing lead-time according to customer’s requirements. The implementation of the future state map attained lead-time reduction from 64 to 55 days. Lean tools such as kanban and continuous flow were utilized to help achieving this reduction. An application of value stream mapping was also found in the distribution industry (Hines and Rich 1997). Partsco a distributor of electronic, electrical, and mechanical component
decided to map the activities between the firm and its suppliers. Partsco introduce EDI which allowed the firm to work with its suppliers effectively and more quickly. In a short time period the company was able to reduce the lead-time from 8 to 7 days.

Value stream mapping can serve as a good starting point for any enterprise that wants to be lean. Rother and Shook (1999) summarize other benefits of value stream mapping as follows:

- It helps you visualize more than just the single process level (e.g., assembly, welding) in production.
- Mapping helps you not only to see your waste but also its source in the value stream.
- It provides a common language for talking about manufacturing processes.
- Value stream maps become the blueprint for lean implementation.

Value stream mapping is a pencil and paper tool, which is created using a predefined set of icons (shown in Figure 4.9 below). There are a lot of benefits to drawing value stream maps by hand with paper and pencil. Manual mapping lets us see what is actually happening in a shop floor value stream, rather than being restrained to a computer. Also, the process of quickly drawing and redrawing a map acts as a plan-do-check-act cycle that deepens our understanding of the overall flow of value or lack thereof.
The first step in value stream mapping is to choose a product family as the target for improvement. Customers care only about their products and not about all products so that it is unrealistic to map everything that passes through the shop floor. Drawing all of the product flow in one company would be too complex. Identifying a product family can be done either by using the product and process matrix to classify similar process steps for different products or by choosing products that use the highest volume.

After choosing a product family the next step is to draw a current state map to take a snapshot of how things are being done now. This is done while walking along the actual pathways from the actual production process. Drawing material flow on the current state map should always start with the process that is most linked to the customers, which in most cases is the
shipping department, and then working one’s way up to the upstream processes. The material flow is drawn at the lower portion of the map. At each process all the critical information including lead-time, cycle time, changeover time, inventory levels, etc. are documented. The inventory levels on the map should correspond to levels at the time of the actual mapping and not the average because it is important to use actual figures rather than historical averages provided by the company.

The second aspect of the current state map is the information flow that indicates how each process will know what to make. The information flow is drawn on the upper portion of the map. The information flow is drawn from right to left on the map and is connected to the material flow previously drawn. After the completion of the map a timeline is drawn below the process boxes to indicate the production lead-time, which is the time that a particular product spends on the shop floor from its arrival until its completion. In second step the value-added time is then added. This time represents the sum of the processing times for each process.

The third step in value stream mapping is to create the future state map. The purpose of value stream mapping is to highlight the sources of waste and help make target areas for improvement visible. The future state map is nothing more than an implementation plan that highlights what kind of lean tools are needed to eliminate the waste and where they are needed in the product value stream. Creating a future state map is done through answering a set of questions with regards to issues related to building of the future state map, and technical implementation related to the use of lean tools. Based on the answers to these questions, one should mark the future state ideas directly on the future state map. After creating the future state map the last step is to carry it out by trying to implement the different ideas generated by the future state map on the actual value stream.
4.21 SUMMARY

Upon reviewing various sources in the literature, this researcher is able to identify various lean tools. These tools have the common goal of improvement to address different areas of business and manufacturing. Many of the benefits and uses of these tools sometimes overlap each other. However, many manufacturers struggle to adopt lean philosophy because they find it difficult to achieve in practice (Womack 1996 and Dennis 2002). Meier has outlined some indicators of successful lean implementation such as quick and obvious problem recognition, creating a sense of urgency regarding system reliability, and consistent application of lean thinking in all areas. In textile industry, many companies may believe that lean manufacturing has been designed for non-textile operations, and that much of the tools and principles may not be relevant or suitable for textile workplaces. However, there have been various textile companies that have published their experience with lean in the form of article. The 5s tool is used to reduce wasted time and motion at micro level. Cellular layout is implemented for Simplify workflow and concentrate on a single product or narrow family. It improves quality, inventory and many other parameters. Kaizen is utilized to improve work processes in a variety of ways. Kanban tool is implemented to Schedule production and minimize work-in-process. Single piece flow reduces the internal inventory to a workcell and forces improvements and work balance. Through this understanding the researcher is able to identify suitable lean tools towards the garment industry application such as Kaizan, Total Productive Maintenance, Value stream mapping, cellular layout, single piece flow, 5s etc.