ABSTRACT

GOFORTH, KELLY ANN. Adapting Lean Manufacturing Principles to the Textile Industry. (Under the direction of Dr. George Hodge and Dr. Jeffrey A. Joines.)

The purpose of this research is to determine which lean principles are appropriate for implementation in the textile industry. Lean manufacturing involves a variety of principles and techniques, all of which have the same ultimate goal: to eliminate waste and non-value-added activities at every production or service process in order to bring the most satisfaction to the customer. To stay competitive, many domestic textile manufacturers have sought to improve their manufacturing processes so that they can more readily compete with overseas manufacturers. Implementing cost-saving lean manufacturing techniques may be used to reduce the impact of cheap imports. This study identifies twenty-four different tools and principles of lean and compares lean manufacturing with other production approaches used in the textile and apparel industry. This research investigates how companies across a variety of industries have used lean principles in their businesses to bring the most benefit. Lean manufacturing use in the textile industry was examined in this research through interviews, plant tours, and case studies. The results from this research were compiled to create a textile specific lean implementation roadmap which consists of a list of barriers applying to textile companies implementing lean, a 5s system and Value Stream Mapping best practice checklists, and a recommendation model for implementing lean tools and principles in a textile environment.

ADAPTING LEAN MANUFACTURING PRINCIPLES TO THE TEXTILE INDUSTRY

by
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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

TEXTILES

Raleigh, North Carolina

2007

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BIOGRAPHY

Kelly Ann Goforth was born September 1, 1979 to Steve and Ann Goforth in Shelby, North Carolina. She spent most of her youth living with her parents and two brothers, Jamie and John in Cleveland County right outside of Kings Mountain, North Carolina. She attended Bethware Elementary School and Kings Mountain Middle School before graduating from Kings Mountain High School in 1997.

Later in 1997, Kelly moved to Raleigh, North Carolina to begin life as a student at North Carolina State University in the College of Forestry. In 1998, Kelly withdrew from the university to pursue life and work in Greensboro, NC. After working for several years in Greensboro, Kelly decided to return to college at NC State. In July of 2002, she moved to back to Raleigh to begin taking classes in the College of Textiles that August. Kelly soon learned how to manage full course loads of classes by day, while working a full time job at night. In May of 2005, Kelly graduated with a bachelors of science in Textile Management from North Carolina State University.

In the fall of 2005, Kelly continued her education at NCSU pursuing a Masters of Science in Textiles. Kelly was fortunate to be selected as an Institute of Textile Technology Graduate Fellow for the Class of 2007. In the summer of 2006, Kelly interned with Guilford Fibers in Fuquay-Varina, NC in their process engineering department. On November 11, 2006, Kelly was married to Kevin Andrew Ross, alumni and employee of North Carolina State University. Kelly will graduate with the Degree of Master of Science on May 12, 2007.

ACKNOWLEDGEMENTS

I would like to express my most sincere gratitude to my research advisors, Dr. George Hodge, Dr. Jeffrey A. Joines, and Dr. Kristin Thoney for their advice, guidance, and support throughout my research. I would also like to thank the other members of my committee and the Institute of Textile Technology faculty and member companies as well as the North Carolina State Industrial Extension Service for their help. I am also grateful to my fellow graduate students and classmates for their encouragement and friendship.

I am most particularly grateful to my family, Ann and Steve as well as Brother Jaime and Johnny Boy for their support, encouragement, love, and laughs throughout my graduate studies. I would also like to thank my cats: Cookie, Midnight, and Little as well as my good buddies Buster, Virginia, BP, April Wagoner, and Matthew Berdine for all their unconditional love.

Finally, I would like to thank my husband who has helped to make much of this possible for me. Without his encouragement, I do not know where I would be now, but I can only imagine that I would not experience the joy and happiness I feel today. I would also like to honor my grandparents, Mamaw and Papaw Patterson as well as the memories of Mamaw, Grandfather Goforth, Sissy, Birdie, and Louise Quinlan.

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1 Introduction

The United States textile industry is facing major competitive pressure brought on by the increased presence of low-cost, foreign manufacturers in the marketplace over the past several decades. Although US manufacturers are known for their high quality, high productivity and innovative product offerings, many US manufacturers are having trouble competing in the deep-discount, global marketplace. This pressure was further intensified with the elimination of quotas as of January 1, 2005, from all textiles and apparel manufactured imported into the United States from World Trade Organization (WTO) members. To stay competitive, many domestic textile manufacturers have sought to improve their manufacturing processes so that they can more readily compete with overseas manufacturers. Implementing cost-saving lean manufacturing techniques may be used to reduce the impact of cheap imports. Lean manufacturing involves a variety of principles and techniques, all of which have the same ultimate goal; to eliminate waste and non-value-added activities at every production or service process in order to bring the most satisfaction to the customer.

1.1 Focus of Research

Specifically, this research focuses on determining which lean principles are appropriate for implementation in the textile industry. This study will investigate how companies across a variety of industries have used lean principles in their businesses to bring the most benefit. Lean principles were first used at Toyota Motor Company, which likely to surpass General Motors as the world's largest automobile manufacturer in 2007 (Naughton & Sloan, 2007). Many other companies that have adopted lean principles have emerged as world-class leaders in various industries. However, the textile industry has been slow to adopt lean manufacturing principles. For these textile companies, lean manufacturing may not seem useful in their environment, or they may simply not want to change the way they operate. In the global marketplace, textile companies will find that a growing number of their downstream customers and their competitors are operating under lean principles. With this increased competition, customers have a growing variety of better products with fewer defects at lower prices to choose from offered at a variety by of sales channels (Womack & Jones, 2005). Many retailers have incorporated lean principles into their inventory decision analysis by using SKU-level analysis, which has put increased pressure on suppliers to deliver goods quickly to the marketplace (Abernathy, Dunlop, Hammond, & Weil, 2000).

1.2 Potential Benefit of Research

There are several possible benefits from this research from the standpoint of textile companies such as reduction in cost, lead time, inventory, and better utilization of production space. Other industries which have used lean manufacturing strategies have experienced improvements in operational performance through eliminating waste and non value added steps, which provided these companies with cost saving and shortened lead times (Aberdeen Group, 2006). These benefits are particularly interesting for textile companies as the industry faces increased global competition from lower-wage-structured nations, and customers along the supply chain demand shorter delivery times at lower prices.

1.3 Objectives of Research

Lean manufacturing encompasses a wide range of methods and tools. The objective of this research is to develop a road map for companies to use, which identifies the best practices and pitfalls that apply specifically to the implementation of lean manufacturing principles in a textile environment. This road map includes a recommended model for implementing lean in a textile firm, listing of common barriers to lean implementation in textile companies and suggested solutions to these barriers, and a best practice checklist for both Value Stream Mapping and the 5s system.

2 Literature Review

The purpose of this literature review is to provide a background on the history, evolution, and application of lean across a variety of industries. This understanding will help determine which lean principles are appropriate for implementation within the textile industry, and how to use these concepts to bring the most benefit to a textile 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 the many methods and tools associated with the term 'lean.'

2.1 Development of Lean Manufacturing

Taichii Ohno developed many of the lean principles used today at Toyota Motor Company (Womack & Jones, 1996). This research focuses specifically on the methods, tools, measurements, and metrics that have been developed in order for companies and industries to find success in the use of Lean Manufacturing. Concepts such as craft and mass production, quality improvement movements, Agile Manufacturing, and the apparel industry's Quick Response are examined in the following subsections as part of the development of or related to the principles of lean production.

2.1.1 Craft Production and Mass Production

Before the Industrial revolution, craftsmen, who were highly skilled and made customized items in their homes or shops for specific customers, produced most all products. The problem with craft production is that it is very expensive. So, there is a relatively small consumer base of those who can afford customized goods. Henry Ford's assembly line revolutionized manufacturing by making his 1908 Model T available in mass quantities for the public. The two World Wars perpetuated the practice of mass production in the minds of the American manufacturer. After World War II and throughout the 1950's and 60's, the general manufacturing attitude was to try to produce as much as possible without regard to waste or the cost of waste (Piciacchia & Bergsten, 2002). In contrast with craft production, mass production consists of many low skilled workers using single purpose machines. To keep high production rates, the mass producer has many buffers such as extra workers, supplies, and space. Mass producers do not change product designs often to help keep costs down, so they keep producing the same products for as long as possible. The lean producer combines the advantages of both craft and mass production and involves multi-skilled workers who use flexible multi-purpose machinery to produce a variety of products at variable volumes (Womack, Jones & Roos, 1990).

2.1.2 Toyota Production System

Toyota Motor Company began an approach to manufacturing called the Toyota Production System or Just in Time manufacturing in the late 1940's. Toyota saw that the system that American auto manufacturers such as Ford were using at the time would not work for his company in Japan. The western practice was to have hundreds of stamping presses to make all the parts required for the car and truck bodies, but Toyota's budget only permitted them to be able to have a few press lines. Also, at this time, Toyota was just starting out in the automobile manufacturing industry, and their entire production was only a few thousand vehicles per year. However, the consumer market required a wide variety of vehicles types. Taichii Ohno, an engineer at Toyota developed a simple die change technique that enabled the die for vehicles to be changed frequently, using rollers to move dies in and out of position, so that a variety of vehicles could be made in one day (Womack *et al*., 1990). Toyota discovered that producing small batches of vehicles was cheaper than producing huge lots, because this eliminated carrying costs of huge inventories, and making only a few parts before assembling them into a car allowed for mistakes to show up much more quickly.

The Toyota production system also differed from American automotive manufacturers in the way the shop floor workers were treated. After visiting Ford manufacturing facilities, Ohno realized that his Japanese workers would not accept the harsh work environment and demeaning job structures he had observed. He also realized that in order for his system of making only a few parts before assembling them into a car to work, he would need a skilled and motivated workforce, which could anticipate problems before they occurred and take the initiative to solve problems (Womack *et al*., 1990). In his book, *The Machine that Changed the World,* James Womack coined the term lean to describe the production system used at Toyota. Taiichi Ohno (1998), Yasuhiro Monden (1993), Shigeo Shingo (1981) and various other authors have provided an extensive review of the Toyota Production System. Womack's subsequent book *Lean Thinking,* published in 1996, which also further explores the concept of lean manufacturing (Womack & Jones, 1996).

2.1.3 Juran's Quality Control

In 1951, Joseph Juran published his revolutionary *Quality Control Handbook*, which remains an important reference for the quality movement worldwide (Dershin, 2000). Juran was a quality guru who visited post World War II Japan to implement 'total quality' which was meant to improve the reputation of Japanese products. The heart of Juran's quality planning structure is the project team. The importance of the team in Juran's model resembles the importance of the workers in Toyota's system discussed previously. For additional review of

Juran's quality theories see publications written by Juran and Godfrey (2000) and Montgomery (2005). The significance of employees working as teams is stressed in many aspects of lean principles, which relates lean to Juran's quality model; while statistical methods for quality control relate more to Lean Sigma, which is the combination of lean and Six Sigma quality control, defined later in this chapter in Section 2.2.7.

2.1.4 Deming's Quality, Productivity & Competitive Edge

After World War II, Japan made major efforts to improve the quality of their manufacturing products by implementing programs of Statistical Quality Control. W. Edwards Deming came to Japan to provide expert training to engineers, managers, and scholars. Deming focused on three key areas: the use of the PDCA cycle (see section 2.31), the importance of understanding the causes of variation, and process control through the use of control charts. Deming insisted that it was management's responsibility to lead quality improvement efforts by defining the quality policy and assuring that all the workers understand and support it (Babich, 1996). For additional details see *Out of Crisis,* by W. Edwards Deming (Deming, 2000). Deming's idea that management must be responsible for quality relates to the lean principle of Hoshin Planning or policy deployment, which is discussed in more detail later in this chapter in Section 2.2.1.

2.1.5 Agile Manufacturing

Agile manufacturing relates to the alliances formed between supplier and customers to provide increased speed to market of products. This initiative is used commonly among automotive, electronics, and equipment manufactures where agile manufacturing alliances are encouraged (Russell & Taylor, 2002). The basic business strategies used under agile manufacturing are flexibility (which is central) customer supplier negotiations, a time Phased approach to production, contingency modeling for consideration of dynamic trade-offs and dynamic paths forward, and a continuous re-planning process triggered by events and time. The dynamics of agile manufacturing are discussed extensively in Gunasekaran's *Agile Manufacturing: The 21st Century Competitive Strategy* (Gunasekaran, 2001). Flexibility is the key component of agile manufacturing. Flexibility is also an important lean principle where production is driven by the customer's demand, and production must flexible in order to meet that demand as it is often changing.

2.1.6 Quick Response

Quick Response is similar to agile manufacturing, except this is the term for supplier customer alliances used specifically in the textile and apparel industry. Quick response has been used in the apparel industry since the 1980's, as a means to stay competitive in the global market. Quick response is a business strategy incorporating time-based competition, production agility, as well as partnering in the supply chain (Kunz, 1998). Quick Response incorporates business planning, order and inventory management, requirements planning, and planning and scheduling so that they all work in unison to achieve the goals of the entire organization. The goals of quick response are reduced lead times, inventories and waste, and improved quality (Hodge, 2001). Like agile manufacturing, the goals of quick response and lean are similar with respect to production agility or flexibility as well as limiting inventories and waste, achieving quality improvements, and partnering within the supply chain.

2.2 Lean Tools and Methods

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, mentioned earlier in Section 2.12. 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 & Jones, 1996).

As mentioned earlier, there are many lean tools. Lean is concerned with eliminating all types of waste, which is much more than eliminating waste by reducing inventory. 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). 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 costs (Womack & Jones, 1996). The various lean tools are discussed briefly in the subsequent sections of this chapter. The tools are presented in the order of relevance from top management to the plant floor of an organization.

2.2.1 Hoshin Kanri or Policy Deployment

Hoshin kanri or policy deployment is the process of bringing the objectives of top management of the company to the plant floor level (Liker, 2004). Policy deployment is the short-term and long-term process used to identify and address critical business requirements and expand the ability of the workforce. The ultimate purpose of 'policy deployment' is to create a companywide philosophy based on quality being supreme with a customer oriented approach (Akai, 1991). Figure 2.1 shows the basic concept of Hoshin Kanri. Policy Deployment aligns company resources to swiftly recognize and react to changes in the business environment. The goals of the organization as a whole, start at the executive level and at each level below they develop into measurable objectives for the year, which support the overall organizational goals. The hoshin planning system consists of the following: the plan, do, check, and act cycle, nemawashi, catchball, the control department concept, and A3 thinking. For more information about the hoshin planning system consult *Hoshin Kanri* and *Hoshin Kanri: Policy Deployment for Successful TQM* by Yoji Akai (Akai, 1988 & Akai, 1991).

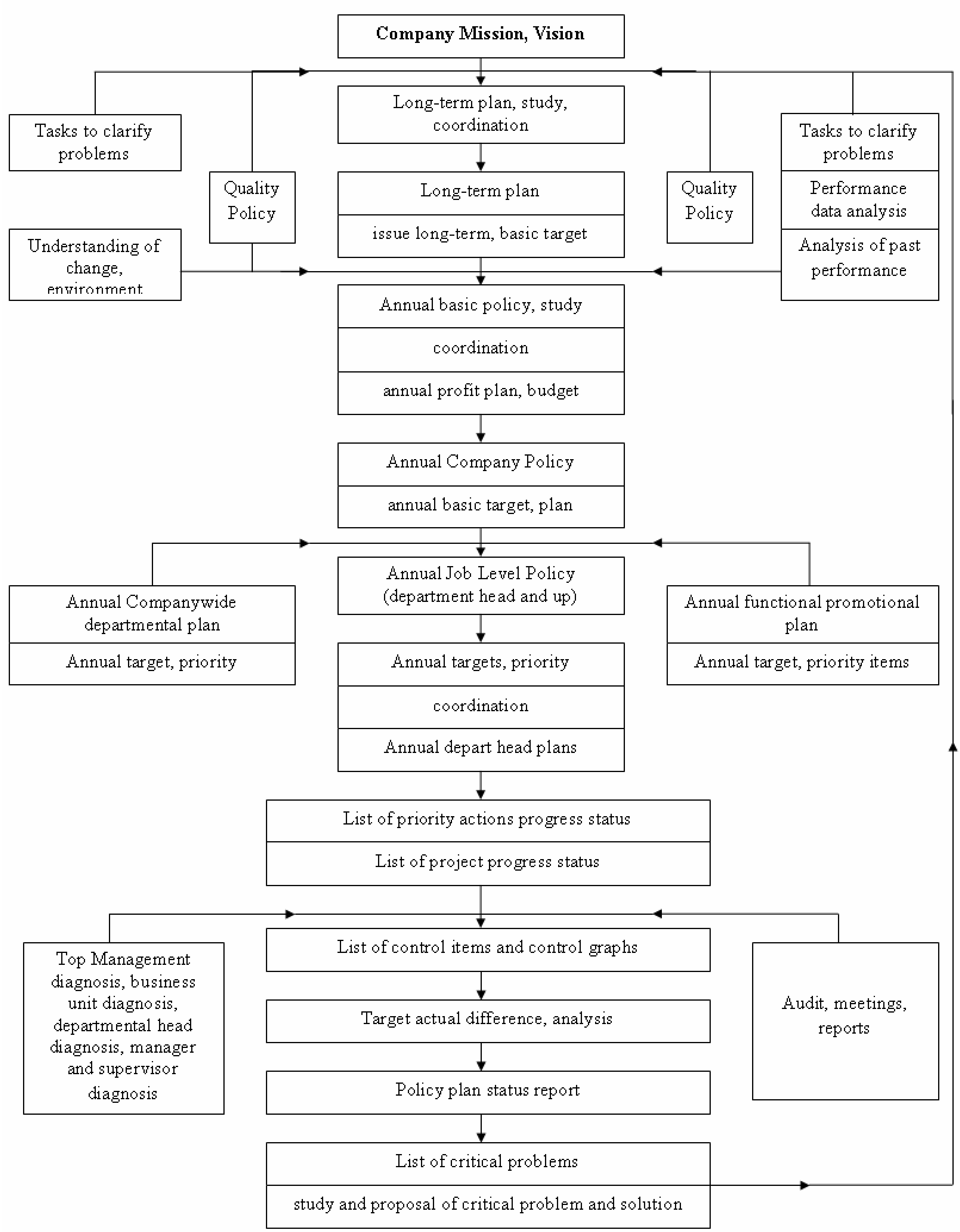

Figure 2.1: Hoshin Kanri: Basic Concept
Source: Akai, Yoji. (1991). *Hoshin Kanri: Policy Deployment for Successful TQM.* Portland, OR: Productivity Press.

2.2.2 Plan, Do, Check & Act (PDCA)

Hoshin planning is made up of PDCA cycles: macro (three to five years) practiced by senior management, annual practiced by operating managers, and micro (weekly, monthly, or biannually) practiced by operating managers and their subordinates. Figure 2.2 shows how the process of 'policy deployment' follows the PDCA cycle as goals pass from top management to the plant floor. PDCA is a continuous cycle which requires cultural change as seen in Figure 2.3.

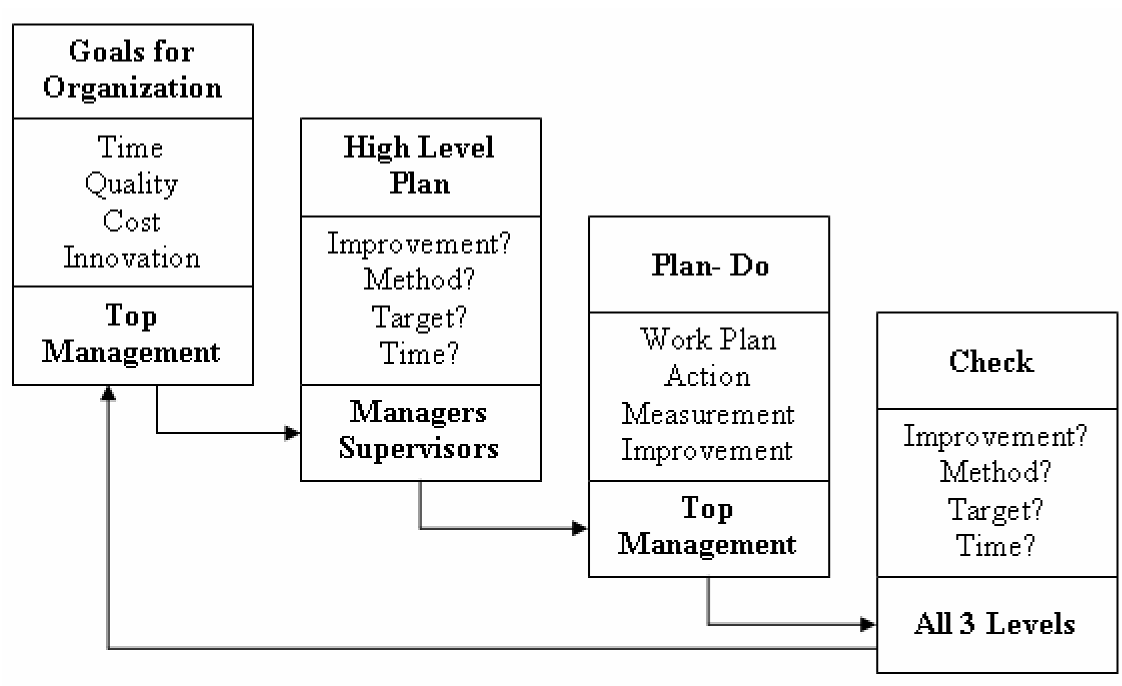

Figure 2.2: Policy Deployment Process (Hoshin Kanri)
Source: Liker, J.K. (2004). *The Toyota Way*. New York: McGraw-Hill.

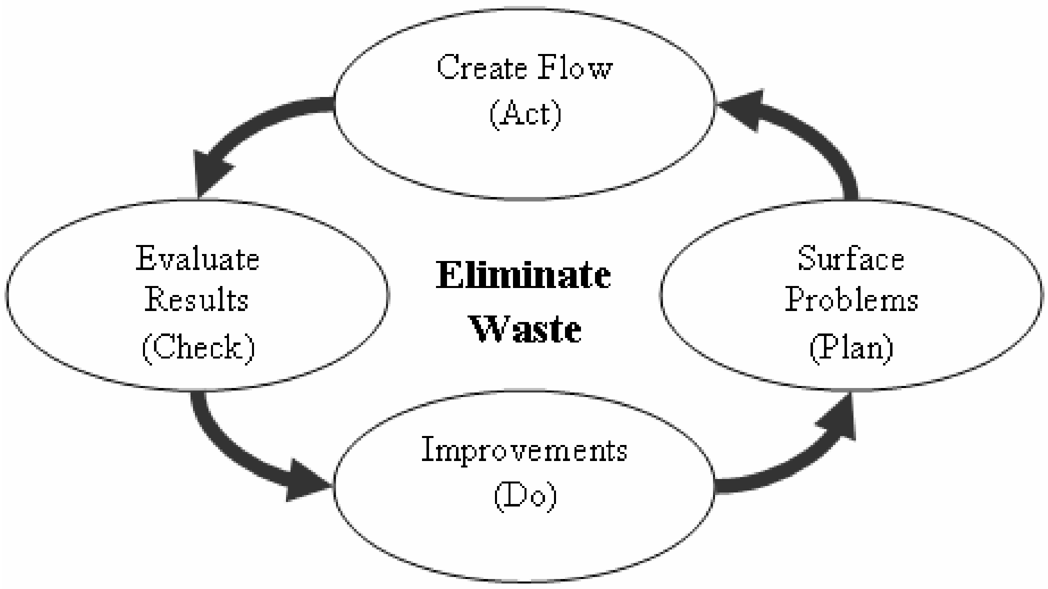

Figure 2.3: Creating Flow and PDCA
Source: Liker, J.K. (2004). ***The Toyota Way*****. New York: McGraw-Hill.**

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 & Akai, 1991).

2.2.3 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 are giving 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 2.4 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 & Liker, 2004).

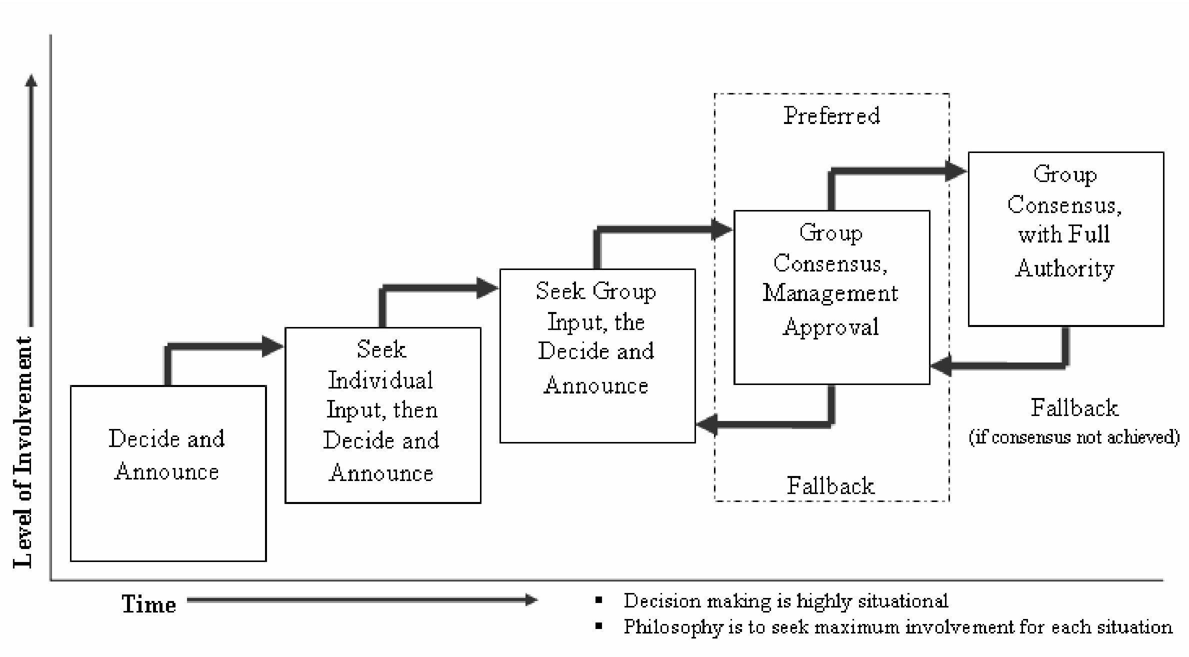

Figure 2.4: Alternative Toyota Decision Making Methods
Source: Liker, J.K. (2004). *The Toyota Way.* New York: McGraw-Hill.

2.2.4 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 & Akai, 1991). Figure 2.5 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.

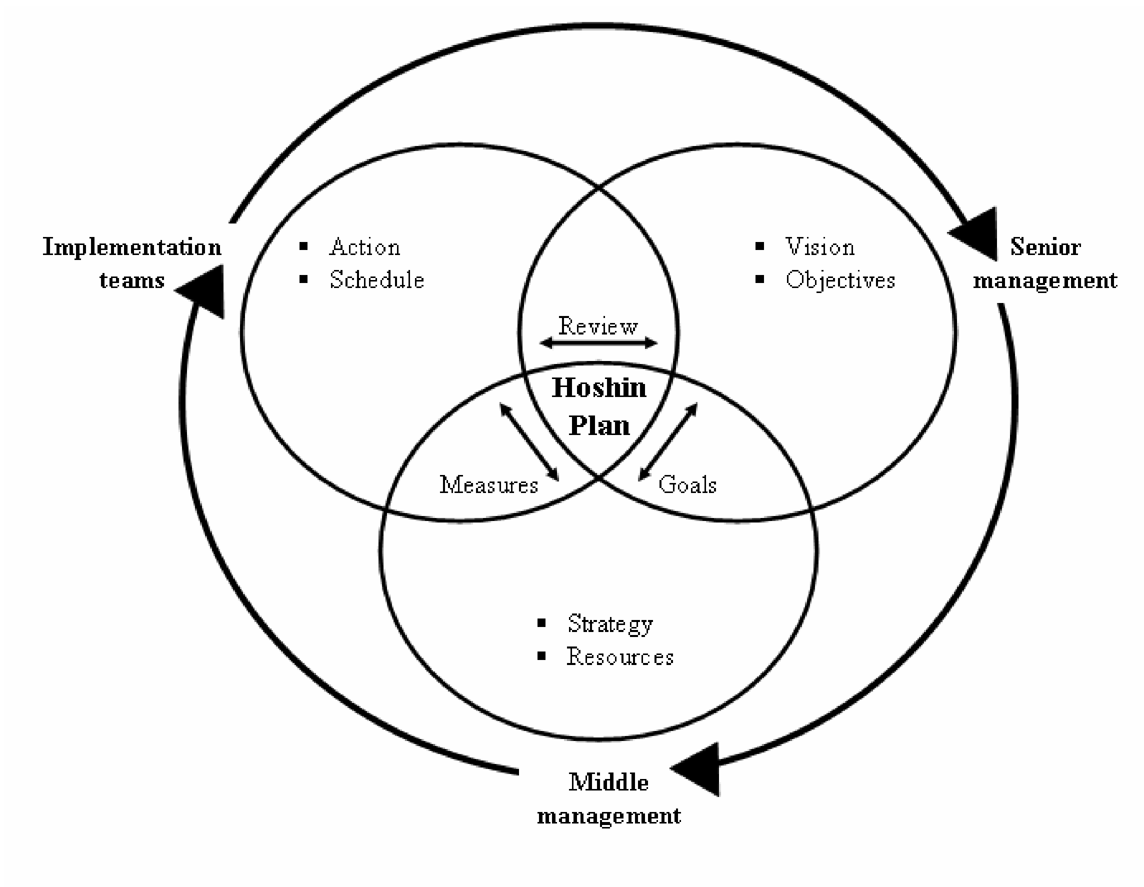

Figure 2.5: Hoshin Model
Source: Akai, Yoji. (1991). ***Hoshin Kanri: Policy Deployment for Successful TQM.*** **Portland, OR: Productivity Press.**

2.2.5 Control Department or Cross Functional Management

The Control Department or Cross Functional Management concept attempts to combine core company focus areas such as productivity, quality, cost, and safety into cross-functional groups with coordinated efforts towards common goals. Figure 2.6 presents the Departmental Control Concept. The control department develops the Policy Deployment plans for the company, while individual departments develop their own plans for supporting their particular purpose. For example, the quality department would develop a quality plan. To support this plan all the other departments would develop plans to support quality in their department. The control departments are responsible for their own performance (Akai, 1991).

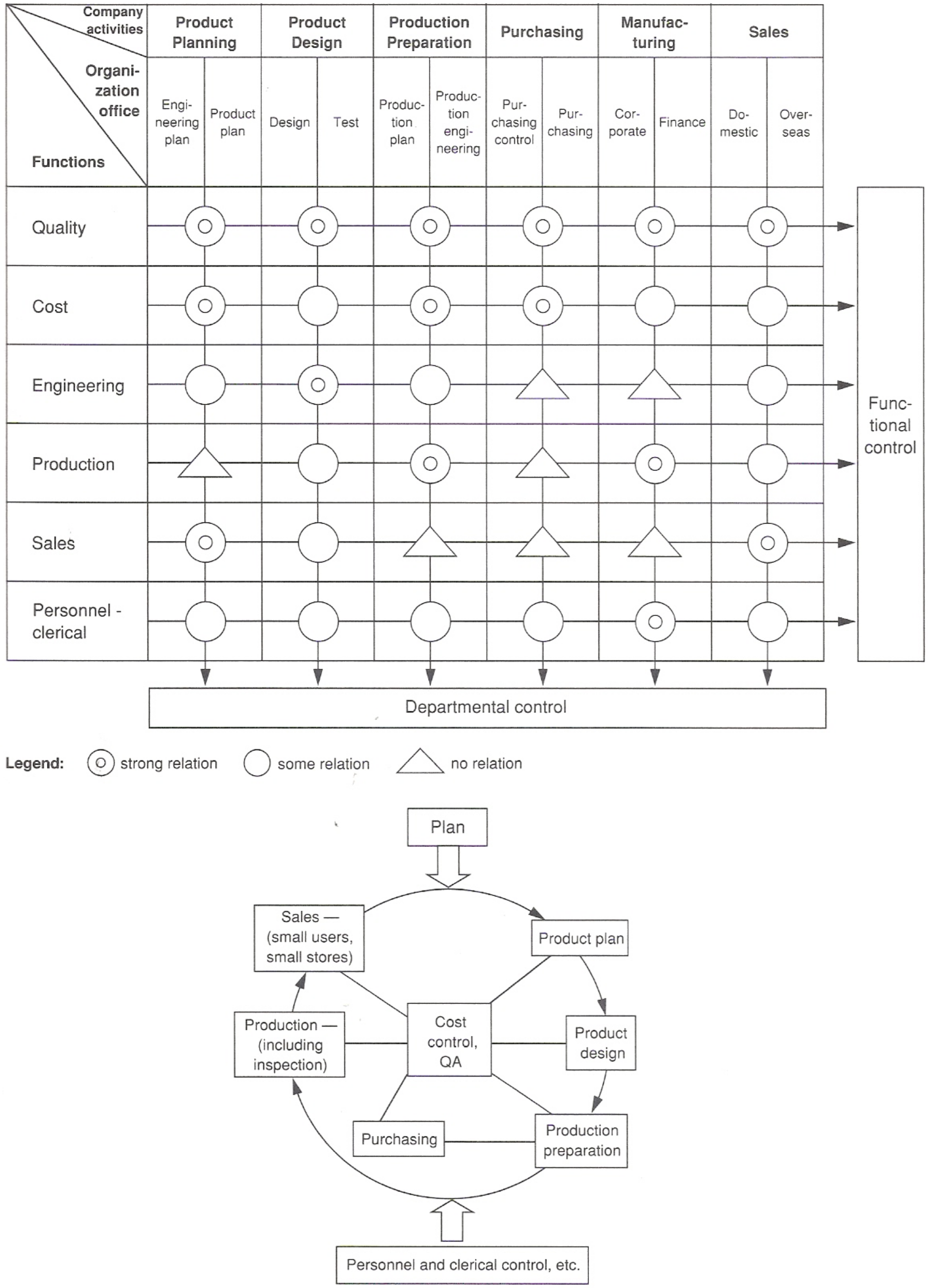

Figure 2.6: Departmental Control Concept
Source: Source: Akai, Yoji. (1991). *Hoshin Kanri: Policy Deployment for Successful TQM.* Portland, OR: Productivity Press.

2.2.6 A3 Problem Solving

A3 reports were originally used at Toyota to summarize kaizen activities (see Section 2.2.14). There are four types of A3: ‘hoshin planning A3’ used to summarize company and departmental plans, ‘problem solving A3’ used to summarize problems and corrective actions, ‘proposal A3’ used to present new ideas, and ‘current status A3’ used to summarize the current condition of a plan, problem, or concern (Liker, 2004). A3 is an important part of PDCA, nemawashi, and catch ball because the reports are a simple means to relay information about the organizational goals and direction to everyone in the company (Liker, 2004 & Sobeck, 2004).

2.2.7 Lean Six Sigma

Six Sigma (6σ) quality is a problem solving methodology which was first used at Motorola to represent its strategy for the lowest possible failed. 6σ represents the mathematical calculation, 99.9996% perfection. The figure equates to 3.4 ppm failed parts per million, which is very close to zero defects. Lean Six Sigma combines Six Sigma methodology with lean manufacturing tools. Lean six sigma is a data driven approach to find the root cause of problems, management strategy to manage lean projects to financial goals, and uses the DMAIC (define, measure, analyze, improve, maintain) process to organize operating processes (Taghizadegan, 2006).

2.2.8 Value Stream Mapping

For almost all companies, value stream redesigns are a critical step to becoming lean; the design of the end-to-end value stream must be considered instead of applying tools randomly, or to address an apparent problem (Womack & Jones, 1996). Value Steam Mapping (VSM) is used extensively in Six Sigma Methodology and has recently been added to the list of tools which can be used to apply the principles of lean (Henderson & Larco, 1999). Value stream maps differ from process flow maps in that value stream maps contain all the value added and non-value added steps/activities, include the information flow along with the material flow to make the product, are a closed circuit from the customer back to the customer, and contain no takt time is taken into account in process flow maps. Figure 2.7 lists and visually represents all the icons used in Value Stream Mapping.

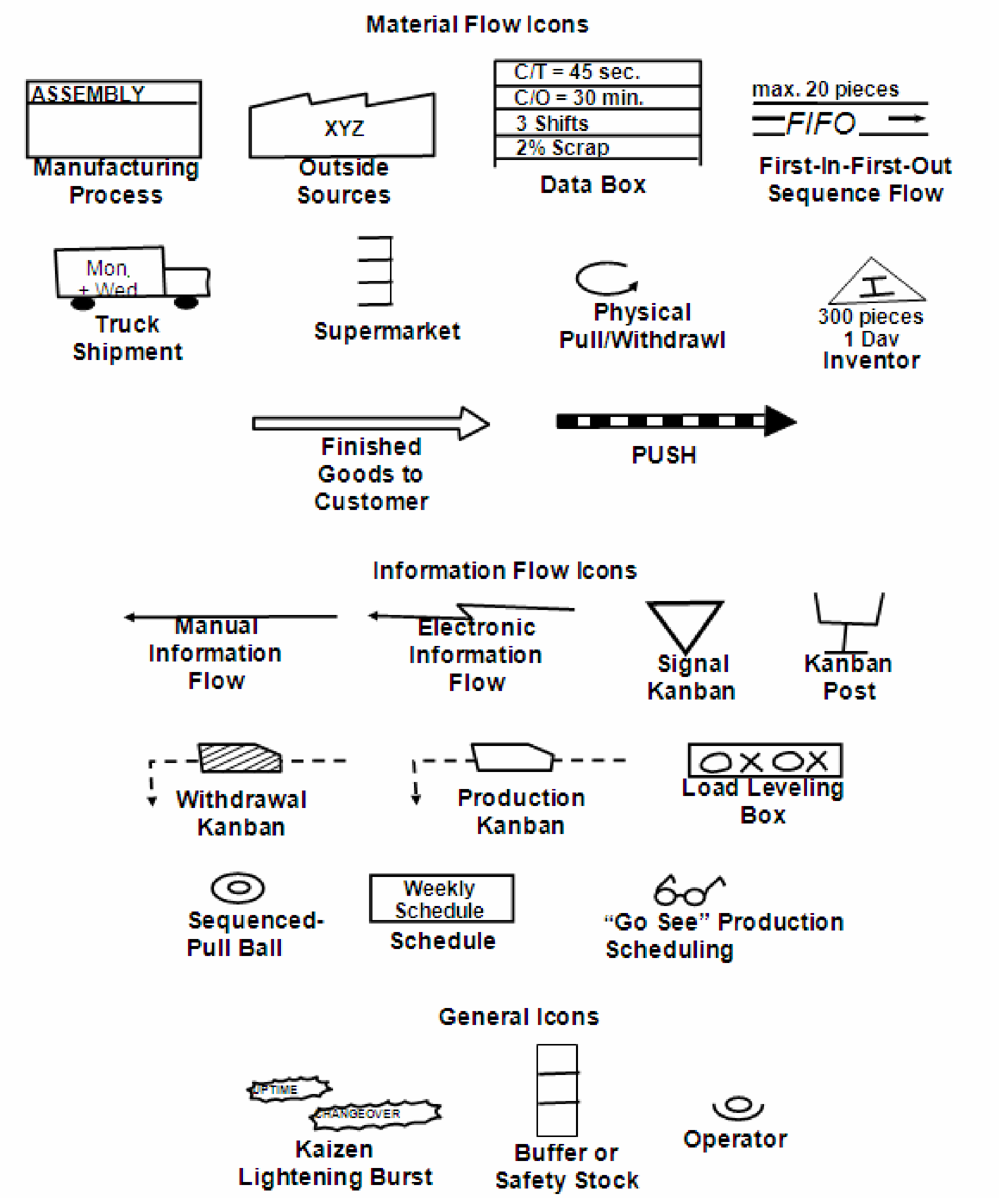

Figure 2.7: Value Stream Mapping Icons
Source: Rother, M. & Shook, S. (2002). *Value Stream Mapping Workshop.* Brookline, MA: The Lean Enterprise Institute.

Value Stream Maps should be made of the current state of the manufacturing process to make a particular product line or family, all the information should be gathered at one time as the map will represent this particular time and date. Figure 2.8 is an example of a current state map.

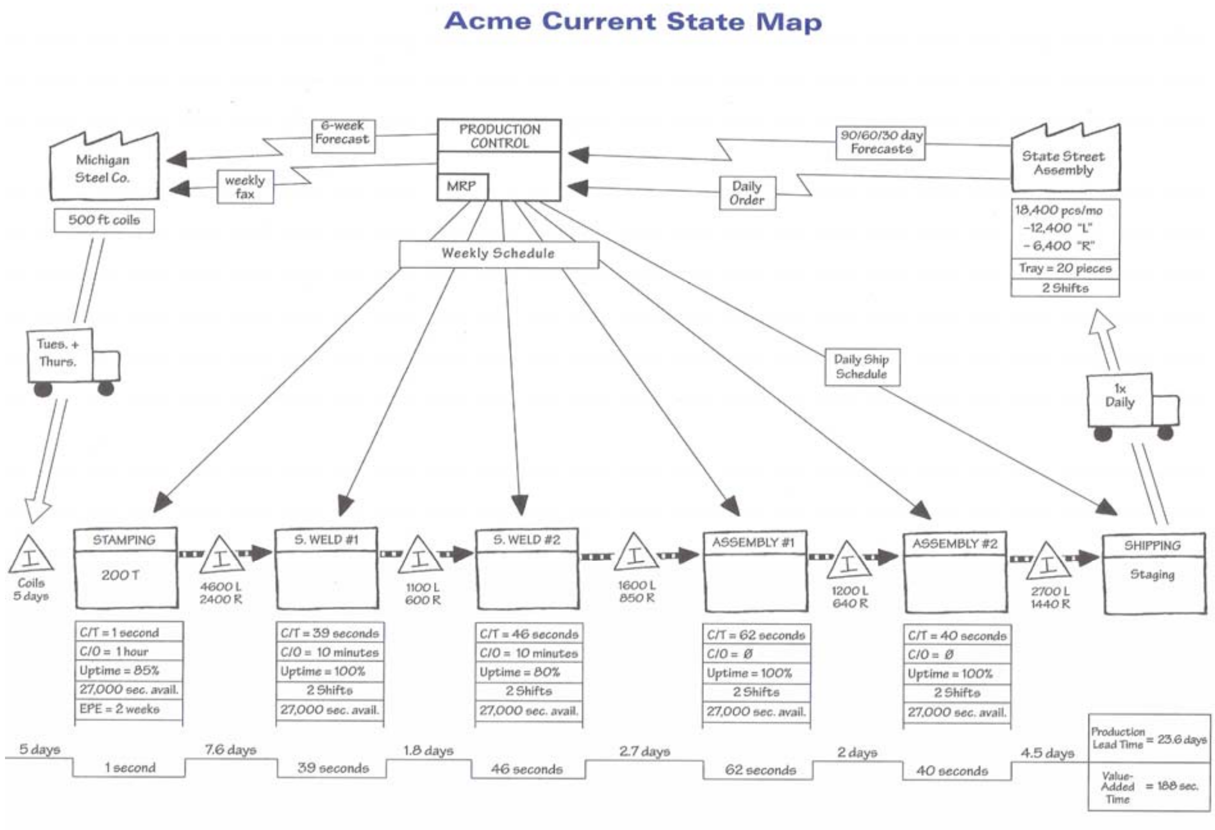

Figure 2.8: Acme Current State Map
Source: Rother, M. & Shook, S. (2002). *Value Stream Mapping Workshop.* Brookline, MA: The Lean Enterprise Institute.

After the current state has been completed, percent value added, the processing time that the customer is willing to pay for, can be calculated as the ratio of the total lead time to value added processing time. From the current state, problems in the process are identified and goals for improvement are identified and placed on the future state map. Figure 2.9 shows an example of a current state map of the same company in Figure 2.8.

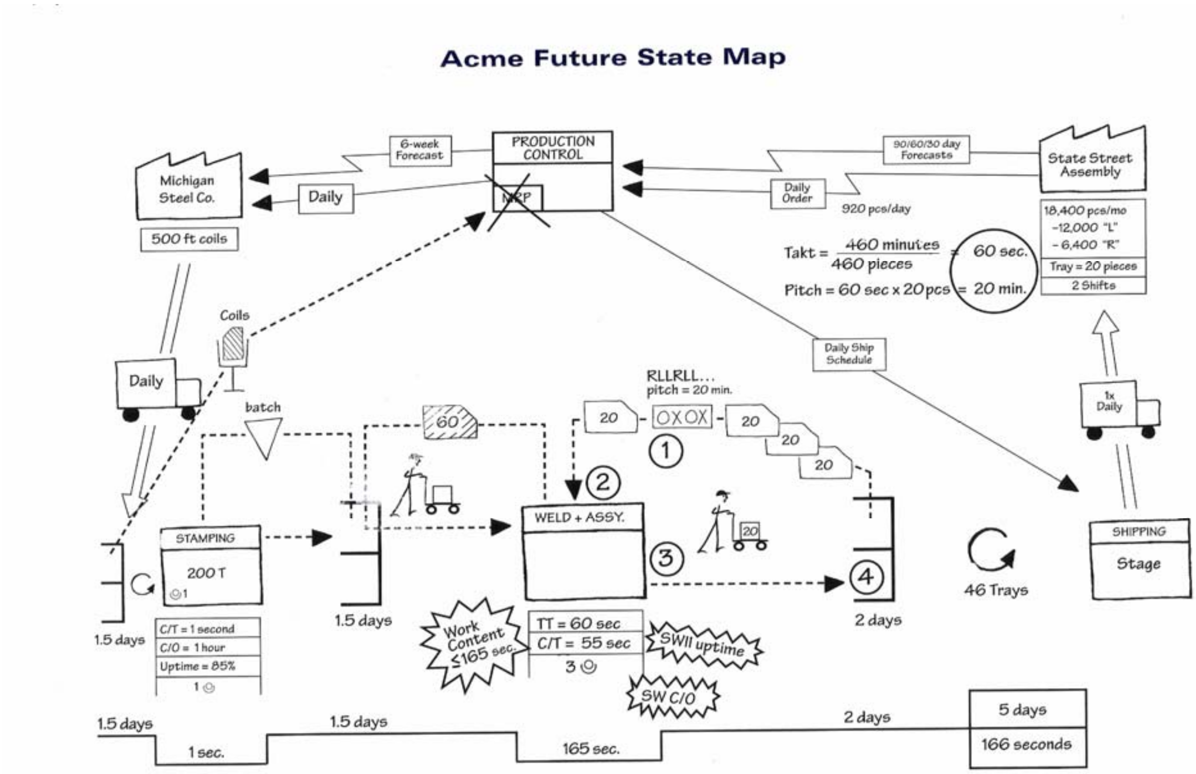

Figure 2.9: Future State Map
Source: Rother, M. & Shook, S. (2002). *Value Stream Mapping Workshop.* Brookline, MA: The Lean Enterprise Institute.

Value stream maps relay information such as machine utilization and inventory in each process and their effect on the overall lead time of the product, which allows for prioritization of projects which would have the most positive effect on the overall lead time. Value Stream Maps can be used in order to visualize and make improvements on a process; this is done through a future state map of the process, which represents the ideal situation of the process.

2.2.9 Spaghetti Diagrams

A spaghetti diagram shows the path of a specific product as it moves from one process to another. In a mass production system the product's path typically looks like a plate of spaghetti (Womack & Jones, 1996). Spaghetti diagrams are a simple way to analyze the product flow, but do not contain the level of information found in Value Stream Mapping.

2.2.10 Visual Management

The goal of visual management is to create a work environment that is self-explaining, self-ordering, and self-improving (Grief, 1995). In his book "The Visual Factory," Grief illustrates this idea in a visual management triangle seen in Figure 2.10. 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 subsection.

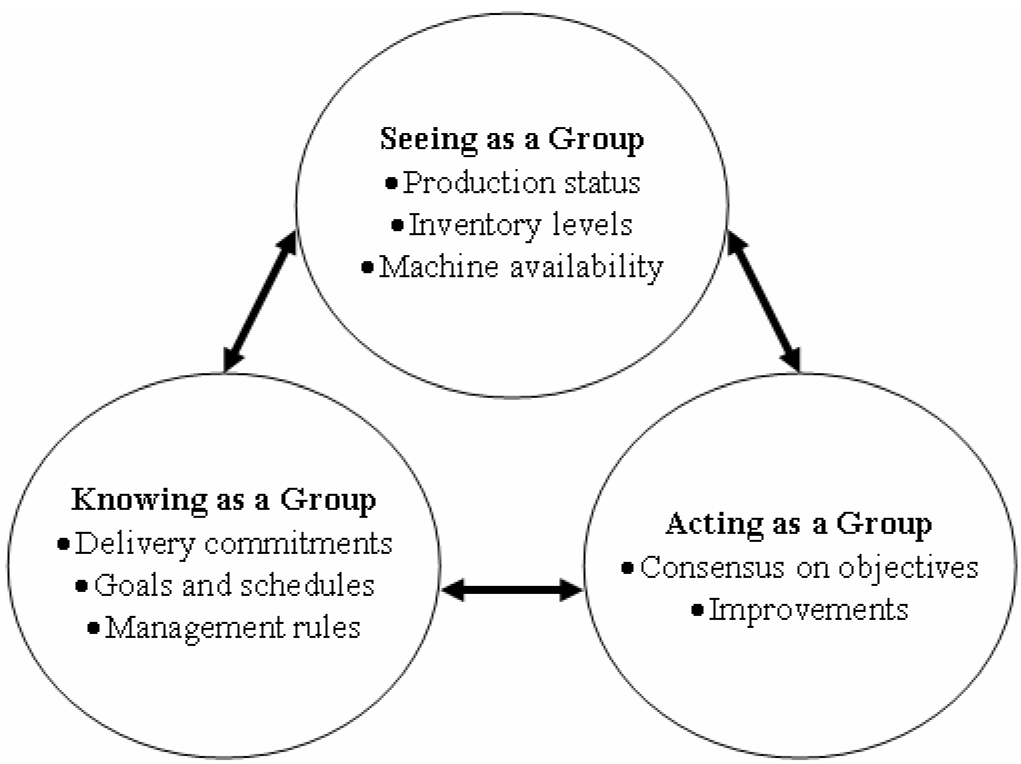

Figure 2.10: The Visual Management Triangle
Source: Grief, M. (1995). *The Visual Factory: Hiroyuki Hirano.* Portland OR: Productivity Press.

2.2.11 The 5s System

The 5s tool is a structural system to organize any type of business or operation, and 5s represents five steps including: 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 in order depending on the needs of the organization using 5s.

2.2.11.1 Sort

The first step, 'sort' means to simply separate what is needed and necessary in the workplace or station from what is not 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 close by to put these unnecessary items and the items in which there is uncertainty. Just about anything can be put into this holding area, including items that may or may not be used such as:

- Machinery - Trucks, presses, drills, hoists, etc.,
- Stock - Raw materials, parts, assemblies, etc.,
- Tools & Equipment - Motors, wrenches, pumps, hammers, phones, etc.,
- Facilities - Work tables, chairs, desks, etc.,
- Documents - Files, notices, awards, memos, folders, etc.,
- Stationery - Pencils, staplers, erasers, paper, whiteout, 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 serve better use, or disposed. 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.

2.2.11.2 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 is plastic tape. 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 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 replace

2.2.11.3 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.

2.2.11.4 Standardize

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

2.2.11.5 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 rewards for maintaining this course of action are 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).

2.2.12 Total Productive Maintenance

Total Productive Maintenance (TPM) is another component of visual management, which works especially well with the 5s organizational system. As discussed earlier, one pillar of 5s is shine in which cleaning is used as a form of inspection. The goal of this is to eventually train the operators to look after the equipment in their workstation (Nakajimi, 1988). Total productive maintenance assigns basic maintenance work such as: inspection, cleaning, lubricating, tightening, etc., to the operator. This frees up the technicians or maintenance team for productive maintenance, which includes higher value-added activities such as:

equipment improvement and overhauls, training, etc. Just as in safety the target is zero incidences, in TPM the target is zero breakdowns (Nakajimi, 1988).

The key measure of TPM is machine effectiveness, which is availability, performance efficiency, and overall equipment effectiveness (OEE).

- Availability =(loading time[1] – down time)/ loading time
- Performance efficiency = (net operating time – lost time) / net operating time
- OEE = availability * performance efficiency * quality rate

Accurate data is essential. It is not time wasted to measure and record machine performance. Accurate equipment records are essential in order to identify potential problems (Hartmann, 1992).

[1] Loading time refers the time to set up machine with material to be processed.

2.2.13 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 & Dennis, 2002). 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 is 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.

2.2.14 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 & 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 & Taylor, 2002).

2.2.15 Kaikaku or Radical, Rapid Improvement

Kaikaku is Japanese 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 one time event to make improvements on a particular problem or issue. Kaikaku and its application are discussed further in Womack's *Lean Thinking* (Womack & Jones, 1996).

2.2.16 Jidoka or Root Cause Analysis

Jidoka is a Japanese word comprised 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 "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 a). The ultimate goal of jidoka is to prevent defects.

The first use of jidoka was in the textile industry in 1902 when Sakichi Toyada, 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 a). To achieve this goal, Shingo developed the concept of poka-yoke.

2.2.17 Poka-yoke or Mistake Proofing Devices

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 is implementing simple low cost mistake proofing devices that detect abnormal situations before they occur or once they occur stop production to prevent defects (Shingo, 1985 a).

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, miss set work pieces, missing or wrong parts, improper equipment set ups 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 a).

2.2.18 SMED or Quick Machine Changeover

Single Minute Exchange of Dies (SMED) is a series of techniques developed by Shigeo Shingo for reduction in production changeover time to less than ten minutes. ‘One-touch set-up’ applies to a changeover taking less than a minute and ‘zero set-up’ are changeovers that happen instantaneous. Shingo has compiled this methodology into his book entitled *A Revolution in Manufacturing: the SMED System* (Shingo, 1985 b).

2.2.19 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 2.11.

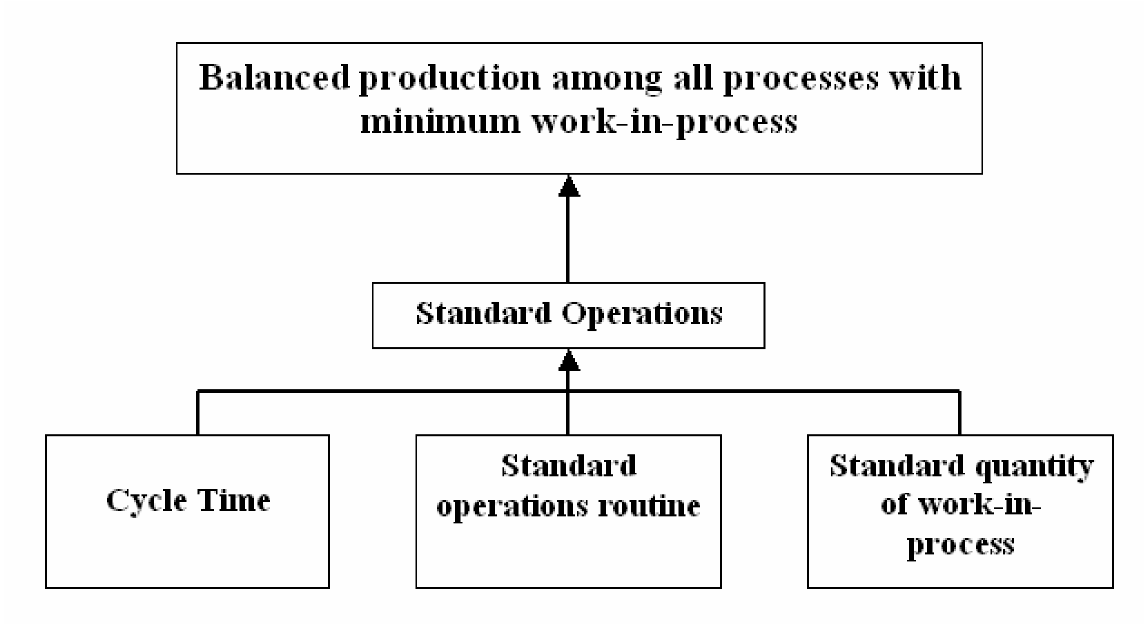

Figure 2.11: Elements of Standard Operations
Source: Monden, Y. (1993). ***Toyota Production System: An Integrated Approach to Just In Time.*** **Norcoss, GA: Engineering & Management Press.**

In order to use standardized work, a process must be stable without continuous line stoppages and slowdowns. Lean activities support stability. For example, 5s and TPM discussed in earlier sections support machine stability and safety. Standardized work involves three elements, which are the baseline against which any given process can be accessed: takt time, work sequence, and in-process stock. Standardized work is relayed to the operators through standard operations sheets and charts that define standard work.

2.2.20 Takt Time and Cycle Time

Takt time or cycle time is the time needed to manufacture one unit of a product to customer demand, measured as the elapsed time between the completion of one unit and the completion of the next (Monden, 1993). The word is German describes a stroke in beating time. The takt time reveals the demand frequency, or how frequently a product needs to be produced, tact time is calculated as follows:

$$\text{Takt Time} = \frac{\text{Daily Operating Time}}{\text{Daily Amount of the Product Requied by Customer}}.$$

This calculation enables understanding of production at a glance. For example, if takt time is 1 minute, we should see a product moving past every minute. This understanding allows for quick countermeasures to get the line moving properly again (Monden, 1993).

2.2.21 Work Sequence

The work sequence is the standard operations routine or the order in which the work is done in a given process and represents the current best way known to accomplish the task. At Toyota, pictures and drawings depicted how to do the job right with such information as proper posture, how the hands and feet should move, how to hold tools, and critical quality and safety issues (Monden, 1993).

2.2.22 In-Process Stock

In-process stock or standard quantity of work in process is the minimum number of unfinished work pieces required for an operator to complete the process. Work cannot progress without this certain number of pieces on hand (Monden, 1993 & Dennis, 2002). The standard quantity held should be kept as small as possible because this will reduce holding costs as well provide a visual control for checking product quality because defects are more evident (Monden, 1993).

2.2.23 Standard Operations Sheet

The standard operations sheet is used to standardize work at Toyota. This sheet contains the following items: cycle or takt time, operations routine or work sequence, in-process stock levels, net operating time, positions to check product quality, and positions to pay attention to safety (Monden, 1993).

2.2.24 Charts Used to Define Standardized Work

There are three common charts used to develop standardized work which are the production capacity chart, standardized work combination table, and standardized work analysis chart (Japanese Management Association, 1989 & Dennis, 2002).

Production Capacity Chart

This chart determines the capacity of machines in a process. Production capacity for a given machine is calculated by the following formula:

$$\text{Capacity} = \frac{\text{Operational Time Per Shift}}{\text{Process Time} + (\text{Setup Time} / \text{Parts Produced Between Setups})}.$$

Setup time represents the time required to change from machine setting to another. Figure 2.12 shows a production capacity chart for an automotive punch press.

Manager	Foreman	Standardized Production Capacity Sheet	Part No. 12375-79543		UnitType: 22L	Section: 533 543		Name: Suziki Sato	
			Part Name: Intake Manifold		No. of Units				
Process No.	Process Name	M/C No.	Basic Operation Time			Tool Changes		Capacity	Comment
			Manual Time	Auto Time	Time to Complete	Interval between changes	Time Taken		
			Min Sec	Min Sec	Min Sec				
1	Machining of Attaching Face	MIL 1754	3	25	28	100	1'00''	965	
2	Drilling Bolt Hole	DR 2524	3	21	24	1000	30''	1148	
3	Tapping of Threads	TP 1102	3	11	14	1000	30''	967	
4	Quality Check		5		5			5520	
		Total	14						

-Operation time=460 minutes per shift (27,600 seconds)

Figure 2.12: Production Capacity Chart
Source: Dennis, P. (2002). *Lean Production Simplified.* Portland, OR: Productivity Press.

For example, the capacity of the drilling machine in Figure 2.12 would be calculated as follows: $\frac{27{,}600 \text{ seconds}}{(24 + 30/1000)} = 1{,}448.5$ parts per shift.

Standardized Work Combination Table

This chart shows: work elements in sequence, time per work element, operator and machine time, and interactions between operator and machine and other operators.

An example, shown in Figure 2.13 breaks down the movements of the operators and relates them to machine time. It helps with kaizen that is discussed in Section 2.2.14 (Dennis, 2002).

Dept. Group Oper.	From: Pick Skin (end of mastic)	Date: Nov 11/06	Qty. per shift: 150	Hand work / Machine time / Walking
Welding Snell Body R.Rr Door	To: Pick/Weld Crash Bar	Signature:		

No	Work Element	Element Time: Hand work	Element Time: Mach-ine	Element Time: Walk-ing
1	Pick Skin (end of Mastic)	1	/	2
2	Load Skin to Hem Machine	1	/	1
3	Pick Sub-assembly	2	/	1
4	Install Sub-assembly	6		3
5	Pick Fr. Skin	2	49	/
6	Load Fr. Skin	2	/	2
7	Pick Rr. Skin	2	/	/
8	Load Rr. Skin	2	/	1
9	Pick Rr. Door Inner	1	160	/
10	Install Weld Not	2	/	/
11	Load Assy Jig	9	/	1
12	Pick fram & Side Hinge	3	/	/
13	Install Frame & Side Hinge	9	/	1
14	Load Hinge Side Jig	7	/	/
15	Weld Sub-Assy & Hinge Side	61	/	/
16	Pick Weld/Crash Bar	14	/	2

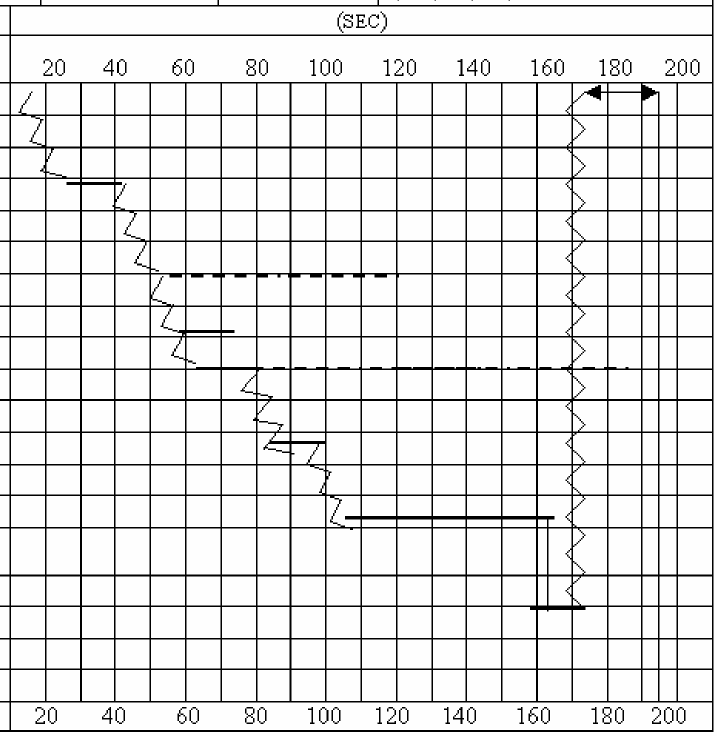

Figure 2.13: Standardized Work Combination Table
Source: Pascal, D. (2002). *Lean Production Simplified.* Portland, OR: Productivity Press.

Standardized Work Analysis Chart

Standardized Work Analysis Charts contain information that can be used to help rationalize the process and layout. These charts should also be used to train workers because they contain the work layout, process steps, and the expected amount of time required, critical quality and safety issues, and standardized work in process stock. Figure 2.14 depicts the typical format for a standardized work analysis chart.

Tact Time: 117 sec	Cycle Time: 138 sec		
Elements of Operation			
Element		Work Time	Walk Time
1	Pick Skin (end of mastic)	1	2
2	Load Skin to Hem Machine	1	1
3	Pick Sub-assembly	2	1
4	Install Sub-assembly	6	3
5	Pick Fr. Skin	2	/
6	Load Fr. Skin	2	2
7	Pick Rr. Skin	2	/
8	Load Rr. Skin	2	1
9	Pick Rr. Door Inner	1	/
10	Install Weld Nut	2	/
11	Load Assembly Jig (2 brackets)	9	1
12	Pick Frame and Hinge Side	3	/
13	Install Frame & Hinge Side	9	1
14	Load Hinge Side Jig	7	/
15	Weld Sub-assy & Hinge Side	61	/
16	Pick Weld/Crash Bar	14	2

Operation Name: R Rr. Door

Operation Number: #1

Revision Date:	Signature	Keypoint	Job Element

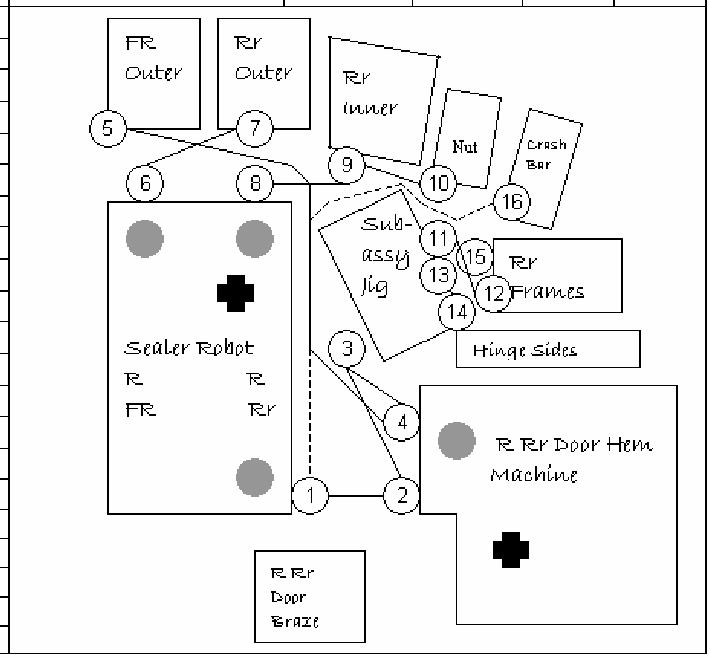

Figure 2.14: Standardized Work Analysis Chart
Source: Dennis, P. (2002). *Lean Production Simplified.* Portland, OR: Productivity Press.

2.2.25 Standard Operational Procedure or Job Element Sheets

Another essential element of standardized work is a standard operation or job element sheet, which contains all the job elements. A job element is the minimum number of actions required to advance in a process. Job element sheets are quick one page snap shots that define: actions making up the job element, rationale, pictures and photos highlighting key points, and a revision record (Dennis, 2002). This sheet is the final step in standardizing an operation at Toyota where the standard operating sheet must also contain: cycle time, operations routine, standard quantity work in progress, net operating time, positions to check quality, and safety issues (Monden, 1993). Figure 2.15 provides an example of this sheet given by Monden in his *Toyota Production System* second edition.

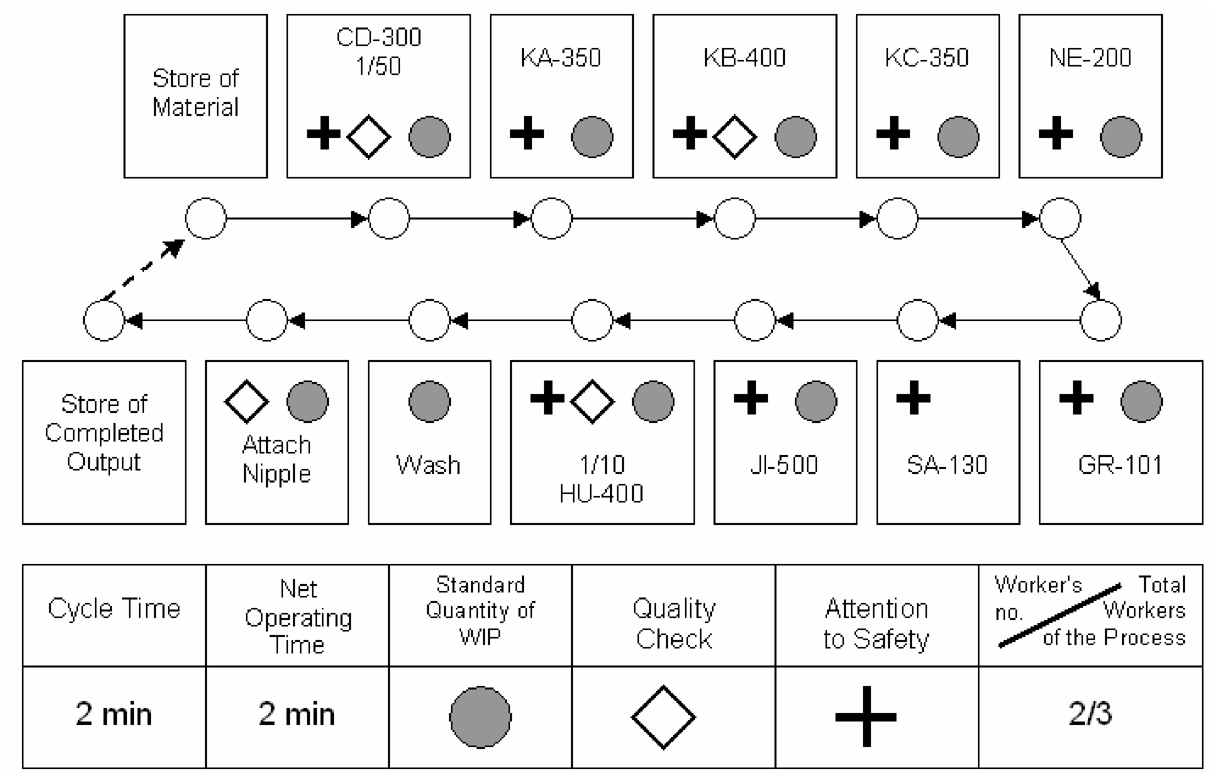

Figure 2.15: Standard Operations Sheet
Source: Monden, Y. (1993). *Toyota Production System: An Integrated Approach to Just In Time.* Norcoss, GA: Engineering & Management Press.

Standard operation sheets should be displayed in plain view of each worker in order to be used as a visual control for management. The sheets serve as guidelines for each operator to keep his work routine, for the foreman or supervisor to check to be sure each operator is following standard procedures, and to allow management to evaluate the supervisor's ability (Monden, 1993). The goal of standardized work is kaizen. Therefore, standard work needs to continually change in order to improve upon the current process. If the standard procedure remains the same for a long time, management could infer that the supervisor is not attempting to improve the process (Monden, 1993).

2.2.26 Just-in-Time Production

Just in Time (JIT) production means producing the right item, at the right time, and in the right quantity. Anything else is muda or waste, which was discussed at the beginning of Chapter 2. JIT consists of many other lean tools such as: kanban (card or signal), heijunka (production leveling), SMED or quick machine changeovers, visual management as discussed in section 2.1, and having a stable process which is a benefit of many different lean tools such as 5s, TPM, and standardized work (Monden, 1993).

2.2.27 Kanban

Kanban is the Japanese word for card or communication. Kanban as applied to lean manufacturing is a stocking technique using containers, cards and electronic signals to make production systems respond to real needs and not predictions and forecasts. A kanban is a major component of JIT production. Three types of kanbans are mainly used: 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 request the delivery of the supplier is product (Monden, 1993). Figure 2.16 provides a visual depiction of the kanban pull system (Vatalaro & Taylor, 2003).

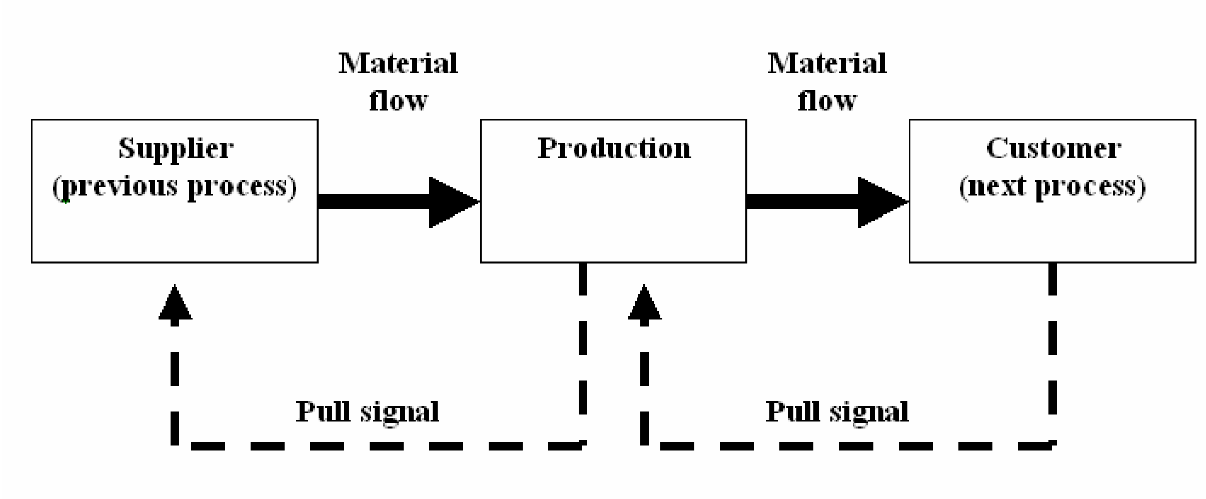

Figure 2.16: Kanban Pull System
Source: Vatalaro J. & Taylor, R. (2003). ***Implementing a Mixed Model Kanban System: The Lean Replenishment Technique for Pull Production.*** **Portland, OR: Productivity Press**

In order to achieve JIT production, Toyota specifies that certain rules in regards 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 convened 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 & 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 required by the system.

$$\text{Number of Kanbans} = \frac{\text{Daily Demand} * (\text{Order Frequency} + \text{Lead Time} + \text{Safety Time})}{\text{Container Quantity}}$$

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 & 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:

$$\text{Run Line} = \frac{(\text{Daily Demand} * \text{Order Frequency})}{\text{Container Size}}.$$

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 & Taylor, 2003). Value Stream Mapping is defined in Section 2.4.

2.2.28 Supermarkets

A 'supermarket' is a kanban stock point. 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. 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 & Taylor, 2003).

2.2.29 Production Leveling, Smoothing or Heijunka

Heijunka or Production Smoothing is Toyota's means for adapting production to variable demand by distributing the production volume and mix evenly over time. Production leveling also determines the schedule of personnel, equipment, and materials (Dennis, 2002). The goal is to have as little quantity variance in the production line as possible. At Toyota, there are two Phases of the leveling process: smoothing the total production quantity and the smoothing of every model's production quantity (Monden, 1993). The goal is to produce the same amount of products every period.

Figure 2.17 shows the analysis of the two Phases of Toyota's production smoothing (Monden, 1993). The first phase is the adaptation to monthly demand changes during a year, and the second is the adaptation to daily demand changes during a month. Monthly planning does the first phase and daily job dispatching does the second phase. The daily scheduling is where kanbans are used to activate the pulling system (Monden, 1993).

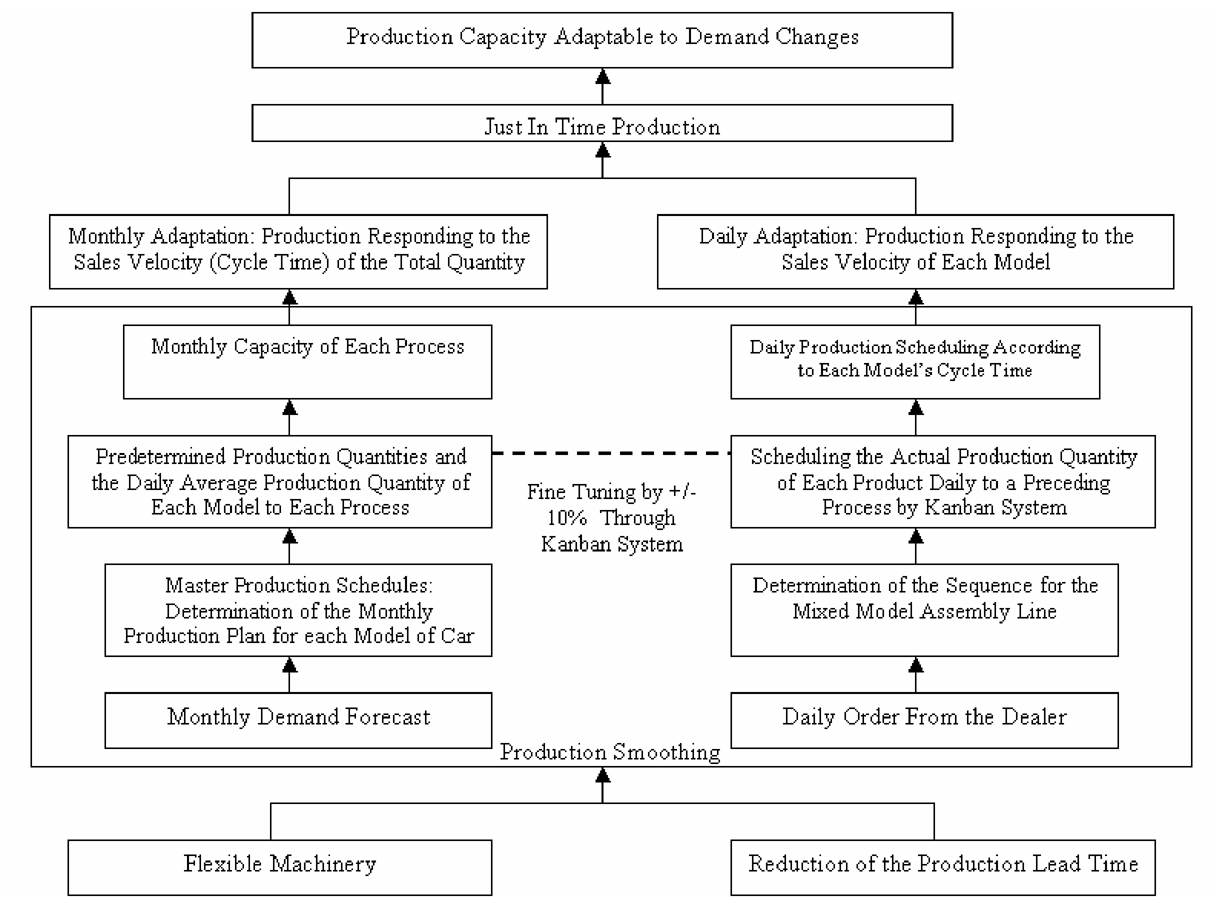

Figure 2.17: Framework of Toyota's Production Smoothing
Source: Monden, Y. (1993). *Toyota Production System: An Integrated Approach to Just In Time.* Norcoss, GA: Engineering & Management Press.

2.2.30 Cellular Manufacturing

Cellular Manufacturing, or cellular layouts, group machinery and processes into work center, or work cells, which produce similar products or styles or products with similar requirements. Unlike traditional functional layout, dissimilar machines are grouped together. These work cells are arranged in relation to each other so that material flow is optimized or a one piece flow is created. Figure 2.18 depicts a work cell using one piece flow.

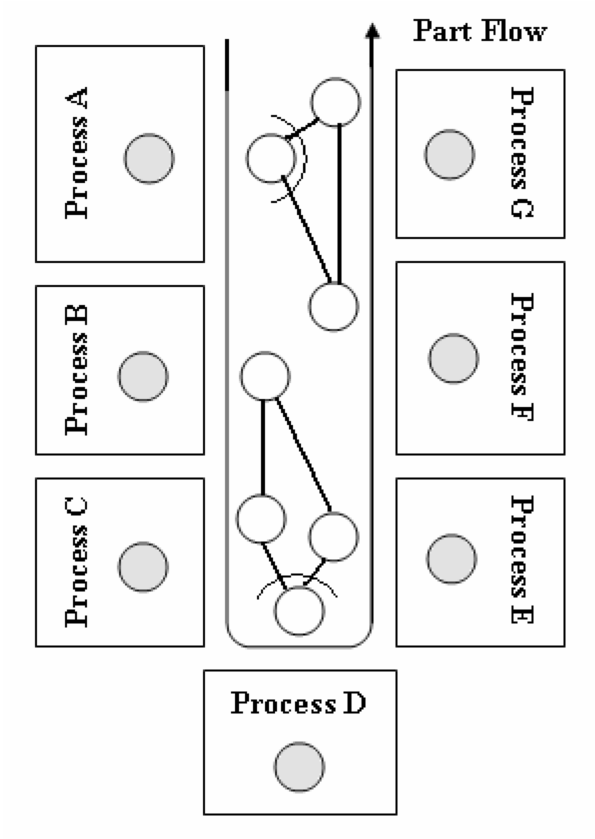

Figure 2.18: U-shaped One Piece Flow Cell
Source: Liker, J.K. (2004). ***The Toyota Way.*** **New York: McGraw-Hill.**

This technique combines the flexibility of a process layout with the efficiency of a product layout. The benefits of 'one piece flow' are better quality, more flexibility, higher productivity, better utilization of space, improved safety, improved morale, and reduction of in process inventory (Liker, 2004).

2.3 State of Knowledge

Upon reviewing various sources in the literature, this research was able to identify twenty-four lean tools. These tools have the common goal of improvement but address different areas of business and manufacturing. However, many of the benefits and uses of these tools overlap. Figure 2.19 lists twenty-four of the tools identified by this research in a conceptual model constructed based upon the review of the many tools of lean presented in the literature review. The six circles represent six major groupings of methods and categories, which are Policy Deployment, Just in Time, Visual Management, Standardized Work, Quality Methods, and Kaizen or Improvement Methods. The other tools listed on the model were categorized and placed in the circle in which they fit best. This model attempts to showcase how the different tools interrelate and interact, by their overlap within the model, towards the ultimate goal of lean, which is customer satisfaction. Other published models were found in Phase I of this research and are presented in Section 4.1.2.

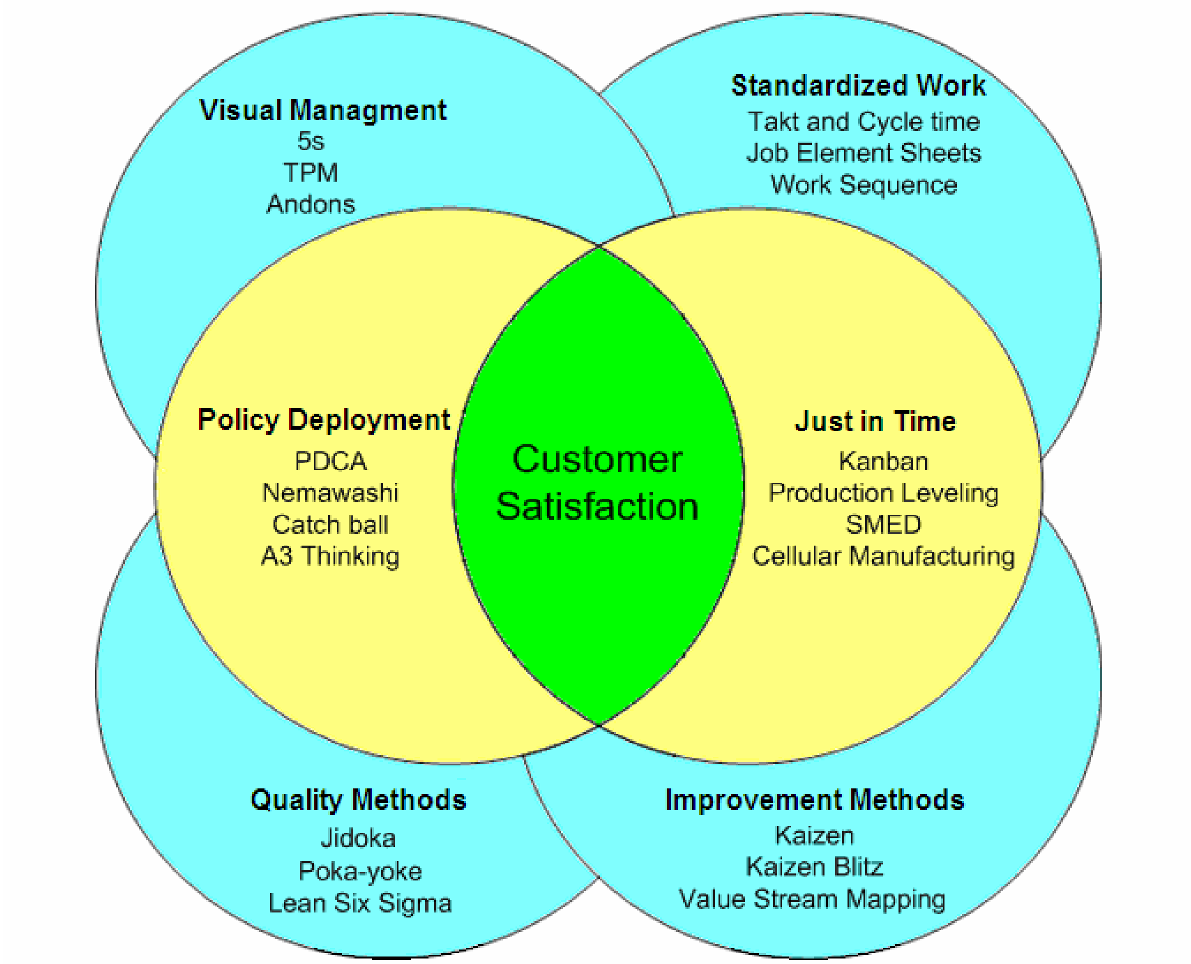

Figure 2.19: Conceptual Model of Lean Tools and Principles

The Toyota Production System and lean manufacturing tools and principles have been studied by scholars and benchmarked by companies in a vast variety of industries. However, many manufacturers struggle to adopt lean philosophy because they find it difficult to achieve in practice (Womack, 1996, Henderson & Larco, 1999 & Dennis, 2002). Meier has outlined some indicators of successful lean implementation: quick and obvious problem recognition, creating a sense of urgency regarding system reliability, and consistent application of lean thinking in all areas (Meier, 2001). In the 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. The capital intensity of spinning, weaving, and finishing often requires producers to schedule machines continuously. Because setup times are time-consuming and expensive, companies prefer to run long lengths of material for weaving and finishing which is in contrast to the apparel sector where styles change frequently and new styles are constantly created (Abernathy *et al.*, 2000). However, there have been various textile companies that have published their experience with lean in the form of journal and magazine articles and white pages. Such companies include: Alice Manufacturing, Joseph Abboud, Absecon Mills, and National Textiles. The experience of these companies is presented in Chapter 4 of this research.

3 Methodology

The previous chapter reviewed the literature concerned with all the different lean manufacturing practices in order to develop an understanding of the various lean tools and their application. This chapter describes the purpose and objectives of this research project, as well as the methodology this study followed to accomplish its objectives.

3.1 Research Objectives

Four research objectives where used in this study to help construct the road map presented in Chapter 5. These objectives are as follows:

RO1: Determine the extent of lean methods and tools used in various industries outside of textiles

RO2: Define which lean manufacturing tools are being utilized in US textile companies' business strategies

RO3: Determine a hierarchy, if any, for implementation of lean tools according to the application or situation

RO4: Develop a means for a textile company to gauge where their organization stands in terms of lean in comparison with other companies

3.2 Research Design

The research was qualitative and used both primary and secondary data resources to approach the research problem in two phases. Secondary resources are data, which have already been collected for purposes other than the study at hand, but will help to identify solutions to the research problems (Malhortra, 2004). The primary data was created specifically to address this research problem and to reach the objectives of this research (Malhortra, 2004). A qualitative approach is one in which the research is based primarily on constructivist perspectives or participatory perspectives or both (Creswell, 2003). In this approach, the researcher collects open-ended or emerging data in order to identify developing themes within the data, as was done in this research. Qualitative research uses strategies of inquiry such as case studies, which were also conducted by this research (Creswell, 2003). Figure 3.1 is the conceptual framework in which this study followed where open-ended interviews were conducted; notes and observations from the interviews were compiled to form themes and categories, and these categories were then compared to the secondary information for validation.

A series of case studies were conducted in order to explore the implementation and application of certain lean tools in the textile industry. These lean tools were identified through Phase II of the research, which includes the company interviews. The company interviews revealed the lean tools being used by the sample of textile companies, which determined what lean tools were chosen for the case studies.

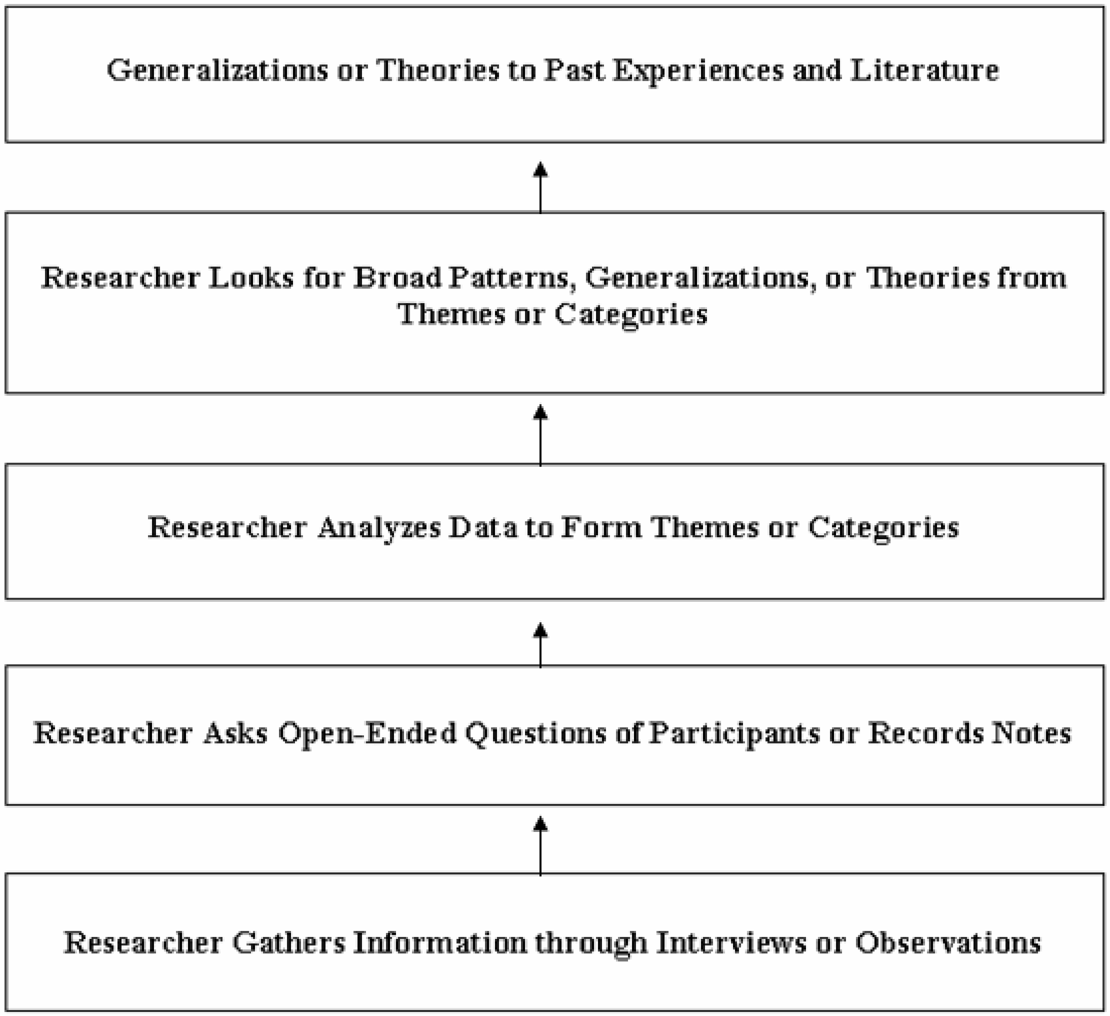

Figure 3.1: The Inductive Logic of a Qualitative Research Study
Source: Creswell, J.W. (2003). ***Research Design: Qualitative, Quantitative, and Mixed Model Approaches.*** **Thousand Oaks, CA: Sage Publications Inc.**

3.2.1 Phase I: Analysis of Secondary Sources

This research provides an understanding of the current state of the US textile industry in terms of becoming lean in comparison to other industries in the US. This objective was accomplished by an analysis of secondary sources.

- Literature: Textbooks, Trade Journals, and Scholarly Journals related to lean manufacturing, industrial engineering, and the textile industry;

- Professional Organizations, Economic Development Organizations, and Educational Institutions;
- Internet Search Engines; and
- Attended the Institute of Industrial Engineering conference on May 20th through the 24th of 2006 in Orlando, FL. to seek information about lean manufacturing, as well as a medium for networking with executives and scholars involved in lean manufacturing.

The results from Phase I were used to develop a structured interview instrument which was used in Phase II of the research (see Appendix A). This revealed the most relevant issues that companies face when implementing lean initiatives.

3.2.2 Phase II: Analysis of Primary Sources

Phase II analysis consists of open-ended interviews with eleven different textile companies, selected through a convenience sampling method. Textile companies were first contacted by phone, then by a follow up email in order to set up an initial face-to-face meeting at their facility. These interviews and plant visits helped to identify some of the best practices in lean manufacturing. These interviews provided information that can be used as a means for a textile company to gauge their progress towards becoming lean in regards to other organizations in their industry. This information was also used to create a lean tool matrix, which identifies specific common tools used among the interviewed companies. The information gathered through this process was also used to develop a series of case studies. The research from the case studies provides examples of problems companies have faced in which lean solutions have been applied. Two case studies centered on Value Stream Mapping, which revealed an easy to follow step-by-step checklist for using this lean tool.

Three other case studies detailed accounts of certain companies' strategies for 5s lean tool implementation. From this, a checklist for 5s implementation was also developed.

3.2.3 Phase I and II Combined

Based on Phase I and II results and analysis, best practice recommendation road map for implementing lean tools and principles were established and presented in Chapter 5. This road map consists of four parts: a recommendation model for implementing lean tools and principles, a summary of the barriers faced by the textile companies interviewed and suggested solutions to these barriers, and a 5s system and Value Stream Mapping best practice checklist based the case studies. Also included in Chapter 5 are the researcher's suggestions for future work in regards to researching the use of lean manufacturing in the textile industry.

4 Analysis and Results

Qualitative data gathered in Phase I and II are analyzed in this chapter. Recall from the previous chapter, Phase I of the research was an exploration of secondary sources and Phase II of the research consisted of the primary data collected through the eleven interviews with textile companies.

4.1 Phase I

In Phase I of the research, secondary sources were reviewed to compare lean manufacturing with other production systems in order to further compare lean manufacturing to other production approached that have been used by the textile and apparel industry. Conceptual Models of lean manufacturing were identified to address research objective number three. Textile industries and industries outside of textiles were benchmarked to investigate their accomplishments in terms of lean manufacturing, which address research objective numbers one, two, and four. Government funded organizations at both the state and community college level were examined, in order to determine to what extent an infrastructure of support for lean manufacturing education and training exists in both North and South Carolina.

4.1.1 Lean Compared with Other Production Processes

To better illustrate lean manufacturing, it has been compared with other existing production processes such as those discussed in the beginning of Chapter 2. Lean manufacturing is often compared with mass and craft manufacturing, which were defined in Chapter 2. Table 4.1 compares these three production approaches. Mass production is the method of producing goods in large quantities at low cost per unit. To remain profitable, mass production requires mass consumption (Womack *et al.*, 1990). In contrast, in craft production, production will not usually be initiated unless there is an order from a specific customer. All employees in the workshop work to satisfy the customer's needs. They understand the purpose of their work, and they have pride producing products with quality. These favorable attributes of craft production are lost in mass production (Womack *et al*., 1990).

Table 4.1: Comparison of Lean Manufacturing with Other Production Systems
Source: Houshmand, M. & Jamshidnezhad, B. (2002). Conceptual Design of Lean Production Systems through an Axiomatic Approach. Proceedings of ICAD 2002 Second International Conference on Axiomatic Design Cambridge.

Functions	**Craft Production**	**Mass Production**	**Lean Manufacturing**
Labor	Highly skilled craft workers	Narrowly & unskilled production workers	Multi-skilled production workers
Product	Customized products	High volume of homogeneous products	High volume with wide variety of products
Organization	Decentralized	Vertical integration or Decentralized divisions	Team oriented
Product Volume	Low	High	High
Unit Production Cost	High	Low	Low
Machinery and Tools	Simple, flexible tools	Single-purpose machines	Flexible automated machines
Ultimate Goal	Customer specification	Good enough	Perfection
Flexibility	High	Low	High
Inventory Turn	Low	Low	High
Inspection	100%	Sampling	100% source
Scheduling	Customer order	Forecast, push	Customer order, pull
Manufacturing Lead Time	Long	Long	Short
Batch Size	Small	Large with queue	Small, continuous flow
Layout	Process	Product	Product

Both mass and craft production have been used in the textile and apparel industries. Quick Response (QR) another production approach, identified in Chapter 2, has been used in the textile and apparel industry. Quick Response has some similarities to lean. For example, some of the objectives of quick response are to balance inventory and capacity to support customer requirements, develop strong supplier relationships, improve quality, shorten lead times, reduce cycle times, eliminate waste, continuous improvement, and building quality into the product rather than inspecting products for quality (Hodge, 2001). Quick Response like lean manufacturing uses the concept of modular or cellular layouts to improve in-process inventory flow between processes. However, some of the requirements for an organization to use quick response differ from that of lean. For example, QR requires a formal, integrated Enterprise Resource Planning (ERP) system (Hodge, 2001). Lean manufacturing does not require any type of integrated management system. Another way lean manufacturing differs from QR is that lean manufacturing provides a wide range of tools which are implemented on the shop floor by the workers themselves.

As mentioned in Chapter 1, the term lean is accredited to Womack's 1990 book *The Machine that Changed the World*, when the word was used to describe the Toyota Production System (Womack *et al.*, 1990). This book is one of the most widely cited references in operations management (Holweg, 2006). However, knowledge of Just in Time or the Toyota Manufacturing System had been available and studied in the United States and through out the world for over a decade prior (Holweg, 2006). The book was intended to present the TPS system as the operations element of Toyota's total management system and to show how the system linked the product development process, the supplier management process, the customer management process, and the organizational policy together. The concept of lean production was intended to describe how these five elements work together (Holweg, 2006). Often in literature the term lean production will be used synonymously with the Toyota Production System or Just in Time, because Just in Time is the term which was first used in publications by Toyota to describe their manufacturing system (Holweg, 2006).

4.1.2 Lean Conceptual Models

This section presents conceptual models of lean, which fulfill the third objective of this research by attempting to establish an order for applying lean tools to a process. The most recognized model, Toyota's House of Lean, attempts to classify lean tools as well as to show how these lean tools work together for the common goal of lean, which is growth through customer focus. Another model, Lean Production Principles, depicts production principles of lean, and this model includes Six Sigma, which was defined in terms of a statistics based improvement methodology in Chapter 2.

4.1.2.1 Toyota's House of Lean

Toyota's model, the House of Lean is shown in Figure 4.1. The foundation of the house is stability and standardization, which implies that these must come first before you can build any other part of the structure. Next, the walls of the house are Just in Time production and Jidoka or automation with human interaction. Recall, both of these terms were defined in Chapter 2. The heart of the house is the involvement of the workforce, which must be a flexible, motivated team continually seeking improvement. Finally, the goal of lean production is 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.

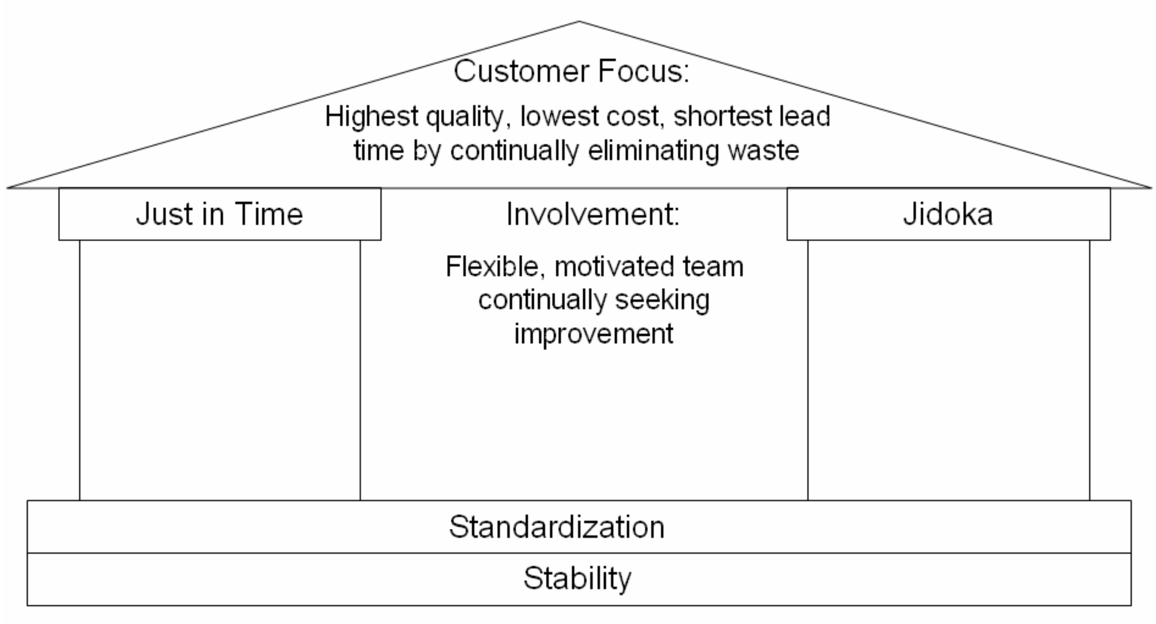

Figure 4.1:Toyota's House of Lean
Source: Dennis, P. (2002). *Lean Production Simplified.* Portland, OR: Productivity Press.

Pascal Dennis, formerly of Toyota, developed the model shown in Figure 4.2, which has added lean tools and activities to Toyota's House of Lean, which allows for a better understanding of how certain lean tools fit into that house and also how the tools overlap (Dennis, 2002).

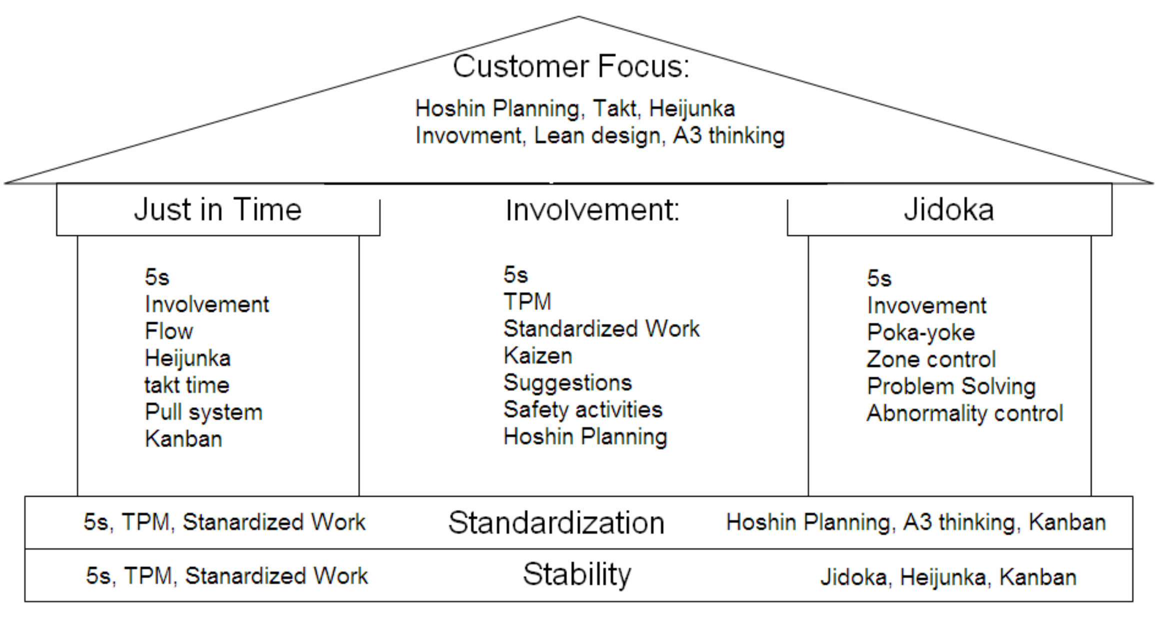

Figure 4.2: Lean Activities
Dennis, P. (2002). *Lean Production Simplified.* Portland, OR: Productivity Press.

This model also gives an idea of which tools can be used for what outcome. For example, to ensure stability of a process 5s, TPM, and Standard Work could be used, or to ensure standardization Standard Work, Visual Management, and Kanban could be used. Brief explanations of all of the lean teams found in Pascal's House of Lean can be found in Chapter 2 of this research.

4.1.2.2 The Lean Production Principles

The Lean Production Principles shown in Figure 4.3 present the aspects of a lean producer. Unlike the Toyota models, this model also includes Six Sigma quality, which is not part of the Toyota Production System, but as the model suggests, may be used as part of lean production (Henderson & Larco, 1999).

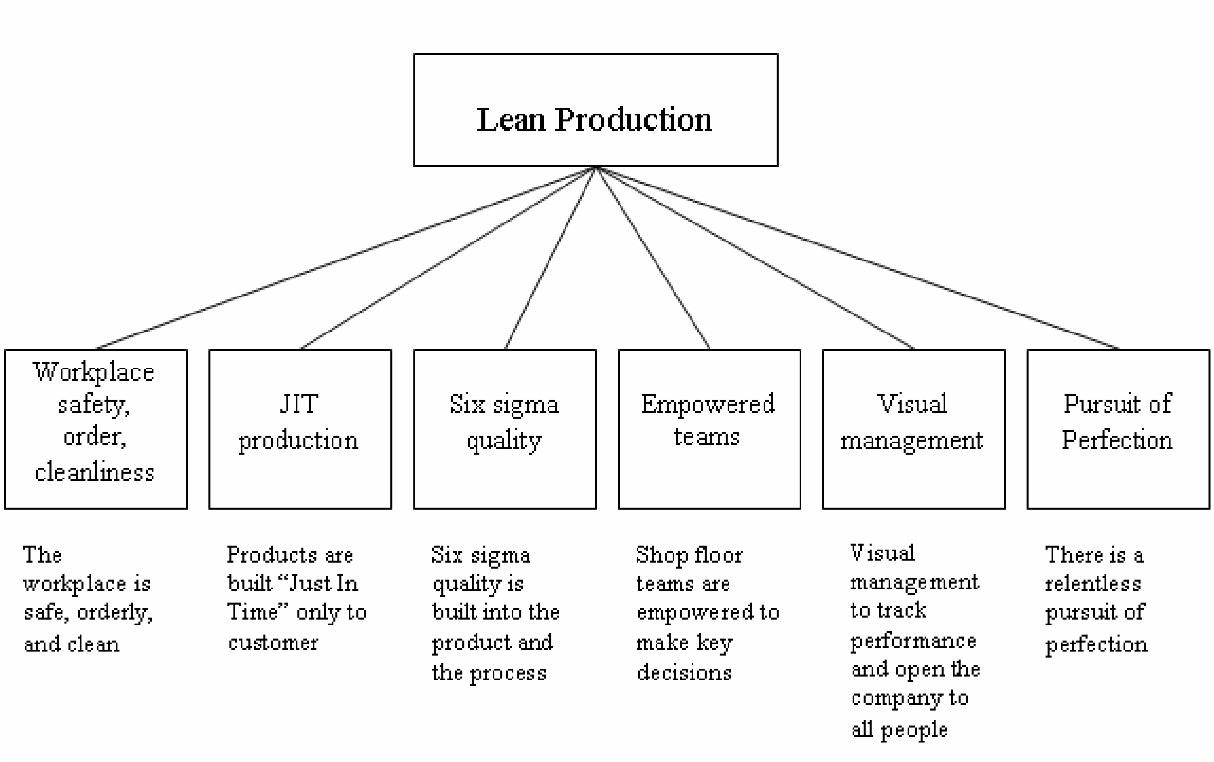

Figure 4.3: The Lean Production Principles
Henderson , B.A. & Larco, J.L. (1999). *Lean transformation: How to change your business into a lean enterprise* (1st ed.). Richmond Virginia: The Oaklea Press.

Both models present a conceptual framework for using lean techniques where the customer determines the highest priority for building products. Many other aspects of the models imply similar goals such as: safe, neat and clean environment, empowered workforce team, visual management and the pursuit of perfection. Both models suggest that the first step to lean implementation is to create a stable and reliable work environment for your employees with standardization using such tools as 5s or TPM. These tools should be followed by some sort of quality system whether it is Jidoka (workers identifying and correcting processing errors) or Six Sigma. These steps must be taken before JIT production and customer focus can be established in the operation. All these principles are vital to successful lean manufacturing implementation.

4.1.3 Lean Use in Textiles

As mentioned in Chapter 2, several textile companies using lean initiatives were identified through review of secondary sources such as interviews, white page papers, or case studies published. Such companies include: Alice Manufacturing, Joseph Abboud, Absecon Mills, and National Textiles. Exploration of these companies experiences address research objectives numbers two, three, and four.

4.1.3.1 Alice Manufacturing

Alice Manufacturing began using lean manufacturing principles as a way to cut costs, eliminate waste, and streamline processes (Dodge Reliance, 2006). The company's management knew of another company, Rockwell Automation who had successfully implemented lean with help from a consulting firm's program, and decided to use that firm as well. Alice Manufacturing was attracted to the firm because of the combination of lean and Six Sigma used in the program (Dodge Reliance, 2006). After using the new program for about six months, the company reported dramatic cultural changes that were positively contributing to the bottom line, because lean thinking had taught employees the value of their suggestions. The company has had many successful improvement projects, which were at the suggestion of shop floor employees. The company did not cite exact figures, but reported that they were more than halfway toward reaching the goal set when they had started the program (Dodge Reliance, 2006).

4.1.3.2 Joseph Abboud

Joseph Abboud, a US suit maker, began to use lean manufacturing principles as a way to lower the company's manufacturing costs to remain competitive against lower wage manufacturing in other countries (Langfitt, 2007). Before lean manufacturing was implemented, each employee stitched together all the pieces of a garment on their own. To implement lean, the company set up work cells, and they work in teams. Now fabric moves rapidly through production in a one piece flow. The employees are now trained in various skills, so if pieces back up at one operation, they can jump to another job. The company has found these changes to be successful. Last year, the factory increased production, and sales are up 15 percent (Langfitt, 2007).

4.1.3.3 Absecon Mills

Absecon Mills, located in New Jersey, began using lean manufacturing techniques as a competitive business strategy to increase customer satisfaction though better quality and shorter lead times (SMEAL, 2005). As a result of lean, Absecon Mills have reported the following benefits: a decrease in raw material and finished goods inventory, reductions in lead times, and improvements in quality (SMEAL, 2005).

4.1.3.4 National Textiles

National Textiles began their lean manufacturing implementation process in 2004 with the help of NC State University's Industrial Extension Service (IES) lean facilitators. The company's goal was to reduce waste and improve productivity (NCSU IES). Their first lean event yielded impressive results, including a 30% improvement in productivity and 40% cost reduction in that production area (NCSU IES). The project implemented such tools as 5s, Standard Work, and flow. The goal of the second lean event was to improve throughput and flow between two processes. To accomplish this goal the project conducted 5S activities, determined cycle time and takt time, and conducted a Value Stream Mapping exercise. The result was a reduction in the number of unnecessary set ups by 50% and a reduction of the set up time from 15 minutes to 5 minutes (NCSU IES).

4.1.4 Benchmarking

Lean Manufacturing has been used in a variety of industries outside of textiles. These experiences may provide insight for the textile industry, which meets the first objective of this research as well as the fourth. The 2006 Industry Week Census of Manufacturers reveals that lean is the most popular improvement method used by US manufacturers. The results of the poll showed that 40.5% of all manufacturers surveyed have adopted lean as their primary improvement method. This statistic increased nearly 5% from the 35.7% reported in 2005 (Blanchard, 2006). Table 4.2 shows the top improvement methods found in Industry Week's poll of over eight hundred companies in the US.

Table 4.2: Census of Manufacturers: Primary Improvement Method 2005 & 2006
Source: Blanchard, D. (2006). Census Of Manufacturers -- What's Working For U.S. Manufacturers. *Industry Week:* 255 (10).

Primary Improvement Method	2005	2006
Lean Manufacturing	35.7%	40.5%
Total Quality Management	15.9%	9.9%
Lean and Six Sigma	8.0%	12.4%
Other	7.0%	5.2%
Agile Manufacturing	4.4%	3.8%
Theory of Constraints[2]	4.0%	3.0%
Six Sigma	1.5%	3.1%
Toyota Production System	1.5%	3.1%
None	21.9%	19.1%

Among some of the improvement methods used by the manufacturers in this survey, there is some overlap. As mentioned previously in the chapter the Toyota Production System and the term lean can be used synonymously. So, the 3.1% using TPS can be added to the percentage using lean manufacturing as well as the 12.4% using a combination of lean and 6σ, which makes the statistic for US manufacturers using lean as an improvement method actually rise to 56%. Table 4.3 shows the results from the same survey in terms of the focus of their improvement method strategy whether it be quality, service, faster deliveries, etc. Table 4.3 shows the results from the same survey in terms of the focus of their improvement method strategy whether it be quality, service, faster deliveries, etc. It is not known if any textile companies participated either of these surveys.

[2] Theory of Constraints is a philosophy of management and improvement originally developed by Eliyahu M. Goldratt and introduced in his book, The Goal (Goldratt, 1992).

Table 4.3: Census of Manufacturers: Focus of Strategy 2005 & 2006
Source: Blanchard, D. (2006). Census Of Manufacturers -- What's Working For U.S. Manufacturers. *Industry Week:* 255 (10).

Focus Of Market Strategy (multiple responses possible)	**2005**	**2006**
High Quality	71.8%	70.1%
Service And Support	56.4%	54.3%
Total Value	39.0%	40.3%
Fast Delivery	35.3%	32.3%
Customization	32.4%	28.9%
Low Cost	26.5%	27.1%
Innovation	21.6%	24.9%
Product Variety	14.1%	16.2%
None Of These	0.2%	0.3%

4.1.4.1 Lean Strategies Benchmark and Best Practices in Lean Reports

A *Lean Strategies Benchmark Report* was conducted by the Aberdeen Group, which is a global consulting and research firm. This study was conducted to determine what type of lean improvements companies were most concerned with achieving. The report was based on survey data from 275 manufacturing executives across several industries. The study found that continuous improvement and the elimination of waste were top concerns of most lean manufacturers (Aberdeen Group, 2004). The study found that over seventy percent of the manufacturers surveyed were leveraging lean philosophies, lean techniques, and supporting technology solutions to eliminate waste, simplify processes, and continuously improve all aspects of their organizations.

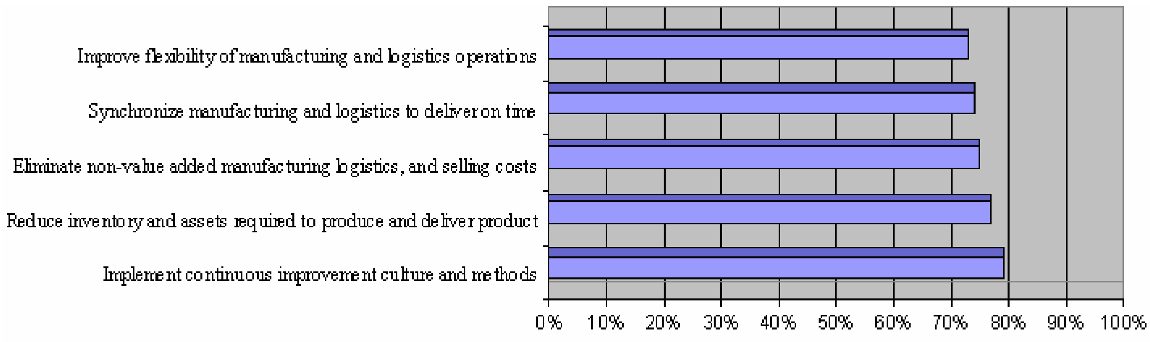

Figure 4.4: Top Five Lean Enabled Business Strategies
Source: Aberdeen Group. (2004). ***Lean Strategies Benchmark Report.*** **Retrieved: January 19, 2007 from** **www.aberdeen.com**

Figure 4.4 shows that continuous improvement culture and methods were most frequently used highest among the companies in Aberdeen's study, followed by reducing inventory and assets required to produce and deliver products, eliminating non-value added manufacturing logistics and selling costs, synchronizing manufacturing and logistics to deliver on time orders, and improve flexibility of manufacturing and logistic operations. All of these were issues chosen by at least 70% of all the companies.

In their 2005 report entitled *Best Practices in Lean*, Aberdeen interviewed the best in class companies from their 2004 *Lean Strategies Benchmark Report* to confirm if the lean techniques from the previous report still held top priority. The best in class consisted of the following businesses located throughout the world: Husqvarna, Integram, Leupold & Stevens, Mahindra & Mahindra Ltd., Marena Group, Pilkington North America, and WIKA Instrument Corporation. However, only one of these companies had any relation to textiles. This company supplies surgical compression clothing for medical applications. Table 4.4 lists each of the organizations in the Aberdeen study, their lean activities, and the value added to the company from lean. Most of these companies experienced reduction in inventory, work in progress, lead times, and cycle time. Many companies reported increases in customer satisfaction, including one company that reported an improvement from 80 to 95%. Several companies reported productivity increases; one company reported a productivity increase of 75%. Another one of the companies in this study reported that their on time deliveries increased from being somewhere between 45-50% to 95-99%. Pilkington North America increased sales by 52 million dollars in 45 days. Changes such as these have a positive effect on a company's profitability.

Studies such as these from Industry Week and the Aberdeen Group reinforce the hypothesis that there has been success achieved through using lean techniques in a variety of industries such as automotive, metalworking, airlines, healthcare, and retailing. Lean principles have proven not only to be applicable, but also to be successful at improving results. A number of different companies such as: Jefferson Pilot Financial, Dell Computers, JLG Industries, and Advanced Tooling Specialist Incorporated, have had interviews, white page papers, case studies published, or have been featured in journals.

Table 4.4: Aberdeen Study's Best in Class
Source: Source: Aberdeen Group. (2005). *Best Practices in Lean: The Momentum Builds.* Retrieved: January 12, 2007 from www.aberdeen.com

Best in Class	Lean Implementation Status	Value Achieved
Husqvarna, division of Electrolux; Turf Care Products Beatrice, Nebraska	Design, layout, process modeling for new facility; Kanban replenishment for service parts	• On-time shipping from 45-50% to 95-99% • Reduced WIP 50%. • Floor space savings 12% • Cycle time reduced 50% • Productivity up 10%
Integram, division of Intier, Automotive supplier seating assemblies St. Louis, Missouri	Less than 5 years; newly overhauled factory; automated control network supports work cell production	•Reduced manufacturing cycle time from 10 hours to 8 hours • Productivity up 20%
Leupold & Stevens, Precision optical equipment for firearms industry Beaverton, Oregon	Less than 5 years; hybrid manufacturing environment; Kanban supermarket for semi-finished; customer demand signals directly scheduled	• Delivery times from 4 weeks to 3 days • Lead times from 4 weeks to 3 weeks • Inventory reduced 50% • Work orders and purchase orders administration reduced 25% to 50%
Mahindra & Mahindra, Ltd. Farm Equipment Division Mumbai, India	Less than 5 years; partial manufacturing to support major lines; Lean supply chain from customer to manufacturing to supplier	• Customer service up from 80% to 95% • Inventory from \$120M to \$40M • Transportation reduced 50%
Marena Group, Inc. Surgical compression clothing for medical industry Lawrenceville, Ga.	Less than 5 years; factory floor implementation drum-buffer-rope for lower demand items; Kanban supermarket for high volume	• 2 week lead time reduced to only 1 day • Work-in-process inventory cut by 50%
Pilkington North America Multi-tier automotive, glass products Toledo, Ohio	Mature Lean manufacturer; added work cell and factory scheduling; integrated customer demand signals	•Increased sales by \$52M in 45 days • Daily throughput up from 8,000 to 17,000 • Machine utilization from 52% to 90%
WIKA Instrument Corp, Pressure and temperature gauges for industrial use Lawrenceville, Ga.	Less than 5 years; factory floor implementation with drum-buffer-rope for precision items	• Lead times cut from six weeks to five days • Revenue has risen 55% • Productivity is up 75%.
Unnamed – leading multi-tier automotive supplier integrated seating assemblies	Mature Lean manufacturer; work cell and factory scheduling; integrated customer demand signals	• 100% on time delivery • Inventory turns increased > 20%
Unnamed – major defense contractor Electronic guidance systems for defense industry	Less than 5 years; DOD requested significant production ramp-up in wake of September 11	• Manufacturing cycle from 60 to 18 days •Inventory turns increase 6-7 fold • Work-in-process decreased 70%

4.1.4.2 *Jefferson Pilot Financial*

Jefferson Pilot Financial is a full service life insurance and annuities company. Rising customer expectations had led to an increase of new insurance products, product complexity, and costs for the company. The introduction of specialized niche competitors with lower premiums and faster handling of policies were forcing Jefferson Pilot to both improve service and reduce costs. In late 2000, the company began a lean implementation. From the advice of a consulting firm, the company appointed a five-person team supported by the consulting firm's lean experts to reengineer operations according to the principles of lean production (Swank, 2003).

One important improvement was to place linked processes near one another. Under the company's old system, work groups were located by function. For example, employees who received applications and employees who sorted them worked on different floors, which made the process take days. After the application receivers were placed next to the sorters, the files were transferred between the groups in a matter of minutes (Swank, 2003). The work flow was smoothed by applying the concept of "takt" time. To satisfy demand, ten applications needed to processed per hour; therefore the takt time was one application every six minutes. Each work element was timed, and a baseline time was established for each element by determining how quickly an untrained person could do it, and then the employees where challenged to make improvements and create shorter baseline times. As workers found ways to cut unnecessary tasks, the minimum number of employees required for completion of all steps was determined (Swank, 2003).

Another key lean improvement was displaying hourly productivity rates along with the company's expectations. These numbers were displayed on large white boards so that all employees could see. These displays were effective for recognizing success and encouraging the team to set new performance records (Swank, 2003). Hoshin kanri, or policy deployment, was also implemented. Now, the metric for the CEO's performance is the ratio of the company's total acquisition expenses to the value of new paid premiums. As productivity increases, the acquisition expense eventually decreases. Employees are evaluated on the number of applications he or she inputs per hour evaluates an employee inputting applications, and the input team's manager is assessed on the hourly number of applications the team inputs. This way the CEO's success is directly linked to each worker's productivity. This method has spread accountability and rewards throughout the company, instead of just at the very top (Swank, 2003).

These initiatives have delivered impressive results. The company cut the average time from receipt application to issuance of a policy in half, reduced labor costs by 26%, and trimmed the rate of reissues due to errors by 40%. These outcomes contributed to a 60% increase in new annualized life premiums in just two years. Positive results are being recorded in other departments as the company deploys lean techniques across the whole organization (Swank, 2003).

4.1.4.3 Dell Computers

In August 1996, Dell Computer’s stock was selling at about $20 per share. After reorganizing their supply chain, one year later, there stock was selling for $148.75 per share (Henderson & Larco, 1999). Dell Computers continues to grow and are currently the number one personal computer seller on the Internet. The reason is that Dell now ships computers with factory-installed, customer specific hardware and software to the customer’s door in about a week or two. Dell produces only to consumer demand. Dell is able to do this through the set up of their supply chain. Once the order is placed uses multiple suppliers for all the components, that way if one supplier cannot supply the component another will (Friedman, 2005). To keep pace with changing demand, Dell must do extensively collaborate with its suppliers working with them on process improvements and demand/supply balancing. For example, if Dell discovers that so many customers have ordered notebooks that its supply chain will run short on a particular product, a signal will automatically be relayed to the marketing department and tell all the operators taking orders. The operators will then tell the callers that for the next hour that they are running specials on upgrades from the notebook in which the component part supply is low and give the callers an incentive to choose something else (Freidman, 2005).

4.1.4.4 JLG Industries

JLG is a supplier of aerial work platforms, industrial man lifts, and material-handlers. Their headquarters are in Central Pennsylvania, but they operate manufacturing and distribution facilities throughout the world. JLG's customers place orders with them as well as several of their competitors. The order is accepted from the first company that is able to fulfill it. The slower manufacturers are then left with partially completed product and no customer demand, adversely effecting inventory levels and profitability (Infor, 2005). To ensure that they could win orders, JLG would stockpile raw materials and component inventories. This was a problem for the company. So, JLG implemented lean manufacturing practices.

JLG created a continuous flow environment with visual queues and kanbans to trigger orders on the shop floor. They used shop floor data collection to ensure the timeliness and accuracy of the information being fed to their primary planning system. Also programs were implemented to streamline the creation of manufacturing and purchase orders, which further simplified the kanban process. The final stage was to create a system to track and estimate kanban usage and to anticipate and accommodate seasonal demand (Infor, 2005). These improvements have reduced JLG's lead times from 88 days to 8 days. Inventory has been reduced dramatically, and old warehouses have been converted to production lines. As a result of their lean initiatives, JLG Industries has been recognized as one of "The 10 Best Run Manufacturers in America" by Industry Week Magazine (Infor, 2005).

4.1.4.5 Advanced Tooling Specialists, Inc.

Advanced Tooling Specialists, Inc. (ATS) designs and builds tools for the thermoform, metal stamping, ductile iron trim die, wire EDM, and custom machining industries. Before lean implementation, on-time delivery was a significant problem. They had to expedite many projects. Between busy cycles there were not enough projects for their workers. The company needed a scheduling system that would streamline processes and utilize manpower in the most efficient way possible (Infor, 2004). ATS's implemented a "pull" versus "push" based scheduling system that uses market demand to activate work on the shop floor. The new scheduling system dramatically reduced lead times, which increased their on-time deliveries. The new scheduling system also improved productivity and profitability, and enhanced customer service. The company experienced almost immediate improvements. In the second month after implementation, ATS saw a record bottom line and had a record first quarter as a result, and the company expects these profit margins to continue (Infor, 2004).

4.1.4.6 Benchmarking the Toyota Production System

Toyota is one of the world's most studied companies; their production system has been benchmarked by researchers, journalists, and executives, because Toyota has repeatedly outperformed its competitors in quality, reliability, productivity, cost reduction, sales and market share growth, and market capitalization (Spear, 2004). Although companies have adopted lean techniques in many diverse fields, it has been suggested that few manufacturers have successfully imitated the system or are anywhere near Toyota in terms of lean (Spear & Bowen, 1999, Spear, 2004 & Liker, 2004). The article “Decoding the DNA of the Toyota Production System” suggests that the reason that so many companies are not successful when using lean is that observers of the systems at Toyota often confuse the tools and practices of lean that they see on plant visits with the system itself. In his book *The Toyota Way,* Liker presents a “4 P Model of the Toyota Production System” and lies out fourteen principles a company should use to have success with lean manufacturing (Liker, 2004).

The article Decoding the DNA of the Toyota Production System is based on a four year study of more than forty plants in the United States, Europe and Japan some of which were using some sort of lean systems while others did not. The article suggests that the reason that Toyota has been so successful is that the company uses a rigorous problem-solving process that requires a detailed assessment of the current state of affairs and a plan for improvement, which is actually an experimental test of the proposed changes. There are four rules that guide the design, operation, and improvement of every activity, connection, and pathway for every product and service at Toyota (Spear & Bowen, 1999). Toyota teaches the scientific method to workers at every level of the organization. The article insists that it is these rules, not the specific lean practices and tools that form the essence of Toyota's system (Spear & Bowen, 1999).

Rule 1: All work should be specified as to content, sequence, timing, and outcome. This exactness is applied to the repetitive motions of production workers, and to all the other activities of all people regardless of their functional specialty or hierarchical role (Spear & Bowen, 1999). New operators at a typical US plant will be trained by experienced workers, who teach by demonstrating what to do. An experienced worker might be available to help a new operator with any difficulties. However, this system allows for considerable variation in the way each employee does the work. Variation translates into poorer quality, lower productivity, and higher costs and restricts learning and improvement in the organization because the variations hide the link between how the work is done and the results (Spear & Bowen, 1999). At Toyota's plants, all employees follow a well-defined sequence of steps for a particular job. Therefore it is instantly clear when they deviate from the specifications. Since the deviation is immediately apparent, workers and supervisors move to correct problems right away and determine how to change the specifications or retrain the worker to prevent a recurrence. Even complex and infrequent activities are designed according to this rule. This rule forces employees to test hypotheses through action. Performance of the activity tests two hypotheses: first if the person doing the activity is capable of performing it correctly and, second, if performing the activity actually creates the expected outcome (Spear & Bowen, 1999).

Rule 2: Every connection must be standardized and direct, unambiguously specifying the people involved, the form and quantity of the goods and services to be provided, the way requests are made by each customer, and the expected time in which the requests will be met (Spear & Bowen, 1999). For example, when a worker makes a request for parts, the supplier is specified, as well as the number of units required and the time the parts should be delivered. Kanban cards and andon cards set up direct links between the suppliers and the customers in Toyota plants. In most US plants, requests for materials or assistance often take a complex route from the line worker to the supplier by means of an intermediary, and any supervisor can answer any call for help because a specific person has not been assigned. The disadvantage of that approach is that when something is everyone's problem it becomes no one's problem (Spear & Bowen, 1999). At Toyota a worker encountering a problem is expected to ask for assistance at once, and a designated assistant is then expected to respond immediately and resolve the problem. If the problem cannot be resolved in a very short period of time, that failure immediately challenges the hypotheses of this customer-supplier connection for assistance. Constantly testing the hypotheses keeps the system flexible, making it possible to adjust the system continually and beneficially (Spear & Bowen, 1999).

Rule 3: All production lines at Toyota have to be set up so that every product and service flows along a simple, specified path (Spear & Bowen, 1999). That path should not change unless the production line is redesigned. When production lines are designed in accordance with Rule 3, goods and services do not flow to the next available person or machine but to a specific person or machine. If for some reason that person or machine is not available, this is seen as a problem. The stipulation that every product follow a simple, specified path doesn't mean that each path is dedicated to only one particular product, because each production line at a Toyota plant typically accommodates many types of products (Spear & Bowen, 1999). The third rule doesn't apply only to products; it applies to services as well. In some of Toyota's plants, this pathway for service or assistance is three, four, or five links long, connecting the shop floor worker to the plant manager. This third rule goes against the conventional understanding of production lines and pooling resources, where as a product or service is passed down the line, it goes to the next machine or person available to process it further. By requiring that every pathway be specified, rule three ensures that an experiment will occur each time the path is used. Rule three, like rules one and two, enable Toyota to conduct experiments and remain flexible and responsive (Spear & Bowen, 1999).

Rule 4: Any improvement to production activities, to connections between workers or machines, or to pathways must be made in accordance with the scientific method, under the guidance of a teacher, and at the lowest possible organizational level (Spear & Bowen, 1999). Shop floor workers make the improvements to their own jobs, and their supervisors provide direction and assistance as teachers. If something is wrong with the way a worker connects with a particular supplier within the immediate assembly area, the two of them make improvements, with the assistance of their common supervisor. When changes are made on a larger scale, Toyota ensures that improvement teams are created consisting of the people who are directly affected and the person responsible for supervising the pathways involved. In the long term, the organizational structures of companies that follow the Toyota Production System will shift to adapt to the nature and frequency of the problems they encounter (Spears & Bowen, 1999).

Spears and Bowen suggest that the insight that Toyota applies in its underlying principles rather than specific tools and processes explains why the company continues to outperform its competitors and recognizing that TPS is about applying principles rather than tools enables companies that in no way resemble Toyota to tap into its sources of success (Spears, 2004). The research of Spears and Bowen found no other company that had all the rules of the Toyota system; however the researchers concluded that if a company dedicates itself to mastering the four rules and using lean tools to instill those rules into the minds of the workforce, it has a better chance of replicating Toyota's outstanding performance.

Liker agreed with Spear with regards to the observation that most companies who had been implementing lean had not seen the success that Toyota has achieved operating under this system. Liker suggests that the reason for this is that the companies have embraced the tools of lean, but do not understand the underlying concepts which make all the tools work together. The author states that the reason that Toyota has acquired such success with lean tools and quality improvement methods such as: just-in-time, kaizen, one piece flow, jidoka, and hejunka is due to the fact that the company basis for using these tools is a deeply ingrained business philosophy based on understanding people and human motivation. It is this philosophy which has lead to Toyota's ability to cultivate leadership, teams, and culture, to devise strategy, to build supplier relationships, and maintain a work environment dedicated to learning and improving (Liker, 2004). *The Toyota Way* describes fourteen principles, which the author suggests are the foundation of Toyota's manufacturing system. The fourteen principles of the "Toyota Way" which Liker explains in his book are as follows:

- Principle 1: Base management decisions on a long-term philosophy, even at the expense of short-term financial goals,
- Principle 2: Create process flow to surface problems,
- Principle 3: Use pull systems to avoid overproduction,
- Principle 4: Level out workload, heijunka,
- Principle 5: Stop when there is a quality problem, jidoka,
- Principle 6: Standardize tasks for continuous improvement,
- Principle 7: Use visual control so no problems are hidden,
- Principle 8: Use only reliable thoroughly tested technology,
- Principle 9: Grow leaders who live the philosophy,
- Principle 10: Respect, develop and challenge people and teams,
- Principle 11: Respect, challenge and help suppliers,
- Principle 12: Continual organizational learning through Kaizen, and

- Principle 13: Go see for yourself to thoroughly understand the situation (Genchi Genbutsu[3])
- Principle 14: Make decisions slowly by consensus, thoroughly considering all options, then implement improvements rapidly

The fourteen principles were combines to form Liker's "4 P model of the Toyota Way," which is depicted in Figure 4.5. Liker suggests that the true power of lean manufacturing is the continuous improvement culture needed to sustain the tools, methods, and principles, and that within the 4 P model most companies are only "dabbling" at the process level (see Figure 4.5). The author claims that companies who do not adopt the other 3 Ps will not have the ability to sustain the improvements that they make at the process level. Liker's model suggests that in order for lean concepts to work in any organization the base of the improvements must be the cultural change to long-term thinking, which establishes an environment of continuous improvement (Liker, 2004).

[3] Genchi Genbutsu means "go and see for yourself" instead of hearing or reading about a problem and then making a suggestion for improvement (Liker, 2004).

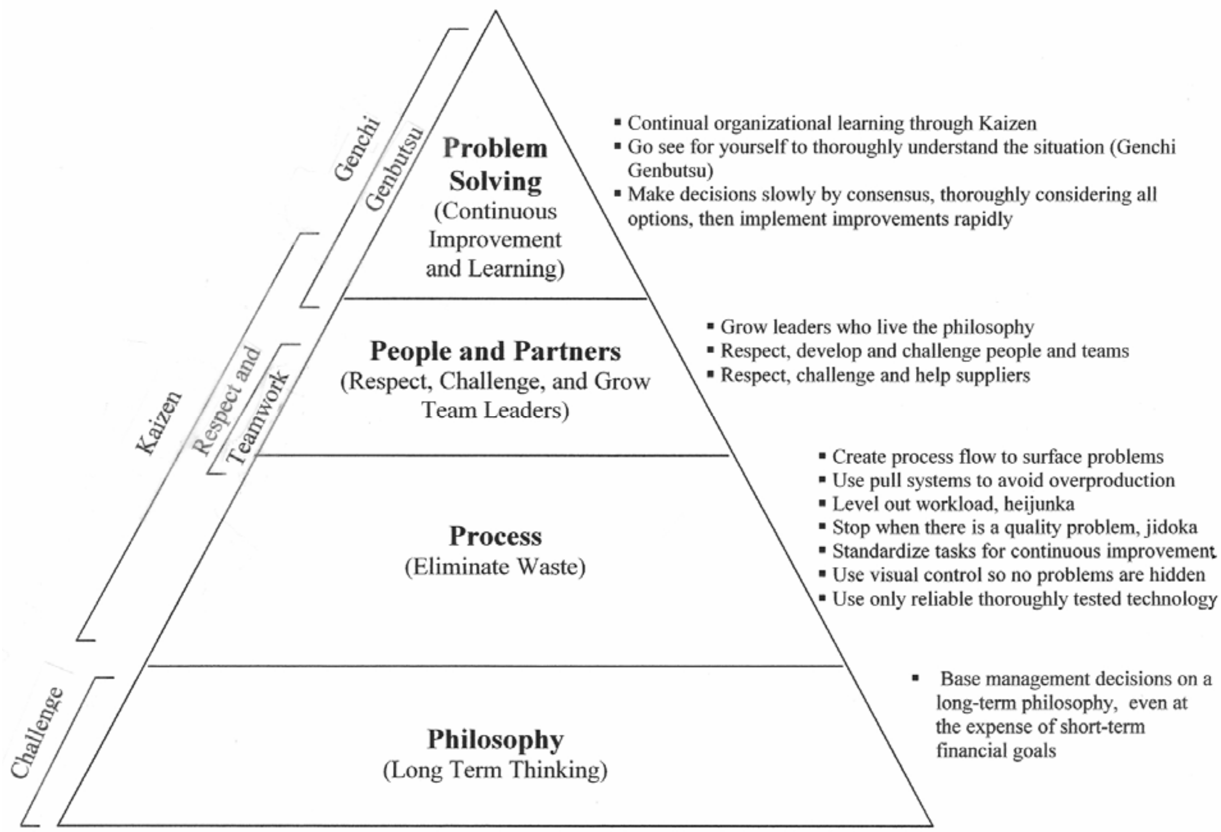

Figure 4.5: 4 P Model of the Toyota Way
Source: Liker, K.L. (2004). *The Toyota Way.* New York: McGraw-Hill.

Both Liker in his *The Toyota Way* and Spear in his “Decoding the DNA of the Toyota Production System” suggest that most companies are not successful when implementing the tools of lean manufacturing or the Toyota production System because they fail to have enact the cultural changes requirement to continue finding and sustain improvements that have been made by applying the tools and methods of lean. This secondary data has not only addressed objectives three and four of this research which are to determine a hierarchy, if any, for implementation of some lean tools versus others according to the application or situation, and help in developing a means for a textile company to gauge where there organization stands in terms of lean in comparison with other companies. This data has also given insight leading to recommendations of best practices for implementing lean manufacturing tools and principle in a textile specific environment, which are expressed in Chapter 5 of this research.

4.1.5 Evaluating Plants, Rapid Plant Assessment

In order to provide means for the development a textile company to gauge its lean development against other companies, a secondary resource was found which provided a baseline for evaluating the companies which were to be toured as part of the primary data collection method used in Phase II this research. The Rapid Plant Assessment (RPA) process was developed by R. Eugene Goodman and has been used in more than 400 tours of over 150 operations since 1998. Exploration of this method for evaluating a company's leanness was also used in this project to help address research objectives one and four which were as follows: to determine extent of methods and tools use in various industries outside of textiles in the U.S and to develop a means for a textile company to gauge where their organization stands in terms of lean in comparison with other companies. The RPA process consists of two assessment tools for teams performing plant tours. One is the RPA rating sheet presents eleven categories for assessing the leanness of a plant, Figure 4.6 and the other is a RPA questionnaire, Figure 4.7 provides twenty associated yes-or-no questions to determine if the plant uses best practices in these categories.

Rating Leanness

Plant ________________

Tour date ________________

Rated by ________________

RPA Rating Sheet

Team members use the RPA rating sheet to assess a plant in 11 categories on a scale from "poor" (1) to "excellent" (9) to "best in class" (11). The total score for all categories will fall between 11 (poor in all categories) and 121 (the best in the world in all categories), with an average score of 55. Factors to consider to rate a plant in each category are described in this article; a more detailed list of evaluative factors appears on the Web at www.bus.umich.edu/rpa. The rating sheet also guides team members to questions in the RPA questionnaire (opposite) that relate specifically to each category.

When plants are rated every year, the ratings for most tend to improve. Ratings are usually shared with plants, and motivated managers first improve their plants in the categories that receive the lowest ratings.

Ratings

Categories	*Related questions in RPA questionnaire*	poor *(1)*	below average *(3)*	average *(5)*	above average *(7)*	excellent *(9)*	best in class *(11)*	**category score**
1 Customer satisfaction	1, 2, 20							
2 Safety, environment, cleanliness, and order	3–5, 20							
3 Visual management system	2, 4, 6–10, 20							
4 Scheduling system	11, 20							
5 Use of space, movement of materials, and product line flow	7, 12, 13, 20							
6 Levels of inventory and work in process	7, 11, 20							
7 Teamwork and motivation	6, 9, 14, 15, 20							
8 Condition and maintenance of equipment and tools	16, 20							
9 Management of complexity and variability	8, 17, 20							
10 Supply chain integration	18, 20							
11 Commitment to quality	15, 17, 19, 20							

Total score for 11 categories ________
(max = 121)

Figure 4.6: Rating Leanness Worksheet
Source: Goodman, R.E. (2002). Read a Plant- Fast. *Harvard Business Review. 80*(5), 105-113.

The eleven categories for rating a company using RPA are as follows:

- Category one is customer satisfaction. This is evaluated by what degree workers in the plant know who their customers are, both internal and external. Plant tours should be welcomed, with an overview of the plant and its layout, workforce, customers, and products. Quality and customer satisfaction ratings should be prominently posted (Goodman, 2002).
- Category two is safety, environment, cleanliness, and order. The plant should be well lit, the air quality good, and noise levels low or earplugs provided and used throughout noisy area. A visual labeling system should clearly mark inventory, tools, processes, machinery and flow (Goodman, 2002).
- Category three deals with evaluating visual management systems. Evidence of a good visual management system uses tools such as kanban scheduling and color-coded production lines as well as unmistakably posted work instructions, quality goals, customer satisfaction goals, and productivity charts, and maintenance records where anyone can see the current operating conditions and performance of the company (Goodman, 2002).
- Category four is an evaluation of their scheduling system. Plants should rely on a single "pacing process[4]" for each product line and its suppliers (Goodman, 2002). This process controls the speed of production for all the activities, since demand for product is triggered by demand at the next. This will keep inventory from building up, improve quality, and reduce downtime because production lines will not be kept waiting for parts (Goodman, 2002)

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[4] Pacing process is the process which sets the pace for production for the entire value stream, usually should be located near the consumer end of the value stream, for example shipping (Rother & Shook, 2002).

- Category five is use of space and movement of materials. Ideally, materials are moved only once, over as short a distance as possible, in efficient containers. Production materials should be stored near point of use, not in separate inventory storage areas. Tools and setup equipment should be kept near the machines. And the plant should be laid out in continuous product line flows rather than in shops dedicated to particular types of machines (Goodman, 2002).
- Category six is levels of inventory and work in process. A quick read on inventory can be obtained by watching a production line and counting the inventory at each work center. In most cases, no more than a few minutes' worth of inventory should be found by a work center at one time (Goodman, 2002).
- Category seven is teamwork and motivation. Motivated employees are easily seen during a brief tour. Also look for posted safety and environmental measures, posters showing quality and productivity improvements, or charts that describe problem-solving and employee empowerment procedures (Goodman, 2002).
- Category eight is condition and maintenance of equipment and tools. The purchase dates and costs should be shown on the side of machinery and maintenance records posted. Workers should know as much as possible about the machines in order to plan for preventive maintenance. This also signals to employees that management cares about the product, and that they have invested in keeping the operation running smoothly (Goodman, 2002).
- Category nine is management of complexity and variability. This is how the operation manages, controls, and reduces the complexity and variability it faces in its industry (Goodman, 2002).

- Category ten is supply chain integration. To keep costs low and quality high companies should work closely with a relatively small number of dedicated and supportive suppliers. A rough estimate of the number of suppliers can be determined by looking at container labels (Goodman, 2002).
- Category eleven is commitment to quality. If employees are proud of their quality program, they usually give it a name and post banners displaying the vision or mission statement, business objectives, and metrics showing achievements to date. Both short- and long-term goals for the plant and team as well as statements about internal and external customer requirements, production schedules, work instructions, productivity levels, incoming and outgoing quality, scrap and rework levels, attendance, vacation schedules, safety, and levels of employee training-should be displayed at each work center. Also, find out what the plant does with its scrap. Better plants will call attention to scrap. Product development time and costs are also indicators of quality. There should be specific goals set for both at the beginning of this process (Goodman, 2002).

After the tour, all those who participated in the visit to the plant should share their observations and impressions and develop the plant's leanness rating. Each of the n categories should be rated on a scale from "poor" (1) to "excellent" (9) to "best in class" (11). Only one plant in each industry, worldwide, deserves a rating of eleven. Then the ratings are totaled. The sum will be between 11 and 121, with the average plant score is 55 (Goodman, 2002). Both the RPA rating sheet and the RPA questionnaire should be used to rate leanness of a plant.

RPA Questionnaire

The total number of yeses on this questionnaire is an indicator of a plant's leanness: the more yeses, the leaner the plant. Each question should be answered yes only if the plant obviously adheres to the principle implied by the question. In case of doubt, answer no.

		yes	no
1	Are visitors welcomed and given information about plant layout, workforce, customers, and products?	○	○
2	Are ratings for customer satisfaction and product quality displayed?	○	○
3	Is the facility safe, clean, orderly, and well lit? Is the air quality good, and are noise levels low?	○	○
4	Does a visual labeling system identify and locate inventory, tools, processes, and flow?	○	○
5	Does everything have its own place, and is everything stored in its place?	○	○
6	Are up-to-date operational goals and performance measures for those goals prominently posted?	○	○
7	Are production materials brought to and stored at line side rather than in separate inventory storage areas?	○	○
8	Are work instructions and product quality specifications visible at all work areas?	○	○
9	Are updated charts on productivity, quality, safety, and problem solving visible for all teams?	○	○
10	Can the current state of the operation be viewed from a central control room, on a status board, or on a computer display?	○	○
11	Are production lines scheduled off a single pacing process, with appropriate inventory levels at each stage?	○	○
12	Is material moved only once and as short a distance as possible? Is material moved efficiently in appropriate containers?	○	○
13	Is the plant laid out in continuous product line flows rather than in "shops"?	○	○
14	Are work teams trained, empowered, and involved in problem solving and ongoing improvements?	○	○
15	Do employees appear committed to continuous improvement?	○	○
16	Is a timetable posted for equipment preventive maintenance and ongoing improvement of tools and processes?	○	○
17	Is there an effective project-management process, with cost and timing goals, for new product start-ups?	○	○
18	Is a supplier certification process – with measures for quality, delivery, and cost performance – displayed?	○	○
19	Have key product characteristics been identified, and are fail-safe methods used to forestall propagation of defects?	○	○
20	Would you buy the products this operation produces?	○	○

Total number of yeses ______

Figure 4.7: RPA Questionnaire
Source: Goodman, R.E. (2002). Read a Plant- Fast. *Harvard Business Review. 80*(5), 105-113.

The plant's total score on the rating sheet and the number of yes responses on the questionnaire give you a fairly accurate assessment of a plant's efficiency (Goodman, 2002). The assessments on the rating sheet are particularly useful because the categories highlight broad areas of strength and weakness. The RPA system is a framework that was helpful in the evaluation of the plants visited in Phase II of this research. More information about the RPA method and the RPA database can be found in the article "Read a Plant- Fast," in the May 2002 edition of Harvard Business Review (Goodman, 2002).

4.1.6 Sources for Lean Education and Training

There are a number of different government supported resources available for companies and individuals in North and South Carolina who offer lean training. Both the North Carolina State Industrial Extension Service (IES) and the South Carolina Manufacturing Extension Partnership (SMEP) offer various courses and workshops such as: basic training in lean principles, lean for office/ administration, Value Steam Mapping, Quick Changeover or Set-up Reduction, Kanban, Kaizen, Visual Management, 5s, Total Productive Maintenance, Cellular Manufacturing, and Policy Deployment. Both the North Carolina Community College System (NCCCS) and the South Carolina Technical College System (SCTCS) offer courses, training, and certification in lean manufacturing and Six Sigma as part of continuing education and industrial development programs.

In North Carolina, there are Focused Industrial Training (FIT) programs at all fifty-eight community colleges whose purpose is to help businesses maintain their competitive edge through education, awareness, and training. The continuous improvement processes such as lean manufacturing and Six Sigma are very important tools to assist companies in remaining competitive. In plant industry training programs such as: Introduction to Lean Manufacturing, Total Productive Maintenance (TPM), 5s, Kaizen, Poka-yoke (mistake proofing), Six Sigma and Value Stream Mapping are available to manufacturing companies are available anywhere in the state. Textile Manufactures may qualify for funds available to the NCCCS through state legislature and may be able to receive training at little or no cost to the company (Glenn, 2007). Attached in Appendix B are detailed information about managing the cost of such training, available courses, and contact information for FIT directors at each of the colleges. In South Carolina, lean and Six Sigma training is available but varies between the sixteen technical colleges. Training can be provided by South Carolina Manufacturing Extension Partnership (SCMEP) instructors in a series of workshops held at particular colleges or on-site in manufacturing plants as a contract class on an as-needed basis. Training can also be provided in the form of faculty instructors or individual consulting firms (Bartanus, 2007). For example, Piedmont Technical College has a lean manufacturing instructor on faculty, while Greenville Technical College uses the George Group[5]. The workshops and on-site training programs include: Principles of Lean Manufacturing, Lean Office Tools, Value Stream Mapping, 5S Workplace Organization & Standardization, Total Productive Maintenance (TPM), Set-up Reduction, Quick Changeover (SMED), Kanban, Policy Deployment, Standard Work, and Cellular Flow. Textile Manufactures may qualify for government funding to help offset the cost of workshops and site training programs. Attached in Appendix C are costing data for these programs, information on how companies can qualify, as well as the contact information to the local workforce investment areas in South Carolina who distribute government funding.

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[5] The George Group specializes in Lean Six Sigma programs for manufacturing and service companies with expertise in training, consulting, and software, see www.georgegroup.com for more information.

4.1.7 Summary of Phase I Results

Based on Phase I, each research objective from Chapter 3 was addressed. Extensive use of lean manufacturing methods and tools used in various industries outside of textiles was uncovered. The use of lean manufacturing tools in US textile companies' business strategies was uncovered through review of textile companies published information about their lean experiences. Some hierarchy was determined for the implementation of some lean tools versus others according to the application or situation, through comparison of different author's conceptual models. Review of textile companies' published information about their lean experiences, benchmarking industries outside of textiles, and the identification of the Rapid Plant Assessment method helped provide information for a textile company to gauge where there organization stands in terms of lean in comparison to other companies. Based on the results from Phase I addressing the four research objectives, a questionnaire was developed that would further investigate those research objectives, as well as help develop a means for a textile company to gauge where they stand in terms of their lean development with regards to other companies. Also, results from Phase I helped to identified possible companies for the sample of US textile companies through contact with the Institute of Textile Technology, and Internet Search Engines.

4.2 Phase II

Phase II consists of the analysis and results of the primary data collected, which will be used to fulfill research objectives two, three, and four from the methodology of this research. A convenience sample was taken from the US textile industry to determine the intent of lean use in the textile industry. One major disadvantage of any convenience sampling technique is that the information collected from the sample may or may not be representative of the population as a whole. However, convenience sampling can still provide some fairly significant insights and be a good source of data in exploratory research such as in this project (Malhotra, 2004). Plant tours of the companies in this sample provided for best practice examples of lean principles observed during plant tours presented in Section 4.3. These interviews revealed that certain lean tools had extended use or interest among textile companies. Two of lean methods were chosen to be studied further through a series of case studies presented in Section 4.4.

4.2.1 Data Sources

Eleven textile companies were interviewed. Out of the eleven companies, nine facilities were toured for this research. Most companies were identified through the Institute of Textile Technology (ITT) and Industrial Extension Service (IES) at North Carolina State University. One company was found through an Internet search and was contacted by phone for an interview. These organizations were selected for their expertise and proximity; because of time and financial restraints the decision was made early on to only focus on companies located in North and South Carolina.

4.2.1.1 Institute of Textile Technology

The Institute of Textile Technology was the first source used to find components for the sample of eleven textile companies used in this research. This method is considered a convenience sample because the selection of units from the US textile industry was based on accessibility (Malhotra, 2004). At the Institute's Technical Advisory Committee, held in Spring and Fall 2006, the members of the committee were asked if they were interested in the project. Each company that relayed interest was contacted to set up a time for an interview and plant tour.

4.2.1.2 Industrial Extension Service

The decision to contact this organization was made through a convenience sampling technique called snowballing, or networking, in which the researcher asks participants in the study if they know anyone else who has had a similar experience or might be interested in participating in the research (Malhotra, 2004). During one of the Technical Advisory Committee meetings one member suggested that the Industrial Extension Service at North Carolina State University be contacted. The Industrial Extension Service (IES) is a government organization, which provides developmental solutions for engineering, manufacturing, energy, and technology issues for industries across the state of North Carolina.   Through contact with IES sixty-two companies were identified which had implemented some type of lean manufacturing technique or received education, sixteen of these were associated with the textile industry. One hundred percent of these remaining textile companies were contacted. Of those, 57% conveyed interest in participating in the study and having us to interview and tour their facility.

4.2.2 Interviews

Through contacts established through the Institute of Textile Technology (IIT) and the North Carolina State Industrial Extension Service ten companies based in North and South Carolina were selected as the sample for this research. One textile company using lean was found through an Internet search was interviewed via conference call to their facility in the Northeastern part of the United States. The companies interviewed produce textile products ranging from yarn to fabric: both woven and knit, and assembly cut and sew production.

Table 4.5 lists the eleven companies interviewed along with their area of manufacture.

Table 4.5: Interviewed Companies with Area of Manufacture

Company	Area of Manufacture	Size of Company
Company A	Performs spinning, warping, slashing, and weaving.	Small
Company B	Plant performs dyeing & finishing, slashing, warping, and weaving.	Large
Company C	Performs cut and sew operations to knit goods. Finished products are	Large
Company D	Plant performs spinning and warping operations which supply an internal	Large
Company E	Spins a diverse variety of yarns supplying only external customers.	Large
Company F	Plant performs spinning and knitting operations which supply an internal	Large
Company G	Performs warping, dyeing, weaving, knitting, and printing.	Small
Company H	Performs cut & sew, assembly, and distribution activities to	Medium
Company I	Performs warping, weaving, and finishing operations. Finished	Medium
Company J	Plant performs cut & sew, assembly, and distribution of a variety	Large
Company K	Performs cut & sew, and assembly of a particular type of product under	Small
*Company size: small, medium or large as indicated by companies own description given during the interview		

4.2.2.1 Company A

Company A performs spinning, slashing, warping, and weaving and produces a wide variety of items from draperies to denim, with capabilities to offer full package. Six members of upper management were interviewed: the president, three plant managers, and two operations managers. Company A began their lean transformation about two years ago in order to eliminate excess waste in one production area. The tools used thus far are 5s, Visual Management, Kaizen or process improvement activities achieved through team meetings, Standard Work, and Quick Changeover, which the company had recently began in the weaving department. The first tool used was 5s, as suggested by a local consultant, which worked with this company to facilitate 5s in one of their production areas. The company agreed that 5s was the right tool to start with in order to clean up and promote cooperation among the workers in the area. Quick changeover project was conducted to reduce set up time in another production area, but the company admitted that this project had not yet produced results, as the 5s project had. The company felt that they needed Standard Work to deal with changes in products and procedures. This company’s experience with 5s will be further explored later in Section 4.4.1 in the form of a case study. The process improvement team meetings that were established began as weekly meetings and then were phased out to bi-weekly meetings, which brought about increased communication among co-workers and supervisors as well as some improvement suggests (see Section 4.4.1). The company described their main barrier to lean implementation as cultural, explaining that getting support from everyone is difficult and that shop floor workers are often reluctant to make suggestions for improvements.

4.2.2.2 Company B

Company B is a large flooring manufacturer. The interview was conducted at a plant, which mainly produced high-end rugs and broadloom carpet. At this plant, the Director of Manufacturing, the Manager of Manufacturing Resources, the Manager of Rug and Broadloom Planning, and a Process Engineer who strongly supports the lean initiatives participated in the interview. The company had recently acquired another business and incurred some debt. In order to improve cash flow, the company realized they needed to reduce work in process inventory by lowering turn around times. Admittedly, raw materials are a high percentage of cost for the plant that was interviewed. Company B began implementing lean in the summer of 2005, when they benchmarked a manufacturer of file cabinets using lean techniques. The company consulted an outside source to conduct three lean information sessions in which about fifty employees from this location and twenty from another location participated. The sessions were also used to generate process improvement ideas from managers and employees. The plant that was visited in this research had created a Value Stream Map for one of their products. The company felt that the VSM was an important tool to be used to find problems in the product's value stream and also could help in conducting a cost savings analysis of the product family mapped. It should be noted that to participate in the information sessions, the hourly employees were brought in off their regular shifts and paid overtime if applicable. During the information sessions, the company observed that many of the hourly employees were more enthusiastic than the managers. There were twenty- two lean project suggestions for this plant agreed upon during the sessions.

These lean projects will be put into place according to the priority that managers have given them. The criteria used for choosing a project here is that initial projects were likely to be winners with tangible benefits. One of the top managers being interviewed stated that choosing projects that will be large successes initially will help everyone to buy into the system and believe that it will deliver results. The importance of basing project selection on a cost savings analysis was mentioned on more than one occasion.

There were barriers to lean implementation that this particular company noted during the interview. One of these barriers was a disconnection between manufacturing and marketing, sales, and product development. Manufacturing has done much to increase efficiencies to try to make higher quality products faster, but the other side of the business has not. One example of this was given during the interview. When sales notice that a particular color or style is a "dog," or does not sale well, that information is not relayed back to manufacturing and that product is still carried when it should be taken out of the product line and out of manufacturing. Another barrier was that some people always are intimidated by change, especially in a company like this were many of the supervisors are at the end of their careers. People can sometimes get in the mindset that if it worked for the last forty years it will keep on working for the next. However, Company B has already seen improvements such as streamlining their rug manufacturing process and creating smaller lot sizes as a result of their lean initiative. Also, the raw materials consumption has decreased and the company is working on reducing complexity by reducing the number of colors. Company B has plans of further implementing lean throughout their business and were considering additional lean projects, including 5s and Six Sigma.

4.2.2.3 Company C

Company C is large vertically integrated textile and apparel manufacturer whose main products are knitwear and intimate apparel. The people interviewed were a member from Strategic Capacity Planning, a member from the Lean Implementation team and the Director of Lean and Quality Management. Company C has a lean and quality division located at their Headquarters that visits each plant to help implement lean and control quality issues. The lean implementation at this company had begun as a grassroots effort by individual plant managers looking for ways to improve their operations. In 2002, a company wide initiative began to spread the methodology throughout the entire supply chain. They decided to start a pull system pilot in one designated plant. The company began to educate top executives, including the CEO, about lean in order to get commitment and endorsement to continue with the implementation. Company C used other industries to benchmark their success, such as Toyota in the automotive industry. A major part of this initiative was to eliminate the different divisions in the supply chain that had existed because the company had been divided according to sectors of the supply chain and also by product. The objective of corporate is to act as one organization working towards the same goal. As a result, the extent of lean implementation levels varies between the former divisions.

One former division in particular was the subject of this interview. The plants within had experience with many different lean tools: VSM, 5s, Visual Management, TPM, Standardized Work, Kaizen, Kanban, Quick Changeover, and Six Sigma. There was also a kanban system used for replenishment of items for one customer in particular, who had requested this. The company had found that the tools were more easily accepted by people working at the plant level, because they want to be competitive in order to keep their jobs from moving to another facility.

Company C also made the comment that VSM may not work in some textile mills because no improvements were made with them. In the interview, the point was made that the biggest barrier to implementing lean was the philosophy that the textile plant was a huge asset, so machines should not be left idle. However, “it does matter how much of something you produce, if it does not sell, then no money will be made,” was another point made in the interview. The focus should be to produce what is going to sell. Company C had experienced benefits from implementing lean techniques including a decrease in inventory of 50% even with continuous gains in demand, and a reduction in change over times from 1.5 days to only 45 minutes.

Company C is working towards implementing lean in all aspects of the supply chain, including finance, internal auditing, product development and design. The have created a pull replenishment system in their apparel division. The company has been working towards being lean for over four years at this point; however, the company executes interviewed still say they are in the early stages. They believe that their positive management team that is willing to try whatever it takes for the plant to remain running has helped the replenishment system become successful.

4.2.2.4 Company D

Company D mainly supplies knit fabric for automotive interior, but also produces polyester cloth for specialty and performance apparel. Company D began using lean to improve their efficiency. The company feels that lean principles are essential for staying in business as an automotive supplier and a means to become world class. The company established a corporate lean department which would serve all of their plants. A few of their manufacturing facilities have been using lean for several years now, but the plant where this interview had taken place had only been implementing lean principles for about one year. At this facility, their first lean initiative was 5s, which was implemented in their major manufacturing department and was spreading to other areas with the ultimate goal of having the entire plant using 5s eventually. The company has used Six Sigma for several years as well and has a trained black and/or green belt at each one of their facilities. Company D states that Visual Management, 5s, SMED, TPM, Standardized Work, Kaizen, Value Stream Mapping, Mistake Proofing, and Six Sigma are the tools that the particular plant visited had used so far, but the plant also had plans to implement a Kanban system.

Company D stated that 5s and Visual Management were an easy place to start because they can be applied anywhere. The company feels VSM is essential to their lean transportation because the tool points out the areas that need improvement and allows for prioritization of projects according to their impact. Company D further explained that you want to pick projects that have a high probability of success and will be easier to tackle especially in the initial Phases of lean. That way the improvements are visible and more people will "buy in." The company feels that different tools can be applied for different problems. For example, visual management helps with training issues or kanban systems help reduce inventory.

Company D pointed out that the biggest barrier to implementing lean was cultural and that many people are resistant to change. However, Company D believes that their lean journey is a continuous process and that change is inevitable in order to improve. They feel that there is no point where lean becomes ineffective and gave the example of Toyota who is constantly striving for perfection even in their supply chain where they have taken the initiative to help train their suppliers in lean so that Toyota has more control over the materials they are supplied. This particular plant where the interview took place expressed that they saw an increase in production of about 16% in a month's time after they had implemented production boards as part of a 5s lean initiatives.

4.2.2.5 Company E

Company E is a large producer of a diverse variety of yarn types for commodity consumption. Among those interviewed were a Vice President, the Six Sigma Manager and the 5s Coordinator. At Company E, the drive for lean implementation came from corporate. Company E first implemented 5s in their plants about one year ago after two employees attended a 5s seminar held at North Carolina State University. Company E used the help of a local consultant, who was later phased out when the program had developed. The company began by establishing a 5s training program which moved from plant to plant within the company. 5s teams were established at the plants, but the ultimate goal is to have every employee trained in 5s. Most plants in the company have modern automation with few employees. Therefore, it was not feasible to pull people off there job for very long periods of time to do 5s events. Thus, the employees on the 5s teams would be expected to complete their projects while on shift. One key component of this was ownership; someone had to take responsibility for the suggested project and that person became the facilitator for that lean team. The way that the company achieved this was to teach team members that the projects they come up with should make their jobs easier, with the motto, "work smarter, not harder." In order to make 5s implementation more widely accepted, the company tried to used vocabulary that everyone could understand, which was one barrier faced by the company. When there was an issue of a foreign language, pictures were used in addition to words. What enabled the 5s implementation to be such a success was that the plant managers and training facilitators have the same vision. Company E says that training is good, but "learning by doing" is even better. Projects are most successful in plants where managers work with employees, instead of keeping away from the project; this is also helpful in sustaining the improvements. Another barrier was that there would always be some people who do not want to change their old habits and would continue to "slack off," which creates some difficulty sustaining 5s. The plant toured used strong Visual Management to standardize and sustain improvements made by 5s in the form of icons, silhouettes, and text descriptions for tool storage areas.

Company E reports success from its 5s program since it began in 2004. The company revealed that their next step in the lean journey would be TPM implementation to work on machine reliability. Company E has had experience with other improvement methodologies such as Total Quality Management[6] and Six Sigma and found successful projects but admit that not everyone can use these tools because of the difficulty in understanding the statistics and the projects have a more narrow focus. Value stream maps were attempted but Company E said the tool was not helpful and was not right for them, because they felt that Value Stream Mapping did not show the projects or opportunities that needed to be worked on in their particular business.

[6] Total Quality Management is a management strategy which goal is to create an awareness of quality in all organizational processes, for more information see *Fundamentals of total quality management: process analysis and improvement* by Dahlgaard, Kristensen, and Kanji (1998).

4.2.2.6 Company F

Company F is a large producer of yarns and finished tubular fabric in large-scale quantities for knit apparel manufacturers. This company was acquired by a larger company which they had supplied. The plant was then pressed by corporate to implement lean in 2003. Corporate used the resources from IES to help train facilitators for different lean tool execution within plants. Company F has Kaizen Teams that meet for 30 minutes each week where they discuss lean projects, such as 5s, Total Productive Maintenance (TPM), Standardized Work, Quick Changeover, and Zone Control throughout the plant. Company F also uses "Gemba[7] walking" to promote awareness about what is going on at each process. Each new employee gets a lean handbook, which covers the basics of lean manufacturing in, easy to understand terms. The handbook's contains a quick definition of what is lean, gives a visual depiction of the company's philosophy, identifies the eight types of waste, and steps in problem solving.

The company began with 5s training and Visual Management projects such as labeling where particular items should be stored, which raw materials go into which products, etc. Next, this plant began working on Standard Work, which was said to be a mistake. The Lean Manufacturing Manager stated that beginning Standard Work before having reliable machinery was a mistake because Standard Work should not be established until the equipment is reliable; because you cannot ask an operator to do work that their equipment is not capable of completing. The way that they were able to maintain reliable equipment was to implement a TPM system.

[7] Gemba is the Japanese word for the place where work is done; therefore "walking the gemba" or "gemba walking" is walking around the workplace or taking time to observe the workplace (Womack & Jones, 2005).

The plant used Rapid Improvement events (see section 2.7.1), which were said to usually last about four days. During these events, operators working from the area (four to seven people) and the supervisor would become a team. The team's purpose was to evaluate the job work of the particular area and develop that area's standard work and standard instructions. Standard work was created from the time studies and observations performed by operators during these Rapid Improvement Events. The operators act as industrial engineers and this particular plant does not employ anyone under that job title. Standard Work and Standard Work Instructions were posted in each area for every job performed in that area, which included detailed step by step instructions in both English and Spanish with pictures of the movement or task to be performed.

Kaizen teams for continuous improvement were formed throughout the company, and they hold weekly meetings to discuss their area or zone. The purpose of these meetings is to continue to generate ideas and to address any problems in the zone. This is what is known in the company as zone control. Each week a different operator working in that area is responsible for holding the meeting, and at the close of every meeting safety is mentioned. This reinforces the ideas that safety is the most important aspect of the job. Because the Kaizen teams for zone control meet every week and new ideas are being generated, the lean tools are always being utilized. For example, during the plant tour a suggestion was made by an employee that the signs on some machines should be changed, because they hung down too far down and could damage material as it passed beneath. The employee suggested that signs which could stick to the machine be used rather than the ones which hung down, therefore would the new signs would not come in contact with the material as passed underneath.

The company representative pointed out that the success of implementing lean manufacturing techniques include getting commitment from top level executives, getting ideas from the workers, implementing standardized work and realizing that it is definitely a culture change. This company relayed a positive outlook towards their progress in becoming lean, but pointed out several times that “the results were not apparent overnight”. The Lean manufacturing Manager explained that it had taken over three years for the real impact of lean to reveal itself and that it was not over, and that the company felt that they still had a long way to go on their lean journey.

4.2.2.7 Company G

Company G is a small textile mill, with under 150 employees, producing woven and knit fabrics for a variety of end uses. Company G contacted IES for help with scheduling in one area of their business, which had at one time at least a six week back log for work in progress. In January 2006, an IES representative held a week long lean basics class with people working in that area. The purpose of this class was to improve the flow of materials through the area. The first lean concept which was applied to the area was 5s. Next, a Visual Management scheduling board was put in place which conveyed to the operators their daily tasks that needed to be performed and at what priority. The company experienced a 17% increase in throughput in that area as a result. It was then decided to try to replicate what had been done in this area within another area using the same concepts. In this new area after implementing 5s and a visual scheduling board, the company saw the back log disappear from that area. The representative from Company G explained that the biggest barrier to becoming lean in his experience was the culture against change. He explained that there were three different levels of buy in. Some people saw the benefits and were enthusiastic and willing to make it work for them. Others do not want to be bothered with learning anything else. A few just do not care. The operators who saw the benefits of lean have taken ownership of their area, and they make and maintain the improvements to their area. The Company has taken steps to further implement lean techniques such as Six Sigma training and VSM activities, which the representative interviewed believes will help identify problem areas in their process and determine their path forward in future improvements to the business.

4.2.2.8 Company H

Company H is an assembler and distributor of textile auxiliary products in the recreational outdoor market that are sold in big box retailers as well as specialty mom and pop stores throughout the United States. Company H was forced to begin importing some of their products to satisfy the demands of their big customers, which are continually demanding lower prices. In 2004, the company began to apply lean concepts to help reduce costs. Company H is successfully using 5s, Visual Management and has implemented work cells in their one area of their operations, which has improved process flow and reduced in-process inventory in the area. They trained 30 workers in lean by learning about 5s, Value Stream Mapping and Spaghetti Diagrams. They have tried constructing Value Stream Maps in the past, but Company H said that the concepts were too complex for some employees to understand. Also in 2004, Company H consolidated all their manufacturing facilities into one plant. This move gave the company the unique opportunity to set up their facility in a way that would improve the flow of production. They were able to create work cell and Supermarkets for heavily used components and raw materials in some areas, which prove to be working well for the company. One of the barriers Company H has faced with lean implementation was the resistance to change. Especially when designing the work cells, change management was required due to issues with workers comfortable in their old ways of working. Now they have competitions amongst the employees to see who can do the best and most work. Company H is currently working on becoming a make-to-order facility and the representative interviewed felt that they would continue to apply the concepts of lean and find more improvements to be made.

4.2.2.9 Company I

Company I supplies woven upholstery fabric under contract for the hospitality industry. Their facility is located in the northeastern region of the United States. Therefore, they were interviewed via conference call with the Executive Vice President. The company's operations include warping, weaving and finishing. The company was first exposed to lean manufacturing by two different sources simultaneously. The CEO went to a seminar were a company who had been successfully using lean for a number of years presented how they had gained a strong competitive edge in their industry through the use of lean. About the same time, one of the company's major customers who had been using lean for approximately five years had decided to limit their suppliers in order to develop stronger relationships within their supply chain. This customer proposed that Company I send an implementation team to their facility to be trained in lean.

The first project that was undertaken by the implementation team was to create a Value Stream Map with the help of the customer. This VSM examined the value added percentage of a core product, which makes up over fifty percent of Company I's business with this customer. The vice president stated that this experience of the customer offering to help their supplier really revealed the "nature of lean," which focuses on improving the entire supply chain, because, “you can only be as good as the materials you are supplied.” For example, Company I used to send a tractor trailer to this customer twice per week. Before it took Company I two to three days to fill up the trailer and a day to unload the shipment to the customer. Now Company I delivers daily to this customer where the product is unloaded and goes straight into production.

Company I has been implementing lean manufacturing principles throughout their operations since 2003. Currently, Company I uses the following tools VSM, Six Sigma, 5s, Visual Management, TPM, Kaizen, SMED (quick machine changeover), Supermarket, and Kanban. VSM exercises are repeated at least once a year and reveal the areas in which the kaizen group should address. The VSM gives the company the opportunity to evaluate their current state and prioritize improvement projects in terms of their impact. The Kanban system is used for their major yarn supplier, which makes up 25% to 80% percent of the raw materials that are in production at any given time. Company I was able to do this by creating a warping Supermarket containing warped in-process inventory with these yarns. There are about thirty different Kanban cards in this Supermarket, and five or six warps of each style are contained within. When any of these styles are doffed from the loom, the Kanban schedules a new warp to be made.

The representative interviewed stated that the company’s lean transformation has allowed for many improvements such as cleared for space for increased production and new business. Kaizen events revealed old outdated inventory where yarn had been bought for styles that did not sell. As a result, the Kanban system had no orders for it and it was not used. Salvaging this inventory had a negative effect for accounting, however the company feels that the freed up space will be worth more to the company in the long term. TPM has also been a struggle for the company due to the fact that it is hard to find trained loom mechanics in the area, and although the company used shadow boards and identifying marks and labels, a battle for cleanliness still exists. The company expressed other barriers to lean implementation such as the fact that over 80% of their workforce is Hispanic and speaks little to know English and it has been difficult to find a trainer who is bilingual. However, the company has been able to secure a grant through their states Manufacturing Extension Program for lean training. In this company's experience, they have gotten numerous improvement suggestions from managers and supervisors but few from the hourly workers. The company representative interviewed believed that this was because their hourly workers were not highly paid. They had other concerns that preoccupied their minds such as paying bills and feeding their families. The company also found that some managers especially those close to retirement, were prone to be resistant to change. The representative interviewed from Company I stated that he believed that it takes a long time for lean to become cultural and felt that his company needed a full time employee committed only to lean to provide leadership and promote an environment where everyone constantly encourages each other to strive for perfection.

4.2.2.10 Company J

Company J is a nonprofit organization whose purpose is to provide employment to persons with disabilities. The company produces various textile items under government contract. The operations performed by the company include quilting, cut and sew, packaging, and assembly. The company representative interviewed said that the company chose to implement lean principles as a mean to compete with the commercial and nonprofit contractors with whom they bid against for their government contracts. The company enlisted the help of IES for lean training and implementation assistance in 2005. All employees have gone through a basic lean training course. Company J has since worked with the following lean tools: VSM, 5s, Visual Management, TPM, Standard Work, Cellular Layouts, Six Sigma, Kanban, Supermarket and were in the process of planning a Plan Do Check Act (PDCA) training event at the time of the interview.

Company J has experienced many tangible benefits from their use of lean tools. In their cut and sew areas, work cells were set up to create a one piece flow of goods instead of the batch system they had used before. This improvement cleared 1500 ft^2 of flow space in the area, reduced the workers travel distance by 72 feet, reduced wasted materials, and increased output by 2% so, that the same amount of work which had been done in 10 hours could now be completed in 8 hours. The company used Kanbans to reduce their finished goods inventory, which is held in a Supermarket before shipping. This cleared up 40% more floor space, which was converted into another production area, and they were able to hire eight more people. Their order fill rate increased because of the Kanban system, which now acts as a checks and balances against their MRP system. Mistakes in inventory counting were reduced which resulted in the increase of filled orders from 91% to 98%. Company I conducted a VSM exercise in their office area that reduced copies by at least fifty pages per day. The representative interviewed stated that they had not experienced many barriers to implementing lean and that the workforce was generally enthusiastic about the changes being made in the facility. He explained that this might be due to the fact that the employees were first educated in the basics of lean before any changes were made. The majority of suggestions for improvements came from them.

4.2.2.11 Company K

Company K performs cut & sew, and assembly operations for a manufacturer of a particular type of military product under US government contracts and to foreign governments. The Vice President of the company first heard about lean manufacturing from a friend working in an industry outside of textiles. In February 2005, the company secured a grant for lean training, which enabled them to hold several basic lean training classes and held a Value Stream Mapping event. Lean needed to prove itself in this plant before a major investment could be made. With the help of a consulting firm, the company held an initial kaizen event and built a lean work cell for a product area which was already struggling. The improvements in this area were enough to get top management behind this company's movement to become lean.

Before the first work cell was introduced, this product area followed the batch system of production where large lots of product went through one operation and were then sent to wait in queue at the next operation. The goal was to create a small work cell with one piece flow for one particular operation. In order to create this work cell, machinery required to perform the operations associated with this product was moved and then rearranged in a u-shape. In the work cell, after one operation is performed on the product, it is passed to the next until completion of all the steps. At first this was a hard concept for the operators to accept because they were working at a piece rate and got paid for their individual performance. The first work cell worked so well that a second work cell was added. The company totally redesigned the work flow. The first work cell was moved and combined under one roof with the second work cell so that they would both have the same ending point which would be the inspection table. This improved the process flow because both work cells are more centrally located which makes it more convenient for the operators. A schedule board relays to each operator in the cell how much of what to produce each hour. One great advantage of the work cell is that if one operator becomes overloaded with work, another waiting on work can come help out. At each machine in both work cells there are visual operation guides with pictures of each step and what the final outcome of each step performed should produce. Since implementation of the two work cells, the company has received positive feedback from their number one customer, the US government. The government inspector stated that the product quality had improved. The percentage first pass accepted from the work cells has improved from about 53% before the project to averaging about 80% first pass currently. The quality manager at this company believes that this happened because now that the area is using continuous flow, issues are found before entire lots have been made. The company also experienced a reduction in the amount of people and time it takes to produce this product as well as an increase in their profitability for this product because they can produce more in the same period of time as before.

Each employee working in the company has now undergone basic lean training; classes were in Spanish with an interpreter because many of the employees do not speak English. Champions were chosen out of the employees in each area, who are expected to take ownership of the lean projects and ensure that the improvements continue in their area. The company currently used the following lean tools at the time of the interview: Value Stream Mapping, 5s, Visual Management, Kaizen, Work Cells, Standard Work, and Policy Deployment. The company plans to deploy these and other lean tools through monthly kaizen events in areas that are chosen with no particular criteria by management. Management meets to make this decision and decide how there are going to improve this area, and which tools to apply. Top management at Company K had been training in Policy Deployment at the time of the interview, and it was suggested by a company representative that this was the lean tool that brought all the tools of lean together and gave management a true understanding of lean and how it will work for them as a company. They had come to the realization that lean "was more than the sum of its tools, but truly a culture change." The company representative expressed that policy deployment was probably the most important lean tools and must be done before any of the other tools can be sustained long term. However, it would not have made sense for Company K to be trained in Policy Deployment first because lean had to show results before their top management would ever give it a chance. Company K admits that they still struggle with creating a lean culture within the workplace and have trouble getting their shop floor employees to bring forth suggestions for improvements. Management believes with time and encouragement that too will change.

4.2.3 Cross Company Comparison

Some common themes emerged among the companies interviewed. Although the companies were all different, they shared some of the same goals and concerns when implementing lean techniques as improvement strategies for their business. They also had to overcome considerable barriers, all of which could be linked back to a culture change within their organization. This may be one of the most fascinating findings. All the companies interviewed agreed that the most important aspect of using lean in any business was the culture change, having that "buy in" and ownership from the people, top management to shop floor. The companies which have had the most apparent and obvious success with the tools they implemented had that ownership for the projects that had been taken on.

Companies interviewed were found to use some of the same tools. The 5s tool was mentioned repeatedly, and was often one of the first lean tools implemented. These findings agree with the fundamental models of lean manufacturing suggested by Toyota's House of Lean and Principles of Lean manufacturing mentioned earlier in this Chapter. This suggested an order or hierarchy for applying lean tools in textiles as in other industries were first a stable and reliable process is established through 5s and TPM. Recall Company F, which stated that they had experienced problems when Standard Work was established before they had stabilized their process with TPM. Company B and K both started their lean journey with VSM. VSM is an important tool if a company chooses to use it and there is no prerequisite and it can be applied to a process at anytime. All the companies interviewed in this research had been using lean for less than five years, and every executive agreed that the changes and improvements from using lean take months and even years to become recognizable. The majority of the companies interviewed were using only a few lean tools, but all planned to implement more in the future. Table 4.6 below is a matrix containing the companies interviewed and common lean tools used.

From the interviews it was clear that 5s and Value Stream Mapping were two tools that had wide usage among textile companies and were usually one of the first tools implemented in textile organizations. Visual Management was also a tool with strong usage. Visual Management is part of the 5s system, and all of the companies which had said that they had implemented 5s agreed that they were also using Visual Management. Some other lean methods that popular among the companies interviewed were Kaizen, SMED, and Standardized Work. With that in mind several case studies exploring these tools and their practice with in companies were conducted, these cases are presented later in the Chapter in Section. 4.4.

Table 4.6: Lean Tool Matrix of Companies Interviewed

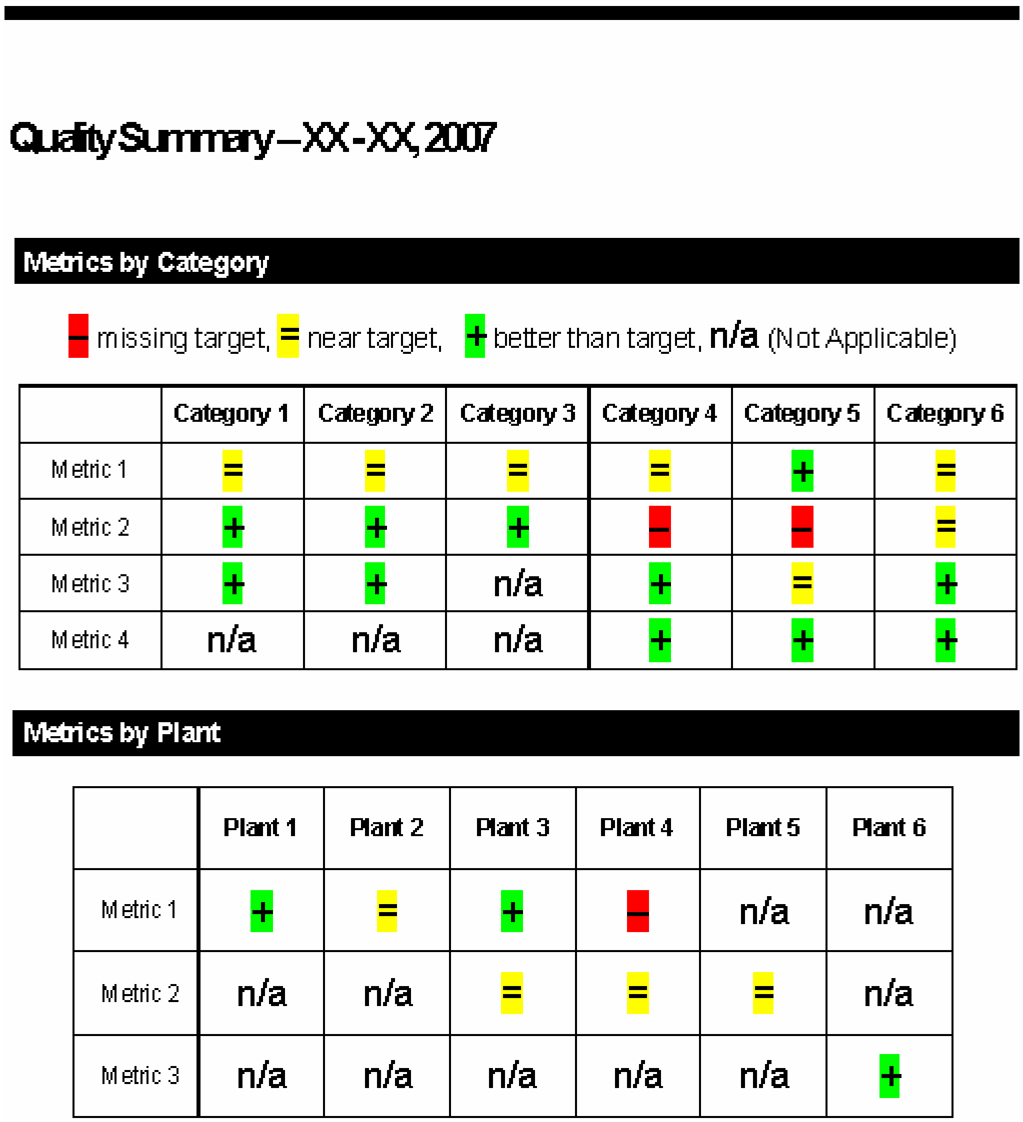
	Companies										
Lean Tool	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
5s	■		■	■	■	■	■	■	■	■	■
Cellular Manufacturing								■		■	■
Kaizen	■		■	■		■		■	■		■
Kanban			■						■	■	
Mistake Proofing				■							
Policy Deployment											■
Rapid Improvement						■					
Six Sigma			■	■	■		■		■	■	
SMED, Quick Changeover	■		■	■		■			■		
Standardized Work	■		■	■		■				■	■
Supermarket							■		■	■	
TPM			■	■		■			■	■	
Value Stream Mapping		■	■	■	■		■	■	■	■	■
Visual Management	■		■	■	■	■	■	■	■	■	■

4.2.4 Rapid Plant Assessments

The Rapid Plant Assessment (RPA) method, presented earlier in this chapter, was helpful for evaluating lean working within companies during the plant tours. Following the RPA methodology, a small group visited and toured each plant. Afterward, the observations of the group were discussed. However, this research did not include rating the leanness of the facilities observed for two reasons: all the plants visited were admittedly in their beginning stages of implementation and the scope of this research is exploratory, as expressed in the methodology. The examples have not been rated in any numerical sense, and there is no claim made that these are the best examples from the entire textile industry. Recall, Goodman's RPA had eleven categories of leanness. These categories are used in this research to evaluate and depict best practices observed from all plant tours from each category. These examples serve as a means for a textile company to benchmark another textile company with regards to Goodman's eleven categories of leanness.

Category One: Customer Satisfaction

Company F had a great example of commitment to customer satisfaction. The plant that was toured had a plant performance board which depicted customer assessment of quality and on target deliveries to employees or anyone else visiting the facility. The board included easily understood graph and charts relaying such metrics as productivity, efficiency, attendance, and quality. Quality was expressed by the internal customer whom the plant supplies yarn. Figure 4.8 is a depiction of a chart on a board similar to what is used at Company F, which is an easily understood assessment of the plant's performance in a quality summary. The board contained other charts and graphs which displayed more detail in terms of performance such as the pending and new issues facing the company, the status of orders in days from scheduled ship date, top failures, plant rankings in defective parts per million (DPM), and trend graphs of DPM.



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Metrics by Category

– missing target, = near target, + better than target, n/a (Not Applicable)

	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
Metric 1	=	=	=	=	+	=
Metric 2	+	+	+	–	–	=
Metric 3	+	+	n/a	+	=	+
Metric 4	n/a	n/a	n/a	+	+	+

Metrics by Plant

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Metric 1	+	=	+	–	n/a	n/a
Metric 2	n/a	n/a	=	=	=	n/a
Metric 3	n/a	n/a	n/a	n/a	n/a	+

Figure 4.8: Quality Summary Example

A board such as this shows employees the importance of their performance in regards to keeping their customers happy. Goodman's RPA category one for ranking a plant suggests that plant tours should be welcomed and that customer satisfaction ratings should be prominently posted (Goodman, 2002). One key observation made during the plant tour of Company F was that every employee who was passed on the tour pleasantly acknowledged the visitors with a smile, wave or hello.

Category Two: Safety, Environment, Cleanliness, and Order

One of the facilities visited belonging to Company E was an excellent example of a safe environment with both cleanliness and order. Goodman states that a plant should be well lit, have good air quality, and low noise levels (Goodman, 2002). Although Company E deals with a product which involves a great deal of dust and lint, the plant was clean and well ventilated. The walkway aisles, production areas, and the tracks for the AGVs were clearly marked for safety. The AGVs made beeping noises so that one could decipher if an AGV was approaching. The tool supply room was immaculate and the extensive labeling of tool storage with was impressive.

Category Three: Visual Management System

Visual management was very evident during the plant tour at Company F. Goodman suggests that unmistakable posted standardized work and extensive labeling of storage and production areas are indicators that a plant is operating under a visual management system (Goodman, 2002). Company F had all these. But the most remarkable example was the detail in which they had expressed their standard work for each job element. Each standard work instruction provided step by step explanations along with pictures. Visual reminders of safety and quality issues were located at each work station or where they might be appropriate as a reminder. These visual cues were usually in the form of a large poster with pictures or icons along with wording to relay the message. In order to accommodate the portion of the workforce for whom English was a second language, one side was always in English and the other in Spanish.

Category Four: Scheduling System

Company J was the only company out of the nine in which were toured that used a kanban system for scheduling production. Goodman suggests that plants should rely on a "pacing process" for each product line which controls the speed and production (Goodman, 2002). Company J's pacing process was the staging area for shipping finished goods to the customer. When the finished goods inventory levels got to close to a certain level, the production of more of that product with low inventory is triggered. These levels were represented by yellow and red dots. If the inventory level was low enough, the yellow dot was revealed the kanban card for that item should be pulled and placed on the kanban board at the material suppliers' work station so that raw materials could be assigned the to the assemblers in order for them to begin production of that particular item. If the inventory level was low enough that a red dot was visible, the kanban card would receive priority and production of that item would begin sooner than other kanban cards with more inventories remaining in finished goods. Company J reported success with this system, and upon touring the plant it was easier to understand its execution on the plant floor level.

Category Five: Use of Space, Movement of Materials, and Product Line Flow

Recall from the interview section of this research, Company K had created two work cells. Company K's two work cells serve as examples of use of space**,** movement of materials, and product line flow. During the tour, the use of these work cells was observed. All the processing steps were arranged in sequential order and each machine had been relocated at or as close to point of use as possible, which cleared floor space. The company is planning to use this floor space for new production lines. In the work cells, the movement of materials followed a one piece flow, where an operator finished their process on one piece and then passed that piece to the next process. The one piece flow created in work cells improves product line flow because problems in processing come to surface. Instead of the defective material hiding in inventory or in queue for the next process, the material automatically enters the next process where the defect is found. This also prevents producing batches or lots of defective products that are found later on in a subsequent process.

Category Six: Levels of Inventory and Work In Progress

Company K is a good example of Category Six. Goodman explains that a quick read of inventory levels can be obtained by watching a production line and counting the inventory at each work center (Goodman, 2002). Company K was using one piece flow in their work cells which were observed during the plant tour, at any given time no more than one piece of inventory was observed in queue waiting for the next process. Also, Company K had very low amounts of raw material and finished good inventory, which is ideal. However, Company K admitted that this was due to the "nature of their business," and that their customer specified a "shelf life" for their products and any raw material components.

Category Seven: Teamwork and Motivation

Recall from the interview section earlier in this chapter, during the plant tour of Company F every employee who was passed on the plant tour smiled, waved, or said hello. Also, during the tour the suggestion was made by an employee that the signs on a machine should be changed, and that a different employee held the meeting for their zone each week. All of which promotes teamwork and a feeling of ownership within the zone areas and through out the entire plant. These are all great examples of team work and motivation. Because the employees seamed friendly and in good humor, it could be concluded that they took pride in their work and enjoyed their jobs. Also, observing a shop floor employee making a suggestion to top management in front of strangers, not only shows the motivation of that employee, but the level of respect and cooperation between the two individuals.

Category Eight: Condition and maintenance of equipment and tools

Goodman suggests that machinery and maintenance records be posted somewhere on the machines, because employees should know as much as possible about the machines in order to plan for preventive maintenance (Goodman, 2002). Company E was a great example of how to keep equipment and tools clean and working well. Upon touring Company E, it was obviously that much that the upkeep of their modern machinery was of the up most importance. Although, the material handled by the machines in Company E is prone to lint and dust the machines were clean with no build up. The tool storage areas had been extensively 5s, with a place for everything and everything in its place. The condition of Company E's tool room is further explored later in this research in a case study presented later in this Chapter in Section 4.4.3.

Category Nine: Management of Complexity and Variability

Goodman's category eight is how the operation manages, controls, and reduces the complexity and variability it faces in its industry (Goodman, 2002). An example of this comes from Company B. Some of their best selling weave designs are simply the same design but with the foreground and background colors reversed. This creates distinctly different styles without changing the spool colors on the loom, which is a timely endeavor. During our tour of the facility, samples of these woven patterns were observed and looked different.

Category Ten: Supply Chain Integration

Supply chain integration helps keep costs low and quality high because the company is able to focus more closely on a small number of dedicated and supportive suppliers (Goodman, 2002). Company E was a great example of supply chain integration because they only rely on yarn from a recently acquired internal supply, which they previously had a long standing relationship with, but now this company only supplies to Company E. This allows Company E to have control over the quantity and quality of their yarn supply.

Category Eleven: Commitment to Quality

Goodman suggests that if companies are proud of their quality program, posters and banners will be displayed with the vision or mission statement, business objectives, and metrics showing achievements to date (Goodman, 2002). Company K, was found to have a strong commitment to quality. This was observed during the plant tour by viewing their plant performance board, which contained charts and graphs relaying the plant's performance (see Figure 4.8 and Category One of this section). The company's vision and mission statement was displayed in several different viewable locations throughout the plant as well as various storyboards related to different project and improvement teams.

4.2.5 Case Studies

Based on the primary and secondary research, the tools that were most frequently used and had gained the most interest from companies in the textile industry were identified. These tools were found to be universal, in that these tools could be applied to any type of company. For that reason, case studies were conducted with five companies highlighting use of 5s and Value Stream Mapping. Recall the 5s system and Value Stream Mapping from Chapter 2. 5s is an organizational tool, which can be applied anywhere: the shop floor, tool room, office area, or even in the home. Value Stream Mapping is a method of visualizing a process where value added steps are separated from non value steps, and can be applied to any process or service provided for a customer.

4.2.5.1 Company A: 5s

Company A was introduced to the concept of 5s to their workforce via a consulting firm, which works with companies to promote industrial development. In one particular area of one of the company's plants, the operation was producing three times more waste than the goal. Therefore, the manager of that area was enthusiastic about the prospect of improvement. At this point, the area had a workforce that did not work particularly well with one another and supervisors felt that there was no sense of urgency from the workers to perform their job elements. This initiative began in January 2005. Production in the department was stopped for three days for the initial event. The company chose to halt production in this area to show their commitment to the initiative because they wanted everyone to take the event seriously. Everyone working on the 5s crew was still paid their regular wage to come in and work on the event, however the event was voluntary. Everyone working in the area showed up for the event, a total of about thirty people.

The first step was to sort out the clutter from tables and workstations and equipment to remove items not essential to performing the process and any unneeded equipment. They used the red tag tactic, to separate these items from the regular production area. Recall from Section 2.6.1.1, the red tagging is when a red tag is placed on the item and it is moved to a specified area with other red tag items or the area where the items are stored is marked of with red tape. The next step was to set locations and limits for equipment and item storage using indicators. Indicators such as lines and identification signs were also placed to demark walkways and the different storage areas. For example, storage locations of empty beams were marked off with lines on the floor, which not only identified to the worker where to store these items but also provided a limit to how many beams could be stored, because beams were not to be stored past the line of the floor. Tools and equipment to be used frequently during the workday were placed and stored close to their point of use making it easy for worker's to retrieve these items to use when needed.

Cleaning up and organizing the area was an important goal that top management had in mind when embarking on this 5s event. The floors and machines were given a good cleaning to remove waste and oil. The next step was to ensure that standard working practices were in place and that everyone in the area was trained in 5s and understood the goals of the organization. The key procedures were written down and readily available for any worker who had a question about their role in the process.

In order to sustain the improvements made to the production area where the 5s event had taken place, the company used a 5s audit system. This audit system is used to ensure that 5s is continually carried out within the area and that the procedures and activity boards are kept current. Figure 4.9 shows an example of the audit sheet, which was used by this company.

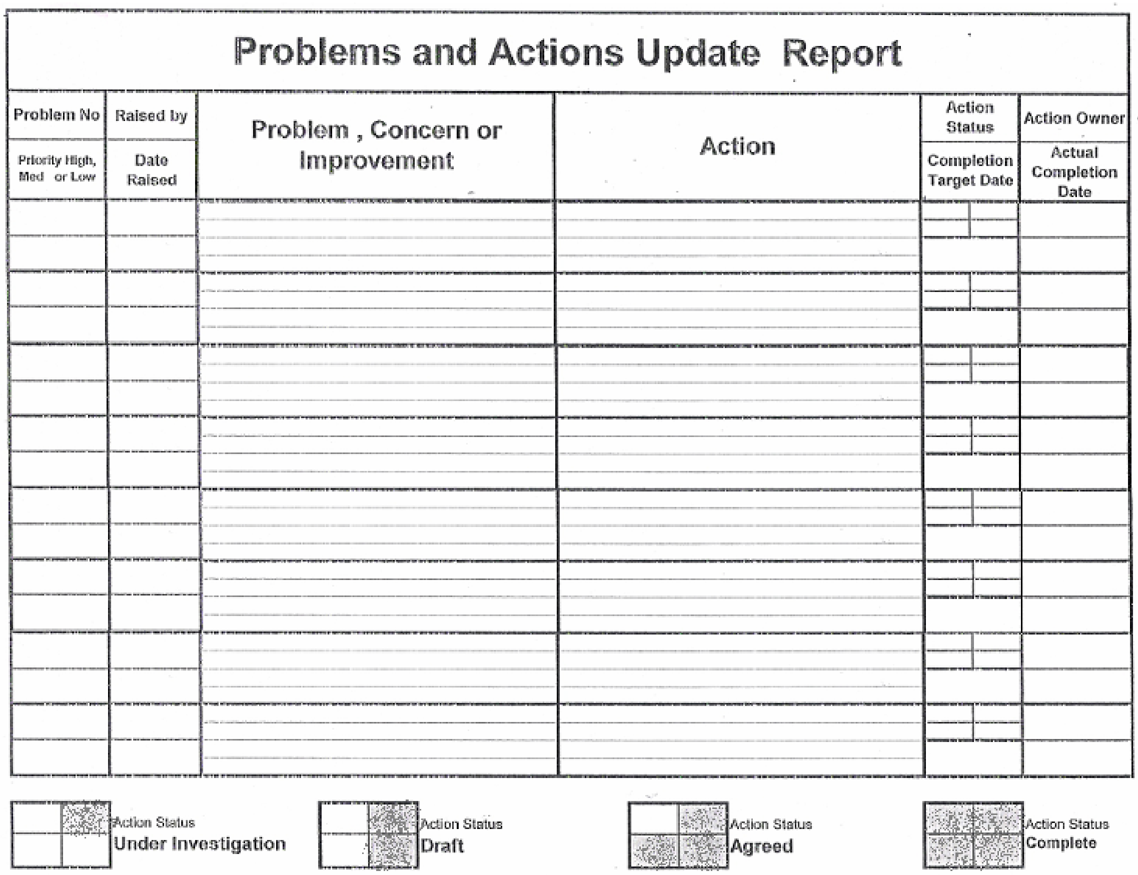
5S	No	Check Item	Description	0 (Very Bad)	1	2	3	4 (Very Good)
Sort out Clutter	1	Tables, Work surfaces and view stations	Are all areas clear of non essential product					
	2	Equipment	Is there any unneeded equipment					
	3	Tools	Are there any unrequired tools					
	4	Visual control	Has the Red Tag tactic been implemented					
	5	Written standards	Information boards display current documents are tidy and legible					
			Sub Total					
Set Locations and Limits	6	Location indicators	Is "equipment" storage and location marked.					
	7	Item identification	Do the locations have individual item identification					
	8	Quantity indicators	Are the maximum and minimum allowable quantities indicated					
	9	Demarcation of walkways and in-process inventory areas	Are "lines" or other markers used to clearly indicate walkways and storage areas					
	10	Jigs and tools	Are jigs and tools arranged to facilitate picking them up and returning them easily					
			Sub Total					
Shine and See	11	Floors	Are floors kept clean and free of waste, water and oil					
	12	Machine exteriors	Are the machines clean and kept free of waste and oil					
	13	Cleaning and checking	Are abnormalities recorded after cleaning					
	14	Cleaning responsibilities	Is there a cleaning rotation schedule					
	15	Cleaning Rotation	Is this being implemented					
			Sub Total					

5S	No	Check Item	Description	0 (Very Bad)	1	2	3	4 (Very Good)
Standardize Working Practices	16	Improvement memos	Is the Problem, Concern & Improvement Report sheet being used					
	17	Improvement ideas	Are improvement ideas being acted on and completed on time					
	18	Key procedures	Are standard procedures written, clear and actively used					
	19	5S Training material	Is the 5S training material reviewed on regular basis					
	20	Internal / External Audit	Are low scores and discrepancies being addressed					
			Sub Total					
Stick to the Rules	21	Training	Is everyone trained to current 5S standards					
	22	Independent Audit	Is an independent audit being carried out					
	23	Internal Audit	Is an internal audit being carried out					
	24	Procedures	Are procedures up to date and regularly reviewed					
	25	Activity Boards	Are activity boards up to date and regularly reviewed					
			Sub Total					

Independent 5S Audit Sheet	
For Production Areas	Dept :
	Audited By :
	Date Audited :
	Audit Total Score :

Figure 4.9: Company A's 5s Audit Sheet

Another important action taken to sustain 5s was the weekly meeting established after the three day event. These weekly meeting brought about suggestions for improving the process and work environment for the people. At first, workers were reluctant to offer ideas, but once some ideas were brought by management for encouragement, the ideas came easier to the technicians and shop floor workers. Since they began the meetings, thirty-two suggestions for improvement actions have been submitted and approved. These suggestions were given priority by the managers a suggestion could be given high, medium, or low priority. These suggestions were documented and put on an action sheet that would get updated as the projects were closer to completion. Actions could have a status of either under investigation, draft, agreed, or complete. Figure 4.10 shows an example of the action update report used to organize the suggestions at Company A.



Problems and Actions Update Report

Problem No	Raised by	Problem , Concern or Improvement	Action	Action Status	Action Owner
Priority High, Med or Low	Date Raised			Completion Target Date	Actual Completion Date

Action Status Under Investigation
Action Status Draft
Action Status Agreed
Action Status Complete

Figure 4.10: Company A's Problem and Actions Update Report

Some of the improvements made from these suggestions included: a retractable air line hook up at each machine making the air line easy to locate and retrieve when the operator needs to use it, splash guards on machines, and mirrors on each machine enabling the operators to see the front end of the machine while not actually standing at the front of the machine.

Company A saw the reduction of waste even beyond their expectations and goals as a result of the 5s program. However, the resulting reduction of waste was gradual and took over six months to take effect. Another benefit of the 5s weekly meeting was a greater awareness of the impact of waste among the employees involved. Operators began competing to have the least amount of waste in the area. Company A plans to continue with the employee meetings but has cut back to bi-weekly meetings at this point due to this being a slower season. Company A was pleased with the success of 5s in that department and would like to implement the program in other areas of the plant as well.

4.2.5.2 Company D: 5s

This case focuses on the training and participation of the employees involved in the 5s events rather than the steps and improvements taken as in the previous case of Company A. Company D began a 5s program set in motion by corporate, which sent a lean engineer to train and facilitate lean education and initiatives within the plant. The 5s program began at this plant in summer of 2006 with one particular department responsible for one type of processing, which is the focus of this case. It has since spread to other departments in the facility with the ultimate goal of converting the entire facility to the 5s organizational system. In order to convert the department, which consisted of three different rooms with nineteen large machines, several different three-day, eight hour 5s events took place. Volunteers for the 5s event came in off their shift and worked overtime in order to participate. Breakfast and lunch at the 5s events was provided by the company.

A typical 5s event began with everyone introducing themselves out loud to the group. After breakfast, a 5s training class, which was accompanied by a PowerPoint presentation for a visual aid, took about an hour. The training class first addressed the issue of waste and how it can sometimes be obvious or hidden. Eight hidden types of waste were taught to the group with the acronym ‘downtime’ defects, overproduction, waiting, non- utilized talent, transportation, inventory, motion, and extra processing. Examples of each were given, and the class was asked by the facilitator to try to think of an example of each that they had seen in their work experience. 5s was introduced as a way to combat this hidden waste and make for a better work environment. Each ‘s’ of the 5s was defined, and then specific examples were given which included pictures to further drive the point and to show the impact of each ‘s.’ During the classes some people were more excited and willing to participate than others, which might be expected in any group project.

After 5s was explained, a plan was constructed to carry out the 5s event. Everyone was encouraged to participate in the planning and bring forth any ideas or concerns they might have. On the first day of the event, when the class was held, decisions were made such as where should the red tag area would be located, and what type of items were needed in the work area, and which items were not needed. These items that were not needed were then removed from the area and everyone on the team helped with this endeavor. At this point, those team members who were more reluctant to participate were encouraged by the other team member to do their share.

The second day of the event began with a review of the concepts of waste, lean, 5s and what the team had accomplished in the previous day. Then the plan for the day’s work was discussed which included where the items, tools, and equipment left in the workstations would be stored. Some of the decisions were easily agreed upon, while other decisions were harder for everyone to come to a consensus. These more difficult decisions were mediated and locations were ultimately chosen by these two criteria: where is most convenient to the operator and most safe for everyone. Due to time restraints, the teams were split up, one addresses shine and the other standardize. The team that went to shine duties included cleaning the machines, floors, countertops, and workstation. The duty of the team that went to standardize was to paint and mark off identification areas for storage locations. Some of the cleaners expressed their concern that they had gotten the short end of the stick because painting was easier than cleaning. This type of negativity was unfortunate, and it may or may not have been prevented by all the members of the team performing the same type of tasks with each other instead of splitting up. The third day followed a similar schedule as the second, wrapping up cleaning and standardization in the area.

At the close of the third day, a graduation ceremony was held. Everyone who participated was asked to share what they had learned from the experience and their opinion of the direction the plant was heading in terms of whether or not they thought 5swas a good idea and if they thought that the system could be maintained. Afterward, everyone was presented with a certificate of training in 5s, signed by the lean engineer from corporate to make it official. The comments made by the 5s teams at the event's closing were very positive. The teams reported that they were proud of what they had accomplished in the area and enjoyed the recognition they had received from their other co-workers on the working on the shop floor, who expressed their agreement with the improvements that had been made in their work area.

4.2.5.3 Company E: 5s

Company E implemented 5s with all of the steps as did Company A and E, but differed as discussed earlier in Section 4.2.2.5. Company E did not pull employees of their job for long periods of time or bring employees of shift for an event. The 5s coordinator taught the 5s system to the teams, but the responsibility of the project was placed on the facilitator for that team. This case involves 5s implementation at a particular plant, which unlike the other two cases was not done on an area responsible for processing a product, but a tool room. This case further exemplifies the fact that a 5s program can be used anywhere.

The extent that the 5s facilitator, a technician, for this project had implemented the 5s system in the tool room at this facility was remarkable. Company E did not use the 5s event format. Rather, Company E trained 5s team members in a short classroom format, which providing them literature: *5s for Operators* by Hirano from Productivity Press and then expected the 5s facilitator and the team members to take ownership of the project. The 5s coordinator interviewed revealed that team and facilitator selection was the key for this system of 5s implementation to work. A supervisor or technician in the area of the project was usually chosen as the facilitator. The teams required the right mix of people, some working in the area and some that did not because sometimes those not working in an area could bring new and different ideas. The 5s projects for Company E have taken a "piece mill" approach, where a little is done at a time. The plant tool room observed in this case study was no exception. The facilitator of the project, who gave the tour of the plant and tool room, explained that the project had taken months to complete.

What made the tool room at this particular facility so remarkable was the detail which had been taken to label each part, belt, screw, and piece of machinery. Each cabinet in the tool room was labeled with a visual icon and text description of the machine in which the parts stored within belonged. On each drawer was an icon and text description of the part contained inside the drawer. On the top of each cabinet was a catalogue of all the parts stored within containing their description, location, and reorder information. To keep the top of cabinets clear of clutter, the surfaces were not flat but slanted. Therefore, anything placed on top would slide off. On the wall, there were hooks to store various belts required by machinery. To ensure that the right belt was stored on the right hook, there were outline drawings of the belts on the walls with the hooks and text descriptions of the belts above the hooks.

The company representative interviewed reported that the money his company had invested in the 5s system was in the hundreds of dollars, while the savings were in the hundred thousands. The 5s project in the tool room in this case study has eliminated the waste of ordering a part already in stock, because all the parts and tools can now be easily found. The facilitator of the 5s project in the tool room believed that this project would save his company over forty thousand dollars over the next year in tool and part replacement costs.

4.2.5.4 Company A: Value Stream Mapping

To create a current state Value Stream Map (VSM) for Company A, the plant was visited for three days in order to observe and collect the information needed. A map of the plant's layout was obtained to further understand the flow of materials within the plant. A process flow map was then created to gain a better understanding of the operation. The assessment began with four major products, all of which are produced heavily by the company. For each of these styles, information such as machine run and set up times, machine utilization, waste, and inventory counts between each process were collected. The scheduling of machines in terms of paper work and electronic interchanges is used to determine what product would run on which machine at what time was also observed and is depicted by the information flow moving from right to left in Figure 4.11. In order to create a value stream map for any product, customer requirements must be known or estimated in the form of a shipping schedule or some sort of forecast. This customer requirement is used to calculate takt.

Recall from Chapter 2, that the takt is the daily amount of the product required by the customer. The takt is used to calculate the inventory lead time and percent value added. A current state map was created for only one of the four products observed, Product A. The takt for Product A was calculated by dividing the yards required by the customer per week in this style by the number of operating days per week as follows:

$$\text{Takt} = \frac{4{,}3300 \text{ yds per loom per week} * 27 \text{ looms}}{5 \text{ days per week}} = 23{,}382 \text{ yds}$$

The result was the yardage required by the process each day to meet the customers demand. The cycle time (C/T), changeover time (C/O), waste percentages (%W), and machine utilization (U/T) for each process was provided by the company. Cycle time was given in yards per minute; the inverse was taken to give us cycle time in minutes. The lower portions of the lead time ladder are the processing or cycle times of each process, which are added together to get the value added time in Figure 4.11.

$$\text{Value Added Time} = .01 \text{ min} + 0.011 \text{ min} + 2.02 \text{ min} = 2.041 \text{ minutes}$$

On December 11, 2006, the inventory between each process in the value stream was counted and converted into lead time in days. This conversion was made by dividing the yards in inventory by the takt (yardage required by customer per day). The result was the lead time in days of this inventory.

$$\text{Lead time between Warping \& Slashing} = \frac{55{,}800 \text{ yds} * 2 \text{ beams}}{10 \text{ beams per creel load} * 23{,}382 \text{ Takt}} = 0.48 \text{ days}$$

$$\text{Lead time between Slashing \& Weaving} = \frac{27{,}900 \text{ yds}}{23{,}382 \text{ Takt}} = 1.2 \text{ days}$$

These lead times are located on the raised portions of the lead time ladder underneath the process map and are added together with the value added time to get the production lead time in days (see Figure 4.11).

$$\text{Production Lead Time} = 0.48\text{ days} + 1.2\text{ days} + 0.0014\text{ days (Value Added Time)} = 1.68\text{ days}$$

The ratio of value added time to production lead time is the percent value added, which in this case is a little more than one percent.

$$\text{Percent Value Added Time} = \frac{0.0014\text{ days (Value Added Time)}}{1.68\text{ days (Production Lead Time)}} = 0.083\,\%$$

A future state map was not made for this product. Mapping the future state is critical in order for improvements to be realized through Value Stream Mapping. The following section presents a case study where both the current and future state maps were created.

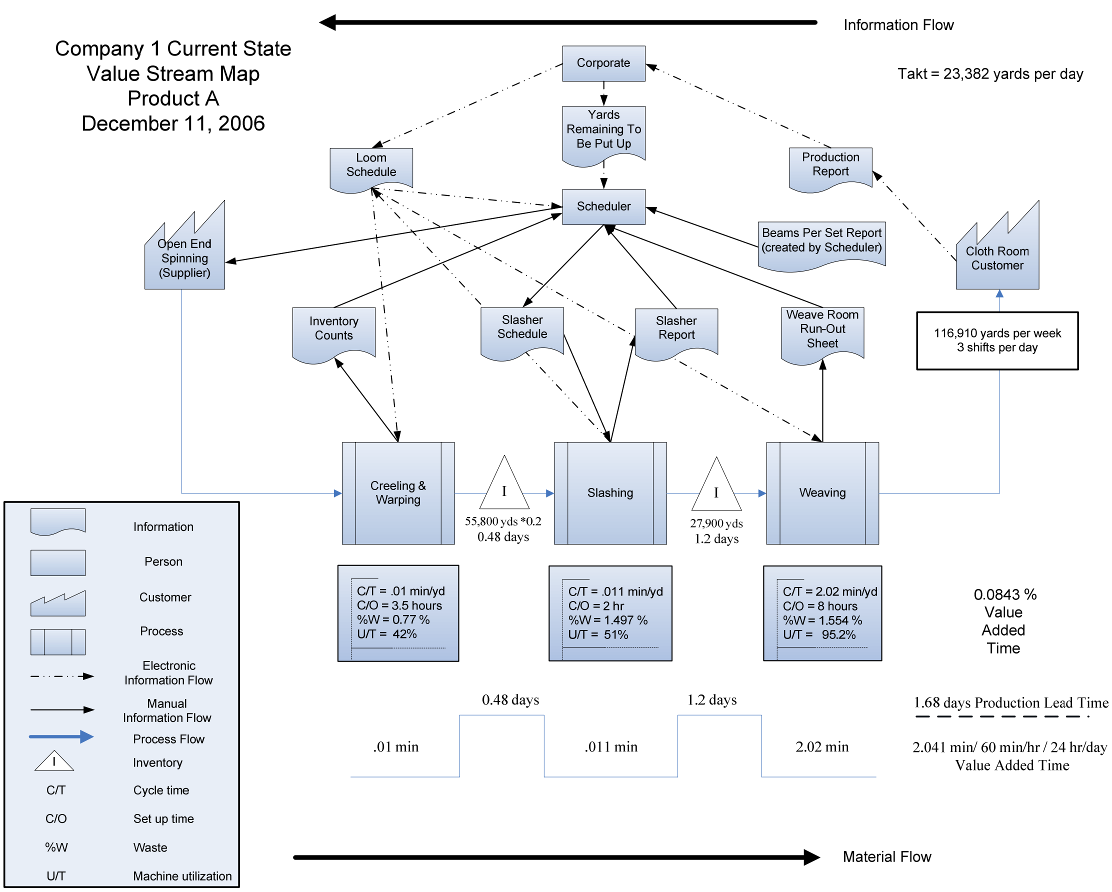


Figure 4.11: Company A's Current State Map Product A

4.2.5.5 Company G: Value Stream Mapping

For this case, a Value Stream Mapping training activity at Company G event was observed which lasted three eight hour work days. Seven of Company G's employees participated in the event among them was the Chief Financial Officer (CFO), Plant Manager, Plant Engineer, Customer Service Manager, two Production Managers, and a technician. The activity was facilitated by lean specialist from the consulting group who Company G is using to help with organization and training in their initial lean program implementations.

First, the facilitator introduced himself and asked everyone in the room to do the same. Afterwards, the facilitator briefly explained lean manufacturing to the group, and the eight types of waste as well as the concepts of value added, non-value added and non-value added but required. Then he explained the purpose of Value Stream Mapping, and the group went through an example of a current state map on a fictitious company together. After lunch on the first day, the team began work on the Company's current state map. The first step was to decide on which product or family of product should be mapped. The facilitator asked that the team choose a product(s) which was produced in high volume. After the team had decided on the product, the takt was calculated based upon a four week forecast from the customer. The team then broke up into two groups, one to gather information to create the information flow and the other to collect the cycle time, changeover time, machine utilization percentage, and to count the inventory between each process of the value stream for this product. Then each process in the material flow was drawn out for everyone in the group to see and agree with; along with every step and report generated in the information flow. After everyone had agreed on the material and information flow of the map, the facilitator adjourned the group for the day.

On the next morning, the facilitator showed the group how they could calculate their lead time in days between each process by dividing the amount in inventory by the takt (customer requirement per day). He also explain that the value added time was the cycle time or the time that was spent at each process actually processing a unit of product, which in Company G's case one unit would be one yard of material. The lead times between each process were then added to get the production lead time, and the cycle times at each process were added to get the value added time, as shown in Figure 4.12 which is a depiction of Company G's current state map. A few of the team members were astounded at how large this number was and did not believe that it could be correct, but the CFO quickly interjected, explaining that the average inventory turnaround for the company was only three days less. The percent value added was then calculated by taking the ratio of value added time to production lead time. Company G's percent value added for this product was less than one percent (see Figure 4.12). That afternoon was spent learning about designing a lean flow. Concepts such as one piece flow, kanban, supermarkets, and push vs. pull were introduced. The facilitator then went through an example of a future state map for the fictitious company that had been used as the current state map example, in order for the group to understand how creating pull systems can reduce lead time and increase the percent of value added time.

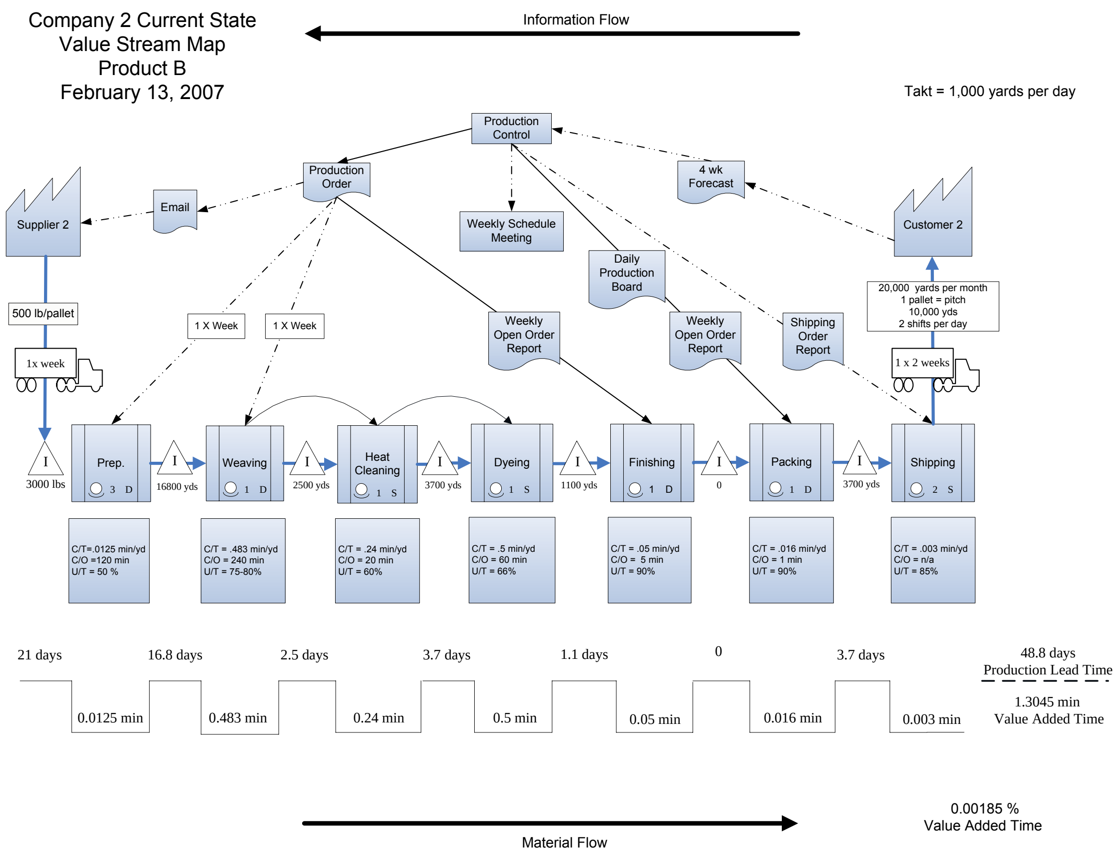


Figure 4.12: Company G's Current State Map Product B

The team spent the next morning brainstorming ideas to improve their process, which would become kaizen bursts[8] in the future state map. Figure 4.13 depicts Company G's future state map. One of the major improvements decided upon by the group was to reduce the paper work from production control. As Figure 4.12 shows, there were three different reports that would be eliminated in the future state (see Figure 4.13) along with two electronic scheduling communications. In the future state, the schedule is only sent to shipping, where a supermarket will be created. When the stock in the supermarket reaches a certain level, a kanban signal will schedule the production at the downstream processes (see

Figure 4.13). Other kaizen bursts in the future state map which target improvement in product flow included creating just in time warps in this style, so that one loom could be dedicated to this product and creating continuous flow through weaving. The other kaizen bursts are associated with updating and repairing equipment. These ideas for improving the process will be prioritized and will then become the basis for scheduling kaizen events.

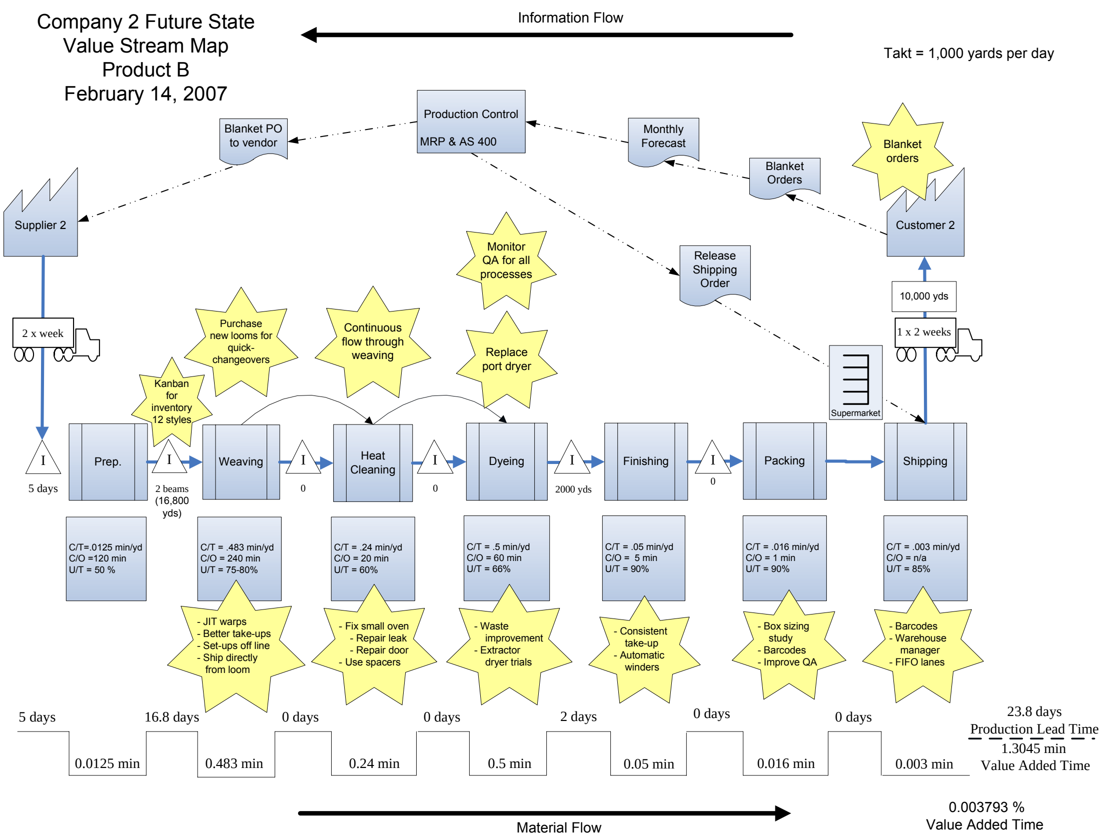


Figure 4.13: Company G's Future State Map Product B

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[8] Kaizen bursts are icons used in Value Stream Mapping to highlight improvement needs at specific process and are critical for the future state map (Rother & Shook, 2002).

4.2.6 Summary of Results from Phase II

Phase II addressed the following research objectives from Chapter 3. Lean manufacturing tools that are being utilized in US textile companies' business strategies were identified and analyzed through interviews, plant tours, and case studies results. A hierarchy for implementation of some lean tools versus others according to the application or situation was examined through analysis of the experiences of the companies. A means for a textile company to gauge where there organization stands in terms of lean in comparison with other companies was addressed through the comparison of the results from the interviews and plant tours assessment. Based on the results from Phase I and II, recommendations for lean implementation in a textile company were constructed and are presented in Chapter 5 of this research. Based on the interviews in Phase II, common themes revealed themselves and are also presented in Chapter 5. The case studies conducted in this phase, allowed for the development of Value Stream Mapping and the 5s system checklists, which are also presented in Chapter 5.

5 Conclusions

In conclusion, lean manufacturing principles can be adapted by US textile companies as competitive business strategies. As one executive stated, his company was using lean to remain competitive and become "world class." Recall from the research methodology in chapter three that there were four objectives to be met in order to develop recommendations for US textile companies to consider when implementing lean as a competitive strategy in their organization. The four research objectives were as follows:

- RO1: Determine extent of methods and tools used in various industries outside of textiles.
- RO2: Define which lean manufacturing tools are being utilized in US textile companies' business strategies.
- RO3: Determine a hierarchy, if any, for implementation of some lean tools according to the application or situation.
- RO4: Develop a means for a textile company to gauge where their organization stands in terms of lean in comparison with other companies.

Research objective one was accomplished by benchmarking other industries' successes and failures to help determine the key principles of lean manufacturing. Research objective two was explored through secondary research of articles and white pages as well as the interviews, plant tours, and case studies conducted among eleven textile companies. Research objective three and four were accomplished through comparison of different authors' conceptual models of lean and its tools and principles as well as by comparison of different companies' experiences with lean manufacturing in textiles and other industries. These objectives were met through completion of Phase I and II of this research. The results and analysis of the secondary and primary data collected during these two phases were combined to develop a recommendation roadmap for lean implementation in the textile industry.

5.1 Roadmap for Lean Implementation

The final outcome of this research is a recommendation roadmap for textile companies to use when implementing lean manufacturing principles. This roadmap consists of four parts: a model for lean implementation, textile specific barriers to lean implementation along with solutions to those barriers, and best practice checklists for the5s system and Value Stream Mapping.

5.1.1 Model for Lean Implementation

The model for lean implementation in the textile industry developed through this research consists of recommendations based on the generalization of themes found in conceptual models of lean from various sources found in the literature as well as through benchmarking the experiences of industry and the companies interviewed by the researcher. The model consists of six major lean tools, which are Policy Deployment, Visual Management, Continuous Improvement, Standardized Work, Just in Time, and Value Stream Mapping and the other tools and methods which fall within such as 5s, TPM, and A3 thinking. Figure 5.1 depicts the recommendation model for lean implementation in the textile industry developed in this study. This model uses the plain English version of some of the Japanese word lean tools, which were identified in Chapter 2. This was done in an attempt to make the tools easier to understand.

At the base of this triangular model is Policy Deployment which addresses the 'philosophy of lean' or the cultural change which must take place in order to base management decisions on what is best for the company in the long term instead of short term financial goals. Recall, 'philosophy' is the base of Liker's 4 P Model of the Toyota Production System presented in Phase I of Chapter 4. Recommending that Policy Deployment be the base of lean implementation is also reinforced by themes exposed in Phase II of this research. All the companies interviewed in this research agreed that the most important aspect of using lean in any business was the culture change, having that "buy in" and ownership from the people, top management to shop floor. In addition, the projects which had the most success within companies were the ones in which people had taken "ownership" and responsibility. Policy Deployment tools address this specific issue. Recall from Chapter 2, the methods of Policy Deployment is Toyota's process of transporting objectives and goals from the executive level of the company to the shop floor level. This process has made the managers at Toyota become successful setting challenging goals jointly with their subordinates who become passionate about measurement and feedback of progress toward those goals (Liker, 2004). The methods of Policy Deployment are meant to get the workforce involved and constantly striving for improvement.

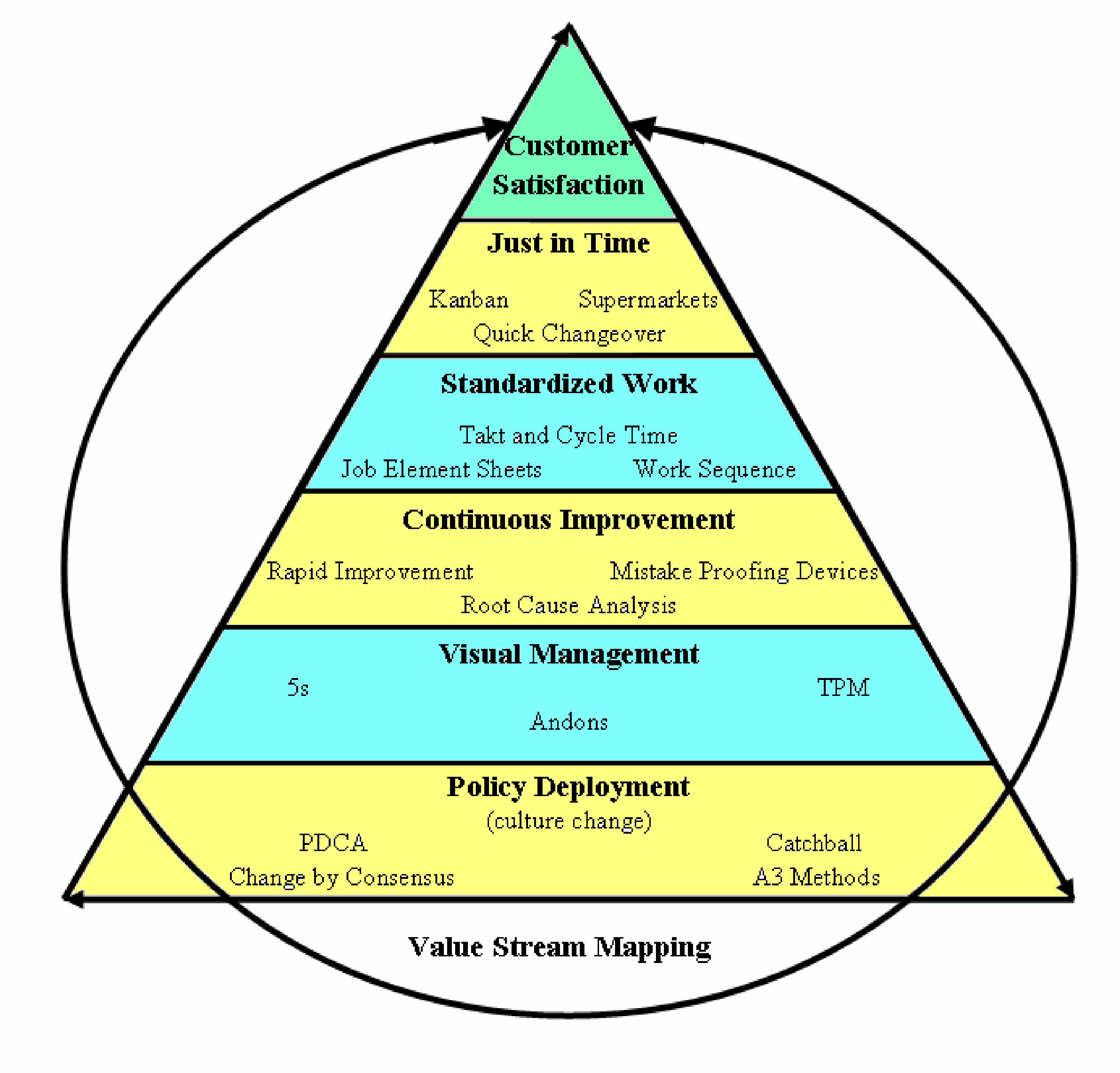

Figure: 5.1: Lean Implementation Model

However, some high level individuals within companies may have to have the effectiveness of lean proven before they will be attracted to the philosophy of lean, such in the case of Company K. In such a situation, it may be appropriate to start with Value Stream Mapping, like Company K, or 5s both of which can bring noticeable improvements. Visual Management tools such as 5s and TPM build a foundation of stability in the process, which enable standardization of the work. Recall Toyota's House of Lean where the house was built on first stability and then standardization. This idea was reinforced in Phase II in the experience of Company F, who had failed at implementing Standard Work before having machine reliability. Kaizen, like all of the lean tools should be done constantly, however, there is no prerequisite for improvements or Kaizen, but suggestions for improvements might not surge readily from employees at first which was a common theme throughout the interviews conducted in Phase II. For this reason, Kaizen and other improvement methods might not take into full effect until after employees have had enough experience using lean through tools such as 5s, TPM, and Value Stream Mapping that they understand how the system works. At the center of Standardized Work is the takt and cycle time required for performing the operation to the customers specification, and if the machine is not capable of performing at this level, the operator can not either.

Just in Time tools are used to improve product flow and reduce inventories and lead times so the product can get to the customer when they want it and in the quantity they ordered. For this reason Just in Time is the block closes to the customer in the pyramid. The ultimate goal of Just in Time is to make product as it is ordered and to have material move through the plant in a one piece flow. However, one piece flow in most textile applications in not possible because the product must go through the value added process in large quantities or batches. Supermarkets can be used to hold small inventory for downstream customers inside a process to come to the supermarket to pick out what they need. Recall from Section 4.2, Company H and I had created supermarkets for heavily used in-process inventory in order to continually supply a subsequent process in their value streams. It is recommended to use Value Stream Mapping to help determine the location and size for supermarkets based on takt as determined by the customer. Value Stream Mapping was placed outside the triangle in Figure 5.1, as there is no prerequisite for using the tool, and companies may want to use the tool as a means to prioritize and schedule their improvement projects. Value Stream Mapping is recommended as an important tool for any company wanting to analyze the value their production or service process provides to the customer. The arrows on each side of the triangle represent the continuous application of these tools. No matter how an organization decides to use lean or its tools, the key to remember is that its purpose is customer satisfaction and growth of the organization.

5.1.2 Barriers/ Solutions to Lean

Common themes of barriers emerged in the interviews conducted in Phase II of this research. These themes were compiled to create a listing of barriers and suggested solutions. These barriers are important for a textile company implementing or interested in applying lean principles as a competitive business strategy.

- Lean requires a cultural change, where people on the shop floor feel comfortable making improvement suggestions to management.

  Solution: Education on the types of waste and lean concepts, encouragement to bring forth suggestions, feedback on suggestions and the progress of projects

- A cultural change requires cooperation and support from everyone in the organization from top management to the plant floor.

  Solution: Education, and strong support from management at all levels

- People are often resistant to change especially if a particular procedure had been followed for a long time.

Solution: Education and training, feedback, and reward system for improvement suggestions and completion of projects

- ❖ Employees need to take ownership of their workplace in order for improvements to be sustained.

  Solution: Education and training, feedback, formal recognition of team members, and reward system for completion of projects (T-shirts, gift cards, etc.)

- ❖ Much of the lean terminology is difficult to understand
- ❖ Adapt terms or translate so, that everyone can understand the concept
- ❖ A disconnect often exists between the manufacturing side of a business and the marketing, sales, and product development side.

  Solution: Align entire organization toward goals so, that different departments or business units work together

- ❖ Some may view textile machinery as assets that can not be left idle for any length of time.

  Solution: Enforce the concept that the long term welfare of the company is more important than short term financial goals; if running machines continuously results in overproduction, the machines may not need to be ran continuously

- ❖ Impact of improvements made may take weeks, months, or years to be realized.

  Solution: Communicate the status of suggestions and projects periodically through meetings and display boards

5.1.3 Implementation Checklists

The secondary research from Phase I was combined with the results from the studies in Phase II to create a 5s system and a Value Stream Map check lists. The case studies presented in

Section 4.2.5 enabled the development of checklists which present detailed best practice recommendations for the application and use of each tool.

5.1.3.1 The 5s System Checklist

The 5s system is used for organization and standardization. This research found examples of the 5s system used in production areas and maintenance storage areas; however the system can be applied anywhere that needs improvement. 5s may be implemented in the form of an event, which would typically last a few days, as in the case of Company A and D. However, the 5s system can also be implemented on a project basis in which a timeline would be set based upon the nature of the project, as in the case of Company E. There are requirements for the 5s system to work, which were revealed through the analysis of the companies' experiences in the case studies in Section 4.4 and compared to the 5s system literature presented in Section 2.2.11. These requirements were compiled into a checklist.

Step 1) Educate and train employees in the types of waste and 5s system: sort, set, shine, standardize, and sustain.

Step 2) Establish 5s teams which include a facilitator willing to take responsibly and provide support and encouragement to the team.

Step 3) 'Sort,' where items that do not belong in the workplace are removed.

a) Remove and red tag these items in order to separate these items from the items needed by the worker. Red tagging not only removes unnecessary items from the workplace, but acts as a safety because someone else may need the item.

b) Record red tag items so, there is a record of how long an item has been red tagged. A red tag item should not be kept more than a week or two. Obvious trash does not need to be red tagged.

Step 4) Set into place all of the items needed to perform work, storing the items as close to the point of use as possible and in an orderly fashion so that things can be easily assessed when needed.

Step 5) Shine or clean the machines, floors, or walls. Always looking for the source of the filth in order to eliminate the source.

Step 6) Standardized the items needed by the worker and all the materials processed in the area which have been 'set into place' The standards should be made so that it will become obvious when any item is out of its place.

Step 7) Sustain improvements made by the 5s system, all of the steps should be continuously carried out after their first implementation, always searching for new improvements.

5.1.3.2 Value Stream Mapping Checklist

There are requirements for Value Stream Mapping, which were revealed through the experiences analyzed in the case studies in Section 4.4. The requirements for Value Stream Mapping were compiled into a checklist.

Step 1) Educate and train employees in the concept of Value Stream mapping, value added, non-value added, and non-value added but required activities, as well as the different types of waste that can be hidden in a process.

Step 2) Establish a Value Stream Mapping team, ideally someone working in each of the processing areas, including hourly employees, and someone from the office/administration.

Step 3) Pick products or product families to map which are heavily produced.

Step 4) Determine customer requirement and time available to work in order to calculate takt (daily customer requirement) for the product.

Step 5) Physically follow the product's production path must from beginning to end.

Step 6) At each process in the material flow cycle time, changeover time, and machine utilization must be determined and the inventory observed must physically counted.

Step 7) Sketch the production path with a visual representation of every process in the material and information flow.

Step 8) Add the cycle times of all the processes to get the Value Added Time.

Step 9) Calculate the lead time between each process by dividing the inventory at each process by the takt calculated earlier.

Step 10) Add the lead times between each process to get the Non Value Added Time.

Step 11) Calculate the percent value added = $\frac{\text{Value Added} + \text{Non Value Added}}{\text{Non Value Added}}$

Step 12) Create the future state map based on current state map.

a) There must be both a current state and a future state map. The current state map is created to understand how the production currently operates and is the basis for the future state map, which is how the production would ideally operate.

b) The future stream map is drawn much of the same way as the current state, but the future state is where the ideas for improving the process are realized.

c) The team should brainstorm together to come up with ways to make the production flow better, these ideas become the kaizen bursts of the future state.

Step 13) Use Kaizen bursts should as a basis to prioritize and plan improvement projects.

5.2 Future Work

In this research, eleven textile companies were interviewed, which was not a large enough sample to conduct any statistical analysis. There is a possibility that later research could include quantitative analysis which could develop into descriptive or causal studies, but a larger sample of companies gathered randomly rather than on convenience would be needed. Another suggestion would be to study implementations of different lean tools over time to follow the progress of the process over time and to document the impact of the tools whether it is positive or negative in order to gauge the effectiveness of lean manufacturing principles. This study consisted of case studies involving only two different lean tools; someone may want to study other tools in order to more closely investigate their application and use. This research uncovered an infrastructure of government funded organizations at both the state and community college level which support lean manufacturing education. However, textile specific training and collaboration between textile companies was not found. There may be a need for the Institute of Textile Technology to provide lean training workshops to member companies and provide a medium for textile companies to showcase their lean projects for other companies to learn from. As mentioned in Section 4.2.3, the assessment rating of the "leanness" of the textile companies observed was not created in this research. A study using the Rapid Plant Assessment's methodology for rating the leanness could be conducted in the textile industry. However, some work on a scale not open to the subjective to the observer may be needed.

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APPENDIX

APPENDIX

A Interview: Lean Manufacturing

Questions

Q) Does your company use any form of lean manufacturing?

Q) Do you have a definition of lean?

Q) Why does your company use lean initiatives?

Q) What type of problems does lean address?

Q) Why some tools and not others?

Q) Which tools are used in your organization?

Q) How was that decision made? (which tools to use)

Q) Was there a particular order for applying tools?

Q) Is there some point where tools become ineffective or barriers to lean?

APPENIX

B Focused Industrial Training Program for North Carolina

Managing the Cost of Training

The State of North Carolina and the Federal Government make funding available to help manage the cost of investment in training. Programs include:

1. FIT: Focused Industrial Training - training for shop floor employees and front line supervisors in manufacturing industries. Focused Industrial Training programs can include needs assessments and consultations for the design and delivery of targeted, customized training. Details are available at http://www.ncccs.cc.nc.us/Business_and_Industry/fit.htm.

2. NEIT: New and Expanding Industry Training - training available to companies that create 12 or more new jobs in any one North Carolina community during a one-year period, and whose maximum employment has not exceeded present employment at any time during the past three years. Services can include pre-employment assistance, classroom instruction and "hands on" training, facilities for training, supplies, and customized course materials for teaching and demonstration. Details are available at http://www.ncccs.cc.nc.us/Business_and_Industry/neit.htm.

3. Occupational Extension - Training that is offered at rates preset by the State. This training is designed for upgrading the skills of current employees or retraining employees for new positions within the company. The rate schedule for Occupational Extension training is:

Cost per person Hours of training

$55 (11-30)

$60 (31-100)

$65 (100 +)

4. CIT: Customized Industry Training - Customized Industry Training (CIT) was created in 2005 to provide greater flexibility for the North Carolina Community College System to meet the retraining needs for existing business organizations in North Carolina's communities. The intent of the program would be to augment the services of the NEIT and FIT programs where their current guidelines do not apply. CIT is available to businesses and industries that meet the following criteria:

- The business is making an appreciable capital investment;
- The business is deploying new technology; and
- The skills of the workers will be enhanced by the assistance.

Details are available by contacting Industrial Training at 828-327-7000 ext. 4293.

5. IWF Grant: Incumbent Workforce Grant - Federal funding that may be available to established North Carolina businesses to help them educate and train current workers.

To qualify, a business must state that it is not currently receiving FIT or NEIT funds or services paid by such funds, is not eligible for FIT or NEIT funding, or that such funding is not currently available. Other restrictions and conditions also apply.

Details are available at http://www.nccommerce.com/workforce/incumbent_worker/guidelines_application.pdf.

Source: Glenn, Crystal of Catawba Valley Community College - Industrial Training. (2007). Personal Interview and Interaction.

Corporate Education: Industry and Manufacturing

Below is a partial listing of classes offered in the past or currently offered. If a business requests specific additional training it can be provided.

Reliability / Productivity

- Introduction to Lean Manufacturing
- Total Productive Maintenance (TPM)
- 5-S
- Office Kaizen
- Poka Yoke – Mistake Proofing
- Value Stream Mapping

Quality

- Implementing TS 16949: 2002 Quality Mgmt. Systems
- APQP Core Tools
- Internal Auditor Training (TL 9000, ISO 9000, TS 16949)
- Process Mapping
- Disciplined Problem Solving with 8-D
- Total Quality Transformation
- OJT Train-the-Trainer
- ISO 14001 Environmental Management

Continuous Improvement

- FMEA (Failure Mode and Effects Analysis)
- APQP (Advanced Product Quality Planning)
- PPAP (Production Part Approval Process)
- Measurement System Analysis
- GD&T (Geometric Dimensioning and Tolerancing)
- Root Cause Analysis using MJII
- Kepner Tregoe: Analytical Problem Solving
- TQT Series
- No Sweat! Statistics
- No Sweat! Blueprint Reading

Leadership / Management

- Operating Styles: Increasing Effectiveness at Work
- Team Leader Survival Skills
- SHL & Work Keys Job Assessments
- Achieve Global Supervisory / Manager Training
- DDI Supervisory / Manager Training

Source: Glenn, Crystal of Catawba Valley Community College - Industrial Training. (2007). Personal Interview and Interaction.

Focused Industrial Training Directory

College	FIT Contact	Telephone	E-Mail
Alamance CC	Jeff Bright	336-578-2002	brightjg@alamance.cc.nc.us
Asheville-Buncombe TCC	Ken O'Connor	828-254-1921	koconnor@abtech.edu
Beaufort County CC	Jack Pyburn	252-940-6311	jackp@beaufort.cc.nc.us
Bladen CC	Tim Nance	910-879-5627	jnance@bladen.cc.nc.us
Blue Ridge CC	Ramona Rogers	828-694-1751	ramonar@blueridge.edu
Brunswick CC	Velva B. Jenkins	910-371-2400	jenkinsv@brunswick.cc.nc.us
Caldwell CC & TI	Steve Melton	828-726-2200	smelton@caldwell.cc.nc.us
Cape Fear CC	Isobel Charlton	910-362-7050	icharlton@cfcc.edu
Carteret CC	Perry Harker	252-247-6000	plh@carteret.cc.nc.us
Catawba Valley CC	Crystal Glenn	828-327-7000	cglenn@cvcc.edu
Central Carolina CC	Ray Epley	919-718-7212	repley@cccc.edu
Central Piedmont CC	Alan Murdock	704-330-4657	alan.murdock@cpcc.edu
Cleveland CC	Chris Nanney	704-484-4117	nanney@cleveland.cc.nc.us
Coastal Carolina CC	Eddie Foster	910-938-6303	fostere@coastal.cc.nc.us
College of the Albemarle	Ed Olsen	252-335-0821	ejolsen@albemarle.edu
Craven CC	Dave Bauer	252-638-7234	bauerd@cravencc.edu
Davidson County CC	Robert Leslie	336-224-4551	roleslie@davidsonccc.edu
Durham TCC	Gordon Copeland	919-686-3563	copelandg@gwmail.dtcc.cc.nc.us
Edgecombe CC	Dan Grimsley	252-823-5166	grimsleyd@edgecombe.edu
Fayettevile TCC	Jack Hurley	910-678-8493	hurleyj@faytechcc.edu
Forsyth TCC	Thomas Jaynes	336-734-7705	tjaynes@forsythtech.edu
Gaston College	Diane Bartle	704-922-6448	dbartle@gaston.edu
Guilford TCC	Jerry Kinney	336-334-4822	Kinneyj@gtcc.cc.nc.us
Halifax CC	Vera Palmer	252-536-6376	palmerv@halifaxcc.edu
Haywood CC	Rinda Green	828-452-1411	rgreen@haywood.edu
Isothermal CC	Thad Harrell	828-286-3636	tharrill@isothermal.edu
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Johnston CC	Michael Starling	919-209-2082	starlingm@johnstoncc.edu
Lenoir CC	Bobby Merritt	252-527-6223	bmerritt@lenoircc.edu
Martin CC	George Anderson	252-792-1521	ganderson@martincc.edu
Mayland CC	Hans Aubuchon	828-765-7351	haubuchon@mayland.edu
McDowell TCC	Juanita Doggett	828-652-0652	jdoggett@mcdowell.mtcc.edu
Mitchell CC	Betty Scipione	704-878-3234	bscipione@mitchellcc.edu
Montgomery CC	Gary Saunders	910-576-6222	saundersg@mcc.montgomery.cc.nc.us
Nash CC	Carla Dunston	252-451-8324	cdunston@nashcc.edu
Pamilco CC	Jerry Prescott	252-745-7348	jprescot@pamlicocc.edu
Piedmont CC	Debra J. Seamster	336-599-1181	seamstd@piedmontcc.edu
Pitt CC	Lynn Creech	252-493-7216	lcreech@email.pittcc.edu
Randolph CC	Don Childers	336-633-0228	dnchilders@randolph.edu
Richmond CC	Herb Smith	910-582-7955	herbs@richmondcc.edu
Roanoke-Chowan CC	David Merrick	252-332-3211	dmerrick@roanoke.cc.nc.us
Robeson CC	Jo Ann Oxendine	910-272-3632	jaoxendi@robeson.cc.nc.us
Rockingham CC	Robert Justus	336-342-4261	justusr@rockinghamcc.edu
Rowan-Cabarrus CC	Donna Ludwig	704-216-3688	ludwigd@rowancabarrus.edu
Sampson CC	Kate Brown	910-592-7176	katiebrown@sampsoncc.edu

Sandhills CC	Alan Duncan	910-695-3769	duncana@email.sandhills.cc.nc.us
Southeastern CC	Beverlee Nance	910-642-7141	bnance@mail.southeast.cc.nc.us
South Piedmont CC	Todd Morris	704-290-5219	t-morris@spcc.edu
Southwestern CC	Keith Corbeil	828-488-6413	kcorbeil@southwesterncc.edu
Stanly CC	Ed Thomas	704-991-0396	Thomase@stanly.edu
Surry CC	Bennie Harris	336-356-5304	harrisb@surry.edu
Tri-County CC	Edward Smith	828-837-6810	ESmith@tricounty.murphy.edu
Vance-Granville CC	Garland Elliott	252-738-3288	elliott@vgcc.edu
Wake TCC	Bill Terrill	919-363-3330	wlterril@waketech.edu
Wayne CC	Joe McMichael	919-735-5151	mcm@waynecc.edu
Western Piedmont CC	Dr. Jim Benton	828-438-6102	jbenton@western.wpcc.edu
Wilkes CC	Jeff Shore	336-838-6206	jeff.shore@wilkescc.edu
Wilson TCC	Theresa Peaden	252-246-1258	tpeaden@wilstontech.edu

Source: http://www.ncccs.cc.nc.us/Business_and_Industry/fitstaffdirectory.htm

Local Area Workforce Directory for Counties in North Carolina

COUNTY	LOCAL AREA
Brunswick **Columbus** **New Hanover** **Pender**	**Cape Fear Workforce Development Consortium** 1480 Harbour Drive Wilmington, North Carolina 28401 Margie Parker (910) 395-4553 mparker@capefearcog.org
Johnston **Wake**	**Capital Area Workforce Development Consortium** Post Office Box 550 Raleigh, North Carolina 27602 Regina Crooms (919) 856-6040 rmcrooms@co.wake.nc.us
Durham	**Durham Local Area** 101 City Hall Plaza Durham, North Carolina 27701 Jim Wragge (919)560-4965 ext. 247 James.Wragge@durhamnc.gov
Anson, Cabarrus, **Cabarrus, Iredell,** **Lincoln, Rowan,** **Stanly, Union**	**Centralina Workforce Development Consortium** Post Office Box 35008 Charlotte, North Carolina 28235 David Hollars (704) 348-2717 dhollars@centralina.org
Mecklenburg	**Charlotte/Mecklenburg Workforce Development Consortium** 700 Parkwood Avenue Charlotte, North Carolina 28205 Deborah L. Gibson (704) 336-3952 dgibson@ci.charlotte.nc.us
Cumberland	**Cumberland County Local Area** Post Office Box 1829 Fayetteville, North Carolina 28302 Pat Hurley (910) 323-3421 patrick.hurley@ncmail.net
Davidson	**Davidson County Local Area** Post Office Box 1067 Lexington, North Carolina 27293 Pat Everhart (336) 242-2065 peverhar@co.davidson.nc.us
Carteret, Craven, **Duplin, Greene,** **Jones, Lenoir,** **Onslow, Pamlico,** **Wayne**	**Eastern Carolina Job Training Consortium** 1341 South Glenburnie Road New Bern, North Carolina 28562 Tammy Childers (252) 636-6901 childers@ecwdb.org

Gaston	**Gaston County Local Area** 330 N. Marietta Street Gastonia, North Carolina 28052 Julie Armstrong (704) 862-7931 jarmstrong@co.gaston.nc.us
Guilford	**Greensboro/High Point/Guilford County Workforce Development Consortium** 342 N. Elm Street Greensboro, North Carolina 27401 Lillian Plummer (336) 373-8041 lillian.plummer@greensboro-nc.gov
Caswell, Franklin, Granville, Person, Warren, **Vance**	**Kerr-Tar Interlocal Cooperative Consortium for Job Training** Post Office Box 709 Henderson, North Carolina 27536 Vincent Gilreath (252) 436-2040 vgilreath@kerrtarcog.org
Bladen **Hoke** **Robeson** **Scotland**	**Lumber River Job Training Consortium** 4721 Fayetteville Road Lumberton, North Carolina 28358 Dana Powell (910) 618-5533 dana.powell@LRCOG.dst.nc.us
Chatham **Harnett** **Lee** **Sampson**	**Mid-Carolina Local Workforce Investment Area** Post Office Drawer 1510 Fayetteville, North Carolina 28302 Denise Day (910) 323-4191 deniseday@mccog.org
Buncombe **Henderson** **Madison** **Transylvania**	**Mountain Local Area** Post Office Box 729 Asheville, North Carolina 28802 Helen Beck (828) 250-4760 helen.beck@ncmail.net
Camden, Chowan, Currituck, Dare, Gates, Hyde, Pasquotank, Perquimans, Tyrrell, Washington	**Northeastern Workforce Investment Consortium** Post Office Box 646 Hertford, North Carolina 27944 Carter C. Dozier (252) 426-5753 CCDozier@NCjoblink.org
Davie, Forsyth, **Rockingham, Stokes, Surry, Yadkin**	**Northwest Piedmont Job Training Consortium** 400 West Fourth Street, Suite 400 Winston-Salem, North Carolina 27101 Theresa Reynolds (336) 761-2111 treynolds@nwpcog.org
Montgomery **Moore** **Richmond**	**Pee Dee Region Workforce Consortium** Post Office Box 1883 Asheboro, North Carolina 27204 Janice Scarborough (336) 629-5141 JScarborough@RegionalCS.org

Cleveland **McDowell** **Polk** **Rutherford**	**Region C Workforce Development Consortium** Post Office Box 841 Rutherfordton, North Carolina 28139 Bill Robertson (828) 287-0262 brobertson@regionc.org
Alleghany, Ashe, **Avery, Mitchell,** **Watauga, Wilkes,** **Yancey**	**Region D (High Country) Workforce Development Consortium** Post Office Box 1820 Boone, North Carolina 28607 Carole Coates (828) 265-5434 ccoates@regiond.org
Edgecombe **Halifax** **Nash** **Northampton** **Wilson**	**Region L (Turning Point) Workforce Development Consortium** Post Office Drawer 2748 Rocky Mount, North Carolina 27802 Pamela Whitaker (252) 446-0411 pwhitaker@ucpcog.org
Beaufort **Bertie** **Hertford** **Martin** **Pitt**	**Region Q Workforce Investment Consortium** Post Office Drawer 1787 Washington, North Carolina 27889 Walter Dorsey (252) 974-1815 wdorsey@mideastcom.org
Alamance **Orange** **Randolph**	**Regional Partnership Consortium** Post Office Box 1883 Asheboro, North Carolina 27204 Janice Scarborough (336) 629-5141 JScarborough@RegionalCS.org
Cherokee, Clay, **Graham, Haywood,** **Jackson, Macon,** **Swain**	**Southwestern Workforce Development Consortium** 125 Bonnie Lane Sylva, North Carolina 28779 Vicki Greene (828) 586-1962 ext. 210 Vicki@RegionA.org
Alexander **Burke** **Caldwell** **Catawba**	**Western Piedmont Job Training Consortium** Post Office Box 9026 Hickory, North Carolina 28603 Sheila Dotson (828) 485-4218 Sheila.dotson@wpcog.org

APPENDIX

C Industry Training through SC Technical College System

Lean Training Series

- Principles of Lean Manufacturing: Tuition $325 (one-day course)
  Lean Office Tools: Tuition $325 (one-day workshop)
- Value Stream Mapping: Tuition $375 (one-day workshop)
- 5S Workplace Organization & Standardization: Tuition $375 (one-day workshop)
- Setup Reduction/Quick Changeover: Tuition $375 (one-day workshop)
  Total Productive Maintenance: Tuition $375 (one-day workshop)

Quality/Six Sigma Training

- Six Sigma Black Belt Certification: Tuition $4,850
- Six Sigma Green Belt Certification: Tuition $3,600
- Problem Solving/Root Cause Analysis: Tuition $350

Source: http://www.yorktech.com/industrial/lean.asp

Government Funding for Industrial Training

Industrial training funding is available through the Incumbent Worker Training (IWT) program. IWT provides funding for training needed in current businesses due to expansion, new technology, retooling, new product lines, and new organizational structuring. IWT may also fund training in new businesses if those jobs are ineligible for assistance through the Center for Accelerated Technology Training, a department of the South Carolina Technical College System.
To be considered for IWT funding, a business must:

- have at least one full-time employee;
- be current on all state tax obligations; and
- contribute to the overall cost of training.

Third party brokers (including business associations, industry councils, chambers of commerce, downtown development corporations, etc.) may enter into IWT agreements on behalf of employers but may not also be involved in the training of employees.
The following factors will be considered when determining funding priority:

- Businesses whose training applications indicate a significant upgrade in employee skills, and/or employee wage increases as a result of training
- Businesses whose training applications reflect a significant layoff avoidance strategy and retention opportunities
- Businesses/Business sites who have not received an IWT award during the prior or current program year

For further information concerning current fund availability and application procedures the specific Local Workforce Investment Area (LWIA) must be contacted.
Source: http://www.sccommerce.com/wia/incumbent.html

Local Workforce Investment Area Training Directory

Area	Contact
Catawba : York, Chester, and Lancaster counties	Robert Barker or Mary Ann McDow (803) 327-9041 rbarker@catawbacog.org mmcdow@ catawbacog.org
Greenville County	Dean Jones or Jayne Adams (864) 467-7220 dejones@greenvillecounty.org jadams@ greenvillecounty.org
Lowcountry: Hampton, Beauford, Colleton, and Jesper counties	Sandy Fowler or Shelly Campbell (843) 726-5536 sfowler@lowcountryog.org scampbell@lowcountryog.org
Lower Savannah: Aiken, Calhoun, Orangeburg, Bamberg, Barnwell, and Allendale counties	Samuel R. Jordan or Benella Floyd (803) 649-7981 sjordan@lscog.org bfloyd@lscog.org
Midlands: Fairfield, Richland, and Lexington counties	Bonnie Austin or Tammy Beagen (803) 744-1670 ext. 101 baustin@mwdb.org tbeagen@mwdb.org
PeeDee: Chesterfield, Marlboro, Dillon, Darlington, Florence, and Marion counties	Vickie Tyner or Joette Dukes (843) 669-3138 v-tyner@sc.rr.com j-dukes@sc.rr.com
Pendleton District: Oconee, Pickens, and Anderson counties	Julia Hoyle (864) 646-1827 jhoyle@worklinkweb.com
Santee/ Lynches: Kershaw, Lee, Sumter, and Clarendon counties	Les Thompson or Areatha Clark (803) 775-7381 ext. 120 lthompson@slcog.org aclark@slcog.org
Trident: Berkley, Dorchester, and Charleston counties	Paul Connerty or Christine Du Rant (843) 574-1815 paulc@toscc.org cdurant@charlestoncounty.org
Upper Savannah: Laurens, Newberry, Saluda, Greenwood, Abbeville, McCormick, and Edgefield	Sandra Johnson or Ann Skinner (864) 941-8055 sjohnson@uppersavannah.com askinner@uppersavannah.com
Upstate: Cherokee, Spartanburg, and Union counties	Ann Fesperman or Lynn Proctor (864) 596-2028 fesperman@upstatewib.org lynnproctor@upstatewib.org
Waccamaw: Horry, Williamsburg, and Georgetown	Shirley Graham or Doug Samples (843) 546-4231 sgraham29@yahoo.com dougsamples@yahoo.com

Source: http://www.sccommerce.com/wia/ApplyInfo.html