ABSTRACT

WAGONER, APRIL GAIL. Plant Floor Scheduling Systems in a Lean Environment. (Under the direction of Dr. George Hodge and Dr. Kristin Thoney.)

The objective of this study was to determine how companies in the US textile industry are using lean manufacturing practices in their planning and scheduling systems. The study uses primary and secondary data sources to explore the utilization of lean techniques in manual or automated planning and scheduling systems. In addition to a literature review, ten open ended in-person interviews with textile industry executives and three in-depth case studies were used to gather data. The case studies were conducted to further explore whether or not the use of lean principles can be applied to planning and scheduling systems in specific textile operations.

Many textile companies are interested in implementing lean scheduling systems for the plant floor but have not quite come to that point in their lean transformation. This study will provide examples, identify barriers and suggest solutions to the barriers for those companies who are on the path forward to implementation of lean planning and scheduling systems. Textile companies who are already using lean practices in their planning and scheduling systems are seeing improvements through reduced finished goods and work-in-process inventory, as well as less time and effort required by the production planners and schedulers to schedule the plant floor. A directory of planning and scheduling software that can handle lean concepts and is applicable to the textile industry was compiled as part of this research.

PLANT FLOOR SCHEDULING SYSTEMS IN A LEAN ENVIRONMENT

by

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BIOGRAPHY

The author, April Wagoner, was born in Charlotte, NC on December 10, 1981. In 2000, April began studying at North Carolina State University. In December of 2004, she received her Bachelor of Science degree in Textile Technology with a concentration in Textile Design and a minor in Design. In the fall of 2005, April returned to North Carolina State University to pursue a Master of Science degree in the Institute of Textile Technology program at the College of Textiles. She is currently completing the degree requirements for her graduate degree in Textile Management and Technology. April has accepted a job with General Motors in Warren, Michigan where she will begin her career as part of the General Motors Design Team.

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ACRONYMS

AGV	Automatic Guided Vehicles
APS	Advanced Planning and Scheduling
ASRS	Automatic Storage and Retrieval Systems
BOM	Bill of Materials
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CRP	Capacity Requirements Planning
CSM	Current State Map
EOQ	Economic Order Quantity
ERP	Enterprise Resources Planning
FMS	Flexible Manufacturing System
FSM	Future State Map
IT	Information Technology
JIT	Just-in-Time
MES	Manufacturing Execution Systems
MI	Manufacturing Intelligence
MIS	Management Information Systems
MRP	Materials Requirements Planning
MQM	Machine Queue Management
MRPII	Manufacturing Resources Planning
NCSU IES	North Carolina State University Industrial Extension Services
ROI	Return on Investment
RPG	Report Program Generator
SCE	Supply Chain Execution
SCM	Supply Chain Management
SCMEP	South Carolina Manufacturing Extension Partnership
TEI	Total Enterprise Integration
TMC	Toyota Motor Company
TPM	Total Preventative Maintenance
TPS	Toyota Production System
TQC	Total Quality Control
VSM	Value Stream Map
WIP	Work In Process

1 Introduction

The US textile industry is facing challenges with the global community. In order to stay competitive with overseas textile providers, there must be some changes in the way that products are manufactured. These changes may include reducing cycle times, reducing lead times and reducing waste. "Muda" is the Japanese term for waste and regards "any activity that consumes resources but creates no value" (Womack & Jones, 2003). Types of waste include extra steps unnecessary for manufacture, excess inventory or even excess distance traveled between manufacturing processes (Japan Management Association, 1989; Langenwalter, 2000; Santos, Richard, & Torres, 2006; Womack & Jones, 2003). Reducing waste and non-value added processes are the main goals of applying lean concepts to manufacturing practices in order to better satisfy the customer.

Lean manufacturing is a concept that stems from the Japanese manufacturing practices of Just-in-Time (JIT) and involves many different tools and methods such as 5s, kanban, cellular manufacturing and total quality control. Many different industries are reaping the benefits of applying lean concepts to their manufacturing processes and even extending the concepts into their supply chains. Companies in the aerospace, automotive and military industries are already in the advanced stages of becoming lean or have already been running lean operations for quite some time. However, the textile industry is slow to catch on to this idea. Some of the hesitation stems from the difficulty in adapting massive capital-rich equipment that continuously and efficiently produces inventory. Unfortunately, the continuous nature of these manufacturing processes produces excess amounts of inventory, seen in most textile warehouses and stock rooms in the form of a surplus of fabric rolls, packages of yarn or cans of sliver waiting to be shipped out or processed in the next step. Slowly, textile manufacturing companies are beginning to adapt lean principles into their operations. Even though textile companies may not be able to apply some lean concepts such as cellular manufacturing which involves moving machinery into work cells or simply moving machinery to create a better flow path, companies can still implement other lean concepts for pull type systems, such as kanban or supermarkets, that will help reduce the amounts of inventory.

In order for a company's lean operations to run smoothly, along with the correct methods and tools to convert the process to lean, the applicable planning and scheduling systems must be implemented, whether manual or automated. Manual planning and scheduling systems include MS Excel™ spreadsheets, scheduling boards and kanban tickets. Various forms of automated planning and scheduling software are available for manufacturing industries, some of which are specifically designed for textile applications.

In larger corporations, there are often two types of planning and scheduling processes that exist in manufacturing. At the highest level, the corporate location or headquarters will plan the production and capacity requirements for longer periods of time, for example one month or six months, using Material Requirements Planning (MRP) systems, Enterprise Resource Planning (ERP) systems or Supply Chain Management (SCM) systems. At a lower level, the manufacturing facility planning and scheduling process is where most often a scheduler will take the production requirements sent from corporate and break them down further according to their plants' specific machine availability. This process can involve a Manufacturing Execution System (MES), Advanced Planning and Scheduling (APS) systems, hand-made MS Excel™ spreadsheets, visual production or scheduling boards, or physically creating the schedule on a piece of paper. This research will cover both levels of planning and scheduling systems that are applicable in lean environments but will focus specifically on the lower level of plant floor planning and scheduling.

Many companies already use MRP and ERP systems; however, the software packages are not used in conjunction with lean principles. Often this is due to the MRP and ERP systems' inability to handle concepts such as line balancing, real-time inventory management, and kanban management. Some software companies claim to incorporate lean concepts into their existing MRP/ERP/SCM packages by offering new lean modules while others develop complete lean applications (Bartholomew, 2005). There also exists a mismatch between the principles of these automated planning and scheduling systems and lean concepts (Bartholomew, 2003; Crabtree, 2005; Gross & McInnis, 2003; Langenwalter, 2000; Womack & Jones, 2003).

Typically, automated planning and scheduling systems operate on push systems that try to predict customer requirements by pushing materials through a manufacturing facility so there will be finished goods inventory waiting on the customer (Langenwalter, 2000; Womack & Jones, 2003). Lean concepts, however, tend to operate on JIT pull systems where no products are produced until a downstream customer orders them (Langenwalter, 2000; Womack & Jones, 2003). In this situation, less inventory is created for both work-in-process (WIP) and finished goods materials.

1.1 Research Objectives

The main goal of this research is to determine which planning and scheduling systems are available to the textile industry that can also be used in lean environments. The research will identify the characteristics of advanced lean planning and scheduling systems that are currently available in the form of MRP, ERP, MES, APS, or SCM. In addition, the research will also address the issues of mismatch between the current automated planning and scheduling system capabilities and an organization's lean manufacturing processes and procedures. In addition to the automated planning systems, the manual systems will also be evaluated. By understanding the features of lean planning and scheduling systems, textile companies will be able to adapt their current systems or acquire new systems when necessary. The intent is to accomplish these goals through evaluating secondary and primary data sources. The specific research objectives to be answered in this study are:

RO1 Identify the degree to which US textile companies are using lean techniques in their manufacturing operations;

RO2 Identify what planning and scheduling systems US textile manufacturers are using;

RO3 Determine the barriers to using lean planning and scheduling systems in US textile companies;

RO4 Determine where the implementation of lean planning and scheduling systems would be best applied;

RO5 Determine the lean planning and scheduling software available to the textile industry and develop a systems directory; and

RO6 Determine the requirements of lean planning and scheduling systems to modify the existing Software Requirements Checklist.

1.2 Significance of Research

This research identifies the barriers and benefits that US textile companies face when implementing lean manufacturing techniques into their operations as well as the barriers and benefits they face when using lean planning and scheduling software. The following table is just one study's results of the Return on Investments (ROI) from implementing lean manufacturing systems.

Table 1.1 Lean Manufacturing Achievable ROI Improvements
Source: (Aberdeen Group, 2005)

ROI Item	Improvement
Lead time	Decreased from 2 weeks to 1 day
Customer delivery time	Decreased from 4 weeks to 3 days
Cycle time	Decreased by 50%
On time delivery	Increased to 100%
Inventory	Decreased by 50%
Productivity	Increased by 20%
Customer service levels	Increased from 80% to 95%
Equipment utilization	Increased from 52% to 90%
Revenue	Increased by 55%
Admin cost with work and purchase orders	Decreased 25% to 50%

Results much like these are possible to achieve with applicable planning and scheduling systems. For those companies that are already running lean operations, this research will aid in aligning their information technology with lean principles. All of these benefits may lead to dramatic cost savings. Cost savings lead to company profit and growth which will help US textile companies compete in this global economy.

An additional benefit from this research will be a directory of planning and scheduling software systems available for the textile industry along with a modified Systems

Requirements Checklist that includes requirements for planning and scheduling systems to be used in lean environments. The directory provides details of the automated planning and scheduling systems and the vendors. For textile operations interested in becoming lean manufacturing facilities, this research will aid in evaluating plant floor planning and scheduling systems that are applicable in their lean manufacturing operations.

2 Literature Review

Literature on the topics of lean manufacturing and plant floor planning and scheduling systems has been reviewed. Planning and scheduling is just one of the many areas affected when companies make the transition to lean manufacturing. For additional information on the numerous other methods and tools that can be used in the textile industry, refer to the study conducted by Kelly Goforth (2007) entitled *Adapting Lean Principles for the Textile Industry*. The main categories of this particular review will include lean manufacturing where basic background information and similar ideas of thought will be covered, and various types of planning and scheduling systems such as Materials Requirements Planning (MRP), Enterprise Resource Planning (ERP), Advanced Planning and Scheduling (APS), and Manufacturing Execution Systems (MES). This review will also provide a better understanding of what has been done before, what was successful, and what attempts are being made in lean planning and scheduling.

2.1 Lean Manufacturing

In the past, mass production was the method that a majority of manufacturers used to make the most money by running at the highest machine efficiency. This involved expensive equipment, a large amount of money tied up in work in process (WIP), and excess finished goods inventory (Sanchez & Nagi, 2001). The ways of the world are changing. Due to rising global competition and rising customer demands, operations no longer wish to have inflexible plants with excess inventory on hand. In order to stay competitive, companies are now trying to adopt manufacturing principles in which lead times and cycle times are shortened, quality levels are increased and excess inventory and other waste is decreased. These are the principles of lean manufacturing, and the resulting benefits will enable many US industries, including the textile industry, to become more competitive by better satisfying their customers, an essential component in today's global economy.

2.1.1 Background

Lean manufacturing tools such as cellular manufacturing, kanban, lean Six Sigma, 5S, total quality control (TQC), and various planning and scheduling systems improve the workflow in organizations by reducing non-value added processes and reducing waste. Lean thinking began roughly 50 years ago with the introduction of the Toyota Production System (TPS) used by Toyota Motor Company (TMC) in Japan to the US automotive industry (Womack & Jones, 2003). The Japanese used the idea of the US supermarkets and applied the concept to their manufacturing process to form the TPS. The actual "lean" terminology began in 1990 when James Womack, Daniel Jones and Daniel Roos coined the term "Lean Production" in their collaborative book *The Machine That Changed the World: The Story of Lean Production*. Their book discusses the transformation of the automotive industry from craft production to mass production to lean production (Womack, Jones, & Roos, 1990).

Lean manufacturing is not only the implementation of tools and techniques. It involves an adaptation at all levels of the company's workforce to the lean philosophy. Lean must involve a culture change and a new way of thinking, often referred to as lean thinking (Womack & Jones, 2003). Womack, Jones and Roos are some of the leading lean experts in the US. Together, they authored the book *The Machine That Changed the World* where the five principles of "lean thinking" were introduced. These five principles are:

1. Specify Value;
2. Identify Value Stream;
3. Make Value Flow;
4. Let Customers Pull; and
5. Pursue Perfection (Womack & Jones, 2003).

The fourth principle, “Let Customers Pull” deals with the scheduling aspects of lean manufacturing. A true lean manufacturing environment runs on a pull system where the customer sets the pace and no product is made until the customer places an order for it. The pull system is a key element of lean manufacturing which allows only the necessary amounts of inventory in process to satisfy customer demand.

Lean techniques may be applied to any stage of the supply chain, although results are often more easily seen in the manufacturing stage. This is due to the visibility of flowing or stationary product as well as the quantifiable nature of the activities in the manufacturing stage, such as inventory counts and cycle times. Lean office, lean product development, lean design, lean accounting and lean warehousing are all lean processes that are becoming more widely spread. For example, OPW Fueling Components’ Cincinnati, Ohio based manufacturing facility implemented lean concepts with a result, several years later, of 79% reduction in cycle time. Improvements like this can only fuel the desire to improve the entirety of a company. As a result of their drastic improvements from implementing lean in its manufacturing processes, OPW had an idea to implement lean concepts at its warehouses in hopes of receiving the same types of results. While lean manufacturing is finally known as a discipline, lean warehousing, in addition to the numerous other lean processes, is far from that widespread knowledge (Trebilcock, 2004).

As mentioned in the Introduction, lean manufacturing has an impressive ROI with quantifiable improvements in items such as cycle time, lead time, productivity, and inventory counts. For example, Blackhawk Automotive Plastics plant in Mason, Ohio was General Motor's largest supplier in 2002. In order to become GM's largest supplier, the company had to improve manufacturing processes. This was partly made possible by their recent implementation of lean manufacturing. For 12 months in a row, they had 100% on-time delivery, increased productivity by 15%, and decreased inventory levels by 25% (Forger, 2003).

Lean concepts can be applied to countless different industries in all stages of their supply chains. In addition to automotive, many other industries, such as healthcare, aerospace, food processing, hi-tech, service, logistics and construction, have begun to implement lean concepts into their operations. The textile industry is slowly catching on to the lean movement. With dramatic improvements in cycle-time, set-up time, inventory counts and more, the temptation to become lean is greater than ever.

2.1.2 Lean Terminology and Tools

Many different terms, such as agile or flow, are used synonymously with lean; however, they are all quite different. In order to become lean, various tools and techniques must be implemented in addition to the adoption of the lean philosophy.

2.1.2.1 Agile

Often "agile" manufacturing is considered quite similar to lean manufacturing; however Sanchez and Nagi (2001) claim that agile manufacturing is an overall strategy and lean manufacturing is a collection of operational techniques. Agile is used with constant change in an unpredictable environment and relies on resources from other operations, while lean relies on current resources (Sanchez & Nagi, 2001).

2.1.2.2 Flow

An additional common synonym is "flow." Flow may be used to describe the flow of information or the flow of materials through an operation. Womack describes "flow" as just one of the steps in the lean transition. Once the waste is eliminated, the next step is making the remaining processes flow (Womack & Jones, 2003). Often the idea of batch and queue methodology is used in manufacturing: perform all of one process for a given amount of product, and then move the finished batch to the next process. This departmentalized thinking is not always the best way of manufacturing in situations where when working on a product continuously from raw materials to finished goods may be more efficient. Henry Ford was one of the first people to utilize the concept of continuous flow. In the fall of 1913 he switched to continuous flow on the final assembly of the Ford automobile (Womack & Jones, 2003). This is a special case, however, with a high-speed assembly line where every product uses the exact same parts and thus is exactly alike. Taiichi Ohno then realized the real difficulty was in creating flow in situations where merely dozens or hundreds of a product were needed or in situations with low volume production. Ohno was able to achieve continuous flow by mastering "quick-change" by being able to quickly change tools from one product to the next. They also "right-sized" their machines, or decreased the sizes so different processing steps could be side by side with each other to achieve the best possible flow (Womack & Jones, 2003).

Still, many manufacturers are in the batch mentality because many feel it is obvious that work should be done in departments (Womack & Jones, 2003). Hesitation also comes from the fact that many manufacturing industries have expensive capital rich equipment that they feel must be in constant utilization in order to get the most efficiency. Womack and Jones (2003) claim that once a company switches to flow processing, they should see results that are similar to a 75% decrease in order processing time and a 90% decrease in physical production time of a product. With the production set up in a flow system, changes in demand are not as detrimental on a company because the line does not have to wait until the entire batch of one product is finished at any particular process. When the process is in flow mode, a company can make what the customer wants when they want it. They can let the customer start the "pull" process.

2.1.2.3 Push vs. Pull

Lean manufacturing uses the techniques of "pull" rather than "push." Pull is a way of moving inventory through the factory by signaling to a previous stage that replenishment materials are needed to make the next product (Womack & Jones, 2003). The signal in pull systems are kanban. In pull environments, less inventory is held but sometimes customer service suffers if the lead times are too long (Beamon & Bermudo, 2000). Push manufacturing systems make the products whether or not there is a need for them and are generally based on forecasting. This often causes a back-up in inventory at the particularly slower stages of the manufacturing process; however, customer service increases due to the abundance of available finished goods (Myers, 2005; Beamon & Bermudo, 2000; Russell & Taylor, 2003). Michel's (2002) article titled "Multiple Paths to Lean" explains how lean manufacturing operations work best by pulling small lots to meet the pace of customer demand rather than pushing lots out the door to meet the forecast.

The concept of push versus pull also arises when comparing current ERP and MRP systems with traditional lean concepts, such as JIT. Typically, automated systems were made to simulate push environments using demand forecasts to create production plans in anticipation of customer demand. The production plans of pull systems, as used in lean environments, are generated only when a customer places an order (Beamon & Bermudo, 2000; Langenwalter, 2000). This is a significant area of mismatch between most automated scheduling systems and lean concepts.

The information flow is also different in push and pull systems. Figure 2.1 shows that in push systems the information flow follows the flow of the product in the form of a production order and is triggered by the arrival of raw materials. In the pull system, the information flow is opposite of the product flow and is triggered by the last process's need for raw materials, or a kanban withdrawal signal (Karmarkar, 1991).

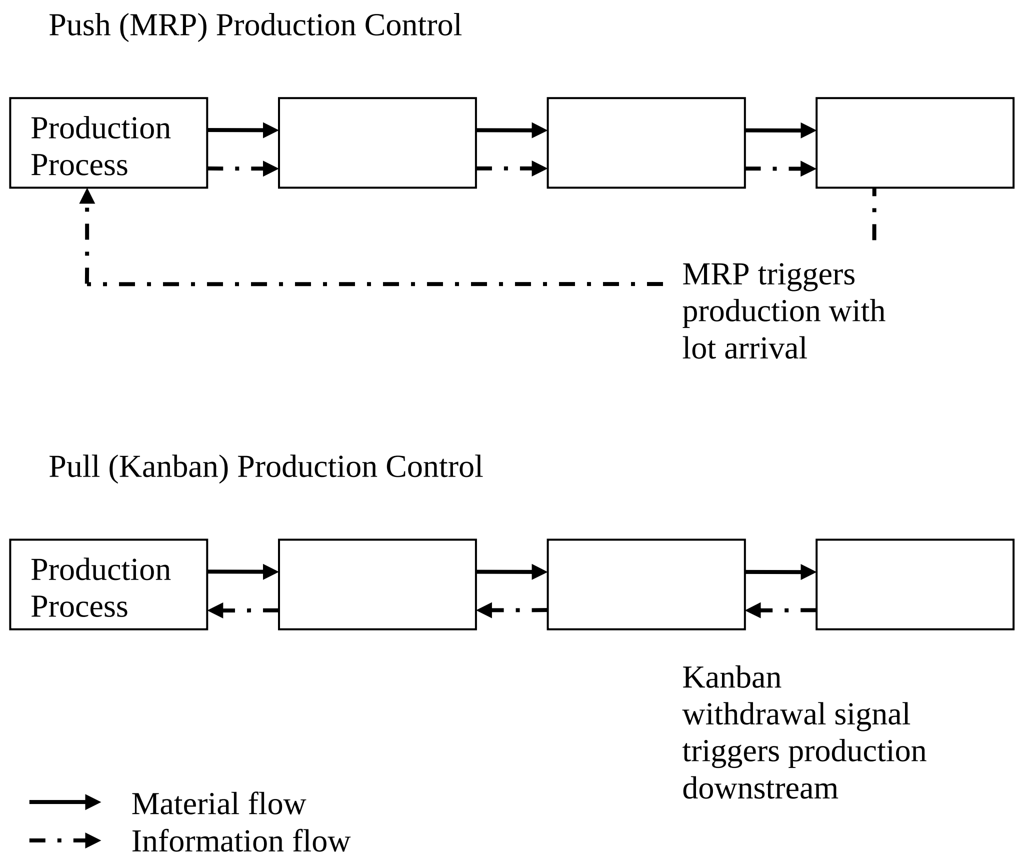

Figure 2.1 Material and Information Flow in Push and Pull Systems
Source: (Karmarkar, 1991)

In some situations, where true pull systems cannot be used due to products with fairly long lead times and variable demand, a combination of push and pull systems can be used. By combining push and pull systems, the negative high cost effects of holding inventory are lessened and customer service can still be maintained (Beamon & Bermudo, 2000). One automated solution for combining push and pull is discussed in the paper by Beamon and Bermudo (2000) titled “A hybrid push/pull algorithm for multi-stage, multi-line production systems” where they minimize the weaknesses of the two systems by combining the positive aspects of both. This type of combination of push and pull systems may be useful in the textile industry's supply chain where the stages may be individual textile processes inside a plant or individual stages of the supply chain.

2.1.2.4 Kanban

Kanban are pull production control strategies created by the Japanese. They are used to schedule production processes and are what some call demand scheduling due to the fact that the operators produce products based on actual usage, not on a forecast (Gross & McInnis, 2003). Kanban can be in the form of a card, ticket or some other type of physical or electronic identifying signal that is attached to a group of parts or products. This signal generates the pull of that part by signaling the production and delivery in preceding processes (Detty & Yingling, 2000; Gross & McInnis, 2003; Womack & Jones, 2003).

Electronic kanban (e-kanban) are becoming a popular variation from the original physical card that was once the ideal kanban signal for more products. In this highly electronic age and with the fast pace of information flow ever increasing, using an electronic signal for kanban may be the most efficient way of signaling for more product. For US discrete-parts manufacturers, a key element in lean manufacturing is said to be the electronic kanban program (Lean manufacturing: It's popular but not easy, 2006). E-kanban utilizes electronically encoded information in the same way the physical cards or signals are used. As the e-kanban passes through a scanning portal or is scanned with a barcode reader, the information is sent upstream and the replenishment order is created (Nicholas & Soni, 2006).

Cardless kanban systems, where no specific cards or tickets are used, are another possible variation of the traditional kanban systems. The signal becomes the empty container that once held the required lot size or it may be a visible line on the floor. When the empty container is visible or the line on the floor becomes visible, operators at the upstream process know they need to produce a kanban to replenish what was used (Nicholas & Soni, 2006). Even with the cardless kanban systems, there should still be information regarding the type and size of the kanban attached to the "signal" whether taped on the floor, as a free-standing sign near the product, or attached to the container.

2.1.2.4.1 Seven Step Process to Implementing Kanban

Gross and McInnis (2003) explain a seven step process for successful implementation of a kanban system into a manufacturing facility in their book *Kanban Made Simple*. The steps are:

1. "Conduct data collection;
2. Calculate the kanban size;
3. Design the kanban;
4. Train everyone;
5. Start the kanban;
6. Audit and maintain the kanban; and
7. Improve the kanban."

Gross and McInnis have included a CD-ROM with the *Kanban Made Simple* book which contains a workbook to be used as an aid in working through their seven step process of implementing kanban. The chapters in the workbook follow the chapters in the book which includes one chapter for each implementation step. The workbook also includes worksheets that can be used to conduct the data collection, calculate the kanban sizes, and design the kanban.

Before the seven step process begins, a cross-functional kanban team should first be formed. Team members should include production managers or supervisors, materials management, material handling/warehouse employees, and plant floor operators. Other useful team members may be from human resources, maintenance, engineering, downstream customers, and trainees for future kanban projects. A team leader should be chosen who understands the importance of the project. With the team, create group rules, member roles, and a schedule and budget for the action items. Gross and McInnis (2003) suggest that implementation should not exceed a month.

The first step of the process is data collection. Collect data about the number of parts produced by the process, change-over times, unplanned downtimes, and scrap levels for each product. Collecting the correct data will help with the kanban sizing calculations. Be specific and detailed about the data and analyze it after collection to ensure it is correct. An example data sheet from the workbook is shown in Figure 2.2.

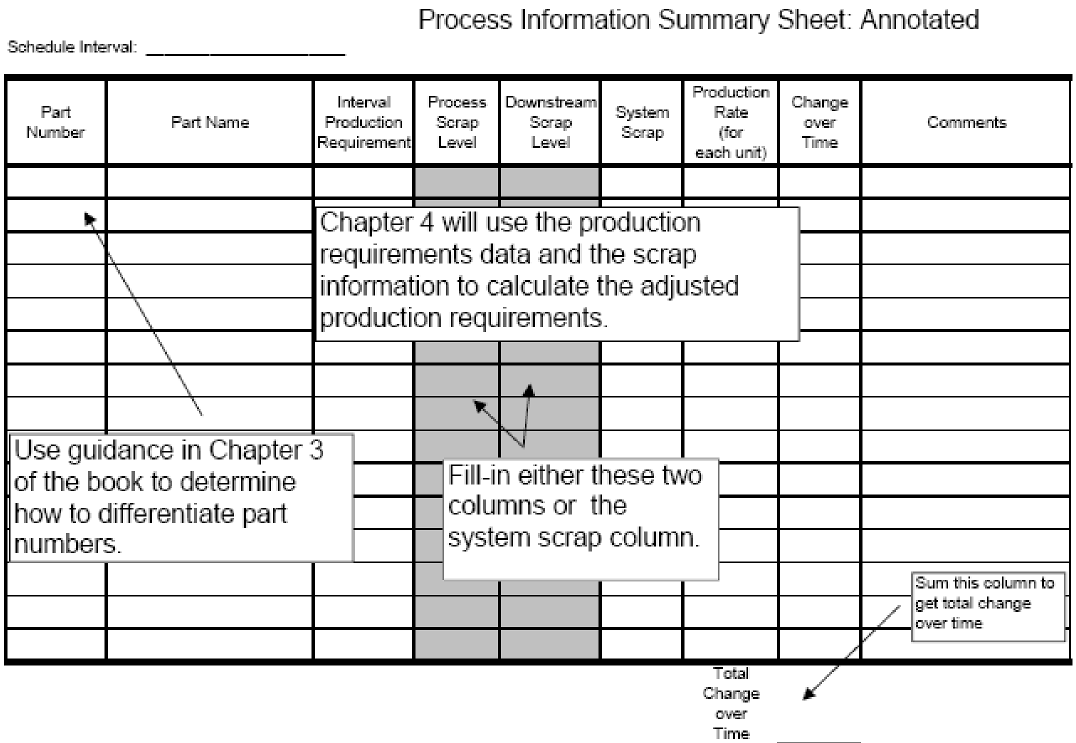

Figure 2.2 Process Information Summary Sheet
Source: (Gross & McInnis, 2003)

The second step in Gross and McInnis' seven step process to implementing kanban involves sizing the kanban, for supplier kanban as well as the production process. This means determining the number of containers for each product so the customer remains satisfied. This kanban calculation will be the maximum inventory level for the particular product or process for which the kanban system is being implemented. Three levels of the inventory will be identified. The red level means emergency, the yellow level means to schedule production, and the green level means normal. A summary of the equations used in *Kanban Made Simple* are shown in Figure 2.3. Gross and McInnis offer two different methods for determining the kanban quantities. One method determines the kanban quantity based on the current process data. This method utilizes more data collection and calculations but also allows the kanban quantities to be reduced, resulting in lower inventory levels. The alternative method uses the current schedule quantities to determine the kanban quantities. This method does not require as much data collection or calculations as the first method; however, the second method may not lead to inventory reductions. The book and workbook cover all of the equations and give examples for each step.

Summary of Kanban Sizing Equations

$$\text{Adjusted Production Requirments} = \frac{\text{Average Production Order}}{(1 - \text{System Scrap})}$$

$$\text{Adjusted Production Requirments} = \frac{\text{Average Production Order}}{(1 - \text{Process Scrap})\,(1 - \text{Downstream Scrap})}$$

$$\text{Available Time} = \text{Total Time in a Shift} - (\text{Planned and Unplanned Downtime})$$

$$\text{Available Time (Continuous Processes)} = \text{Total Time in a Shift} - (\text{Time for Planned Maintenance, Cleaning, and Breakdowns})$$

$$\text{Time Required for Production} = \text{Sum}\left(\text{Adjusted Production Requirements} \times \text{Cycle Time Per Part}\right)$$

$$\text{Time Available for Changeovers} = \text{Total Available Time} - \text{Time Required for Production}$$

$$\text{Replenishment Interval} = \frac{\text{Total Time } \textit{Required} \text{ for Changeovers}}{\text{Total Time } \textit{Available} \text{ for Changeovers}}$$

$$\text{Container} = (\text{Buffer Quantity} + \text{Replenishment Interval Quantity})$$

Figure 2.3 Summary of Kanban Sizing Equations
Source: (Gross & McInnis, 2003)

The third step in *Kanban Made Simple* is designing the kanban. Gross and McInnis make it clear that there is more to implementing kanban systems than simply figuring out the kanban quantities. The kanban system must be designed using three key points: determine what signals are to be used for the kanban, develop the rules for operating the kanban system, and create the visual management plans for the kanban system. The signals will enable the operators to know when to produce parts, change over products, and stop production. The signals will replace the production schedule. As previously mentioned, signals may be electronic, paper tickets, or containers. Rules for the kanban system may include the meanings of the scheduling signals, what to do if specific situations occur, and where the signals are placed and what information is included on them. Visual management should be used to visually instruct and remind all employees how the kanban system operates. The signals, rules, and visual cues must all be tailored to fit the specific company.

The fourth step is training employees. Gross and McInnis explain the flow of training should start with kanban basics, then proceed to kanban operations, kanban flow, kanban rules, and finally kanban "what if" examples.

The fifth step is deploying the kanban. Once the design is successfully implemented and the training is complete, the last step before starting the kanban system is checking the inventory. This is a final check to determine if the inventory levels will be sufficient to support the kanban implementation. Gross and McInnis cover several examples of common pitfalls that may occur when starting up the kanban system. Some of these examples are when production operators did not follow the signals or rules and the production operators and supervisors were not sure the kanban had started.

The sixth step is auditing and maintaining the kanban. When auditing the kanban system, look for missing signals, ensure that the inventory levels are correct, the operators and supervisors are following the signals and rules, and that the containers contain the correct amount of parts/products/pieces. The auditing process will help to keep the kanban system running successfully.

The seventh step is improving the kanban. The goal is to continually reduce the kanban levels. The best way to do this is to improve the process. Gross and McInnis' suggestions for improving the process include reducing change-over times, reducing scrap or waste, reducing downtime, reducing lead times and reducing the buffer and safety stock. When necessary, the kanban quantities need to be recalculated, and the process should cycle from there.

2.1.2.4.2 Additional Kanban Calculations

When implementing a kanban system, the correct number of kanban or the size of the kanban must be calculated for each particular product. There are numerous equations to determine the correct number of kanban needed for a pull process. Some companies utilize previous knowledge and historical information coupled with trial and error lot sizing. Other companies may use one of the varieties of kanban calculations available in the literature. Below are four additional examples of kanban calculations.

This first example calculation was given in a seminar by Dr. Thomas Greenwood on Lean Enterprises at the Institute of Industrial Engineers Conference in October of 2006.

# of Kanbans = $\left[\frac{D*U*RLC*(1+SF)}{K}\right]+C$

Where:
D = daily rate of production U = usage rate of component/product

SF = safety factor (percentage) RLC = replenishment cycle in days

K = quantity per container (kanban) C = replenishment lot size, C = order qty / K

Source: (Greenwood, 2006)

The second example calculation comes from Michael L. George's *Lean Six Sigma* (2002) book on combining lean principles with Six Sigma techniques.

Kanban (Max Strategic Buffer) = (Mfg Lead Time * Demand)
+ (Cycle Time Interval * Demand)
+ Safety Stock
+ Seasonality
+ (Transport Time * Demand)

Source: (George, 2002)

The next example comes from Nicholas and Soni (2006) in their book titled *The Portal to Lean Production: Principles and Practices for Doing More with Less*. In this book, the authors describe their journey through lean manufacturing by going through the process their companies took to become lean. One chapter deals specifically with the implementation of pull production using a kanban system.

$$K = \frac{\text{Replenishment Quantity + Lead Time Quantity}}{\text{Container Quantity}}$$

$$= \frac{\text{(Replenishment Interval + Lead Time Interval) Usage Rate}}{\text{Container Quantity}}$$

Where:

K = Number of kanban cards

Replenishment Quantity = Amount that must be produced each production run

Lead Time Quantity = Amount needed to satisfy demand during the lead time to produce part

Container Quantity = Number of pieces held in each container

Replenishment Interval = Fraction of days (assuming one shift day) between production runs for a part

Lead-time Interval = Time between posting a signal to begin a new production run and completion of the run

Source: (Nicholas & Soni, 2006)

The following example calculation was proposed by Chan and Tang (1996) which follows the original Toyota kanban calculation.

$$\text{Number of kanban (n)} = \frac{d_{ave}\ (t_w + t_{pc})\ (s)}{k}$$

Where:

d_{ave} = average daily demand t_w = waiting time

t_{pc} = processing time per container s = safety factor

k = container size

Source: (Chan & Tang, 1996)

Many different examples of equations are available; however, all deal with knowing a fairly exact demand or usage rate of the product. If demand is unstable, as is the case with many textile manufacturing companies, the calculated kanban quantity is most often modified by trial and error (Martin, 2006). Cimorelli (2006) mentions that kanban works best for products in a stable environment with predictable demand. However, he also says that kanban may also work with low-cost and low-volume products with somewhat unstable demand patterns because they can be protected with safety stock (Cimorelli, 2006).

The coefficient of variation (CoV) can be used to determine if a product should be placed on kanban. The coefficient of variation is found by dividing the standard deviation by the mean. A small CoV means a relatively small variability in demand, and a high CoV means a large variability in demand. Kanban would work well with products with a low or moderate CoV. High CoV products tend to require a larger amount of safety stock which can become expensive for costly products (Cimorelli, 2006). Cimorelli (2006) says if the high demand variation products are inexpensive, they may still be good candidates for a kanban system.

Limitations do exist when implementing kanban. As Nicholas and Soni (2006) discuss in their chapter on kanban, the human aspect of implementing kanban is more troublesome than the actual conceptual and physical aspects. They have found that employees tend to stray from the rules of the system and fall back into the old ways of manufacturing. Also problematic was the shop floor managers who reverted to taking the responsibility for the shop floor manufacturing, a concept far from that of a kanban system where the operators and the system itself are in control of the shop floor (Nicholas & Soni, 2006). Gross and McInnis (2003) also mention that the human is the person implementing is the biggest obstacle in kanban. The person implementing often tends to get lost in their fears of losing control of the process, running out of materials, or even the concern for operators lacking the abilities (Gross & McInnis, 2003).

Authors have determined key points and rules for successful and sustainable kanban systems. Gross and McInnis (2003) give seven key points for the successful implementation kanban are given. They are:

- "Size the kanban to current conditions;
- Adapt container size to allow flow;
- Make kanban signals visual;
- Develop rules that provide decision points plus checks and balances;
- Train the operators to run the kanban system;
- Set up audit plans to keep assumptions current and maintain system discipline; and
- Develop a phased improvement plan to reduce the kanban quantities" (Gross & McInnis, 2003).

Additionally, *Kanban Just-in-Time at Toyota: Management Begins at the Workplace* gives six rules for helping to keep a kanban system functional after implementation.

1. Do not send defective products to the subsequent process.
2. The subsequent process comes to withdraw products.
3. Produce only the quantity withdrawn.
4. Equalize production.
5. Kanban is a means to fine tuning.
6. Stabilize and rationalize the process (Japan Management Association, 1989).

In some situations, implementing a pull system is not the best option. Typically a pull system does not work best in the following situations:

1. Assembly variability (involving trials, matching, testing, adjustments) that does not support upstream demand;
2. Operations with lengthy or difficult setups that cannot be shortened and must be started before the pull signal;
3. Numerous product options for which carrying buffer stock for each option would be unfeasible;
4. Processes or products with a high level of defects that cause frequent interruptions;
5. Products that need to be produced in batches for quality control or certification;
6. Large disparities in cycle times between operation processes; and
7. Long periods of downtime resulting in long setups or unreliable equipment.

For these types of situations, a combination push/pull system may work best where the special situations are treated as outside processes and are scheduled using traditional systems (Nicholas & Soni, 2006). The other processes should utilize kanban if possible. Although the combination system is not an ideal lean manufacturing pull system, it is far better than pushing at all steps. Each company will need to modify lean manufacturing to fit their own process and operation characteristics.

2.1.2.5 JIT

Just-in-time (JIT) is a concept that requires using a pull system where a part is not manufactured until a preceding operation calls for it. It means to have the right product in the right place at the right time (Standard & Davis, 1999). The term was created by Kiichiro Toyoda, the first president of the Toyota Motor Company and the system was implemented by Taiichi Ohno (*Kanban Just-in-Time at Toyota: Management Begins at the*

Workplace, 1989; Womack & Jones, 2003; Gross & McInnis, 2003). With JIT, no excess inventory is produced and the optimal results are achieved in a continuous flow layout because parts in a preceding or upstream process are made right before they are needed and in the correct quantity by the succeeding or downstream process (Detty & Yingling, 2000; Langenwalter, 2000; Standard & Davis, 1999; Womack & Jones, 2003). The benefits of JIT are shortened lead time, reduced operations other than processing, reduced inventory and WIP, balanced processes, and clearly defined problems (*Kanban Just-in-Time at Toyota: Management Begins at the Workplace*, 1989; Standard & Davis, 1999; Gross & McInnis, 2003).

2.1.2.6 Heijunka

Heijunka is a Japanese term that means level loading or level scheduling. Heijunka is a tool used to create level, mixed production (Standard & Davis, 1999; Womack & Jones, 2003). The goal is to have customer orders distributed evenly throughout the production, but not necessarily at the same time. This helps the supplies to be used at a steady rate. Standard and Davis use a backyard barbeque example to explain the idea of Heijunka. One barbeque host may choose to cook the different types of meat in large batches where all hamburgers come out first; next they cook the hotdogs, and then the bratwurst. This situation satisfies all of the hungry guests (i.e., customers) who wanted a hamburger, but the hotdog and bratwurst customers had to wait until their batches were finished, and the hamburger customers who wanted seconds had to settle for a cold burger. This batch situation is good for the cook who only has to use one utensil at a time and the cooking times are uniform so the cook does not have to stay near the grill to continually flip the meat. In the second situation, a cook may choose to add meat to the grill according to what their guests are eating, for example, a few hamburgers, a few hotdogs and a few bratwursts are all on the grill at the same time. While this is less efficient for the cook due to having different cooking times for the meat and using different utensils, the guests are much more satisfied. Everyone gets what they want, when they want it. They do not have to wait or get poor quality food due to level, mixed loading of the grill (Standard & Davis, 1999). In this last situation the guest, or customer, is the primary focus just as in JIT and lean manufacturing.

2.1.2.7 The Seven Types of Deadly Waste

Muda, the Japanese term for waste, is any activity that consumes resources but creates no value (Santos et al., 2006; Womack & Jones, 2003). The goal of lean manufacturing is to reduce all types of waste in order to improve production and satisfy customers. Shigeo Shingo from the Toyota Production System identified seven types of waste that are most common to manufacturing factories. These types of waste are:

1. Overproduction;
2. Waiting;
3. Transportation;
4. Processing;
5. Stock (Inventory);
6. Motion; and
7. Making defective products (Japan Management Association, 1989; Langenwalter, 2000; Santos et al., 2006).

An additional source of waste not included by Toyota is employee underutilization (Forrest, S. of NCSU IES, 2007; Standard & Davis, 1999).

2.1.2.8 Value Stream Maps (VSM)

A value stream is the set of actions, processes or tasks, both value added and non-value added that occur to make a particular product or service. When these processes are documented, recorded or drawn out for evaluation, it becomes a Value Stream Map. The first step is to start with a current state and then brainstorm to come up with a future state map for how the company thinks the process should truly look (Nicholas & Soni, 2006). These maps are used to identify material flow and information flow using a standard set of icons to depict any given process or step in manufacturing a product (Nicholas & Soni, 2006). These processes may be value added, non-value added but necessary, or non-value added and unnecessary. Many companies underestimate the value of the VSM, but it helps to show the future goals of a company as well as encourage a new way of thinking and seeing the material and information flow throughout the process.

The value added processes are something the customer is willing to pay for, for example, warping and slashing yarn to prep for the weaving process. Non-value added but necessary processes do not necessarily add value to the product but must be carried out in order to complete the process, for example, waste water processing. Finally, non-value added and unnecessary processes are ones that the customer is not willing to pay for, for example, washing fabric twice when only once is required for the customer. These non-value added processes that the customer is not willing to pay for are simply waste, and the purpose of being lean is to reduce the waste and non-value added processes. Once the value stream is mapped out, the processes that clearly do not add value can be evaluated and possibly eliminated. Participants on the VSM team will then try to conceptualize a future state map representing the ideal way the process should be running. The VSM participants will create teams to work on projects in order to get closer to the future state map (Nicholas & Soni, 2006). Once the non-value added and wasteful processes are eliminated, the remaining processes are ready to become streamlined or made to flow.

Several calculations and process variables are required to create a VSM. These variables include inventory counts, takt time, cycle time, setup time, and machine planned capacity. For this reason, experts say that when conducting a VSM, it is best to choose a product or product family that is fairly high volume and is also currently running in the plant (Forrest, S. of NCSU IES, 2007). Each variable will be explained in the Value Stream Mapping Case Studies in the Section 4.2.4.

2.1.2.9 Kaizen

Kaizen is a Japanese term that means continuous improvement (Aberdeen Group, 2006d; Standard & Davis, 1999). Kaizen events are used to make continual improvements throughout a plant at the process or system level. Process improvements are more detailed and take place on the shop floor by the people who are involved in the specific process at hand. These types of Kaizen events may include reducing the setup times or tool layout. The Kaizen event is used to reduce the waste and non-value added steps in order to minimize the time needed to flow through the processes. The system improvements are generally broader in approach and focus on improving the flow through the entire value stream. Typically Kaizen events are done in less than a week, but an additional Kaizen improvement term, called Kaizen Blitz is when small improvements are made over a shorter period of time (Standard & Davis, 1999).

2.1.2.10 Product/Process Layouts

Product layouts, or assembly lines, are arranged according to the sequence of processes or functions required to manufacture a product. This manufacturing technique was invented by Ford and is based on orderly flow and efficiency and is suitable for mass production (Russell & Taylor, 2003; Womack & Jones, 2003).

Process layouts are used when machinery is grouped together according to the process or function they perform, e.g., grouping all of the drilling presses together. Logic may infer that this way is better for manufacturing because items are organized and departmentalized, however Womack says this type of structure restricts flow through a plant and is detrimental to lean manufacturing (Womack & Jones, 2003). In terms of continuous manufacturing, often where textile manufacturing is categorized, this technique is flexible however inefficient (Russell & Taylor, 2003).

2.1.2.11 Cellular Manufacturing

Cellular layouts combine aspects of both product and process layouts. The flexibility of a process layout and the efficiency of the product layout benefit are key aspects in becoming a lean manufacturing operation. When using cellular manufacturing, families of parts are processed together using groupings of dissimilar activities (Russell & Taylor, 2003). For example, a group of dissimilar machines are placed together to process an entire family of parts. The large manufacturing floor is subdivided into smaller, independent factories. This type of layout will reduce material handling, setup time, work in progress inventory, and is easier to control and automate. However, increased capital investment, expanded training and scheduling of workers, and poorly balanced cells are sometimes an unfortunate result.

James C. Myers, senior advisor of Lean Advisors, Inc. says that becoming lean is often easier for basic machining operations where the products are made one piece at a time. Machines in these types of operations are more often easily rearranged into cells for cellular manufacturing or set up for kanban and supermarkets where items can be pulled through the manufacturing line (Myers, 2005).

2.1.2.12 Lean Six Sigma

Lean Six Sigma combines the quality control efforts from Six Sigma with lean concepts. The theory is fairly new and stems from organizations trying to better satisfy their customers' quality specifications. Where lean strives to reduce waste, Six Sigma strives to improve process variability and product quality by having no more than 3.4 defective parts per million (Aberdeen Group, 2006a). In typical industries, having 99% of products without defects may be exceptional and an extremely difficult task, however, in industries such as the aerospace, medical and defense, this is not good enough. To be at the Six Sigma level, a company must achieve 99.99966% defect-free products (Aberdeen Group, 2006a). Six Sigma uses a structured problem solving approach called the DMAIC methodology (Define, Measure, Analyze, Improve, Control). This process is used to build quality into the product rather than inspecting quality after the product is manufactured (Detty & Yingling, 2000).

The Aberdeen Group's industry analysis of Lean Six Sigma was created in September of 2006. The analysis was conducted on 418 different companies in aerospace and defense, automotive, industrial products and other industries. The report revealed that 37% of the companies who responded were using lean and Six Sigma techniques together and only 20% of the respondents were using lean alone (Aberdeen Group, 2006a). Not only are companies struggling with the concept of implementing lean throughout the enterprise, they are also having difficulty with implementing Six Sigma projects throughout the enterprise as well. The Aberdeen Group also found a lack of Six Sigma principles throughout the supply chain. For example 16% of the companies were working on Six Sigma projects in their design departments, and only 8% of companies use Six Sigma in customer service (Aberdeen Group, 2006a).

2.1.2.13 5s

5s uses visual control methods of maintaining an efficient workspace where problems are clearly and easily identified (Detty & Yingling, 2000). The 5s stands for sort, stabilize, shine, standardize and sustain. Sorting is keeping what only is needed in the area. Stabilizing is identifying a particular place for each item so every person can find them, use them and return them to the correct place. Shining focuses on cleaning the work area and keeping it clean. Standardizing is the routine of maintaining the previous steps. Sustaining is using self discipline to enforce the entire system (Santos et al., 2006).

2.1.2.14 Inventory Control

Inventory control is an important key in lean manufacturing because large amounts of money is wasted and tied up in excess inventory, not to mention the floor space and warehouse space that can be better utilized. Inventory is one of Toyota's seven deadly types of waste. One of the goals of the Toyota Production System is to have zero inventory. Carrying zero inventory is unlikely, but it must be a goal for lean manufacturing. Once the inventory is reduced by half, the next attainable goal should be to reduce the remaining inventory by half, and so on. Pull systems greatly help to reduce inventory (*Kanban Just-in-Time at Toyota: Management Begins at the Workplace*, 1989).

Blackhawk Automotive Plastics now uses plastic totes to store their inventory rather than the cardboard boxes. Blackhawk also began storing the work-in-process molded parts inventory in "markets" next to the succeeding process. This change from storing the inventory wherever there was available floor space cut down on confusion of finding the correct work-in-process inventory and increased the organization of the plant (Forger, 2003).

2.1.3 Simulations for Implementing Lean Pull Systems

Detty and Yingling (2000) propose a tool, a discrete event simulation that will also aid traditional manufacturing operations in their adoption of lean manufacturing. Simulation will enable manufacturers to see the possible benefits and quantify the performance improvements before the implementation of lean practices as a persuasive method. Detty and Yingling, along with others have proposed various simulations in two categories. The simulations are used to establish the parameters of lean manufacturing system and to design, test, and improve lean manufacturing systems (Detty & Yingling, 2000).

Chan (2001) conducted a simulation study for implementing a kanban system in two different scenarios. The first is a pull system and the second is a hybrid push/pull system. In this simulation study, Chan tests the effects of varying the kanban size for a JIT manufacturing operation using the SIMPROCESS simulation package. The performance measures used were manufacturing lead-time, fill rate, in-process inventory and unsatisfied orders. The results in Table 2.1 show that an increase in kanban size will decrease the fill rate and increase the lead time for both single product scenarios, but will increase the fill rate and decrease the lead time for the multi-product scenario, which is more typical of a textile environment (F. T. S. Chan, 2001). Chan also says that there must be a trade off between the inventory levels and customer service performance measures of lead time and fill rate.

Table 2.1 Impact of Increasing Kanban Size on Performance Measures
Source: (F. T. S. Chan, 2001)

Performance Measures	**Pull System (Single Product)**	**Hybrid System (Single Product)**	**Hybrid System (Multi Products)**
Manufacturing lead time	Increase	Increase	Decrease
Fill rate	Decrease	Decrease	Increase
In-process inventory	Increase	Increase	Increase

Chan and Tang developed a simulation where the effects of a traditional push system, a pull system, and a hybrid push/pull system were compared (1996). For this study, the hybrid system, again, received the best rating (F. T. S. Chan & Tang, 1996).

Beamon and Bermudo (2000) developed a hybrid push/pull system that combines the aspects of JIT used in lean manufacturing with push based production systems. The possible weaknesses of creating extra inventory in a push system and of decreasing customer service in a pull system by are offset by combining both approaches into the hybrid push/pull system. Their model creates buffer stock for the first several stages of a multi-stage line by utilizing a push system (Beamon & Bermudo, 2000). The final stages utilize a pull system with the buffer stock, shown in Figure 2.4. A situation such as this may benefit the textile industry where the stages become individual processes inside a plant or individual stages of the textile supply chain.

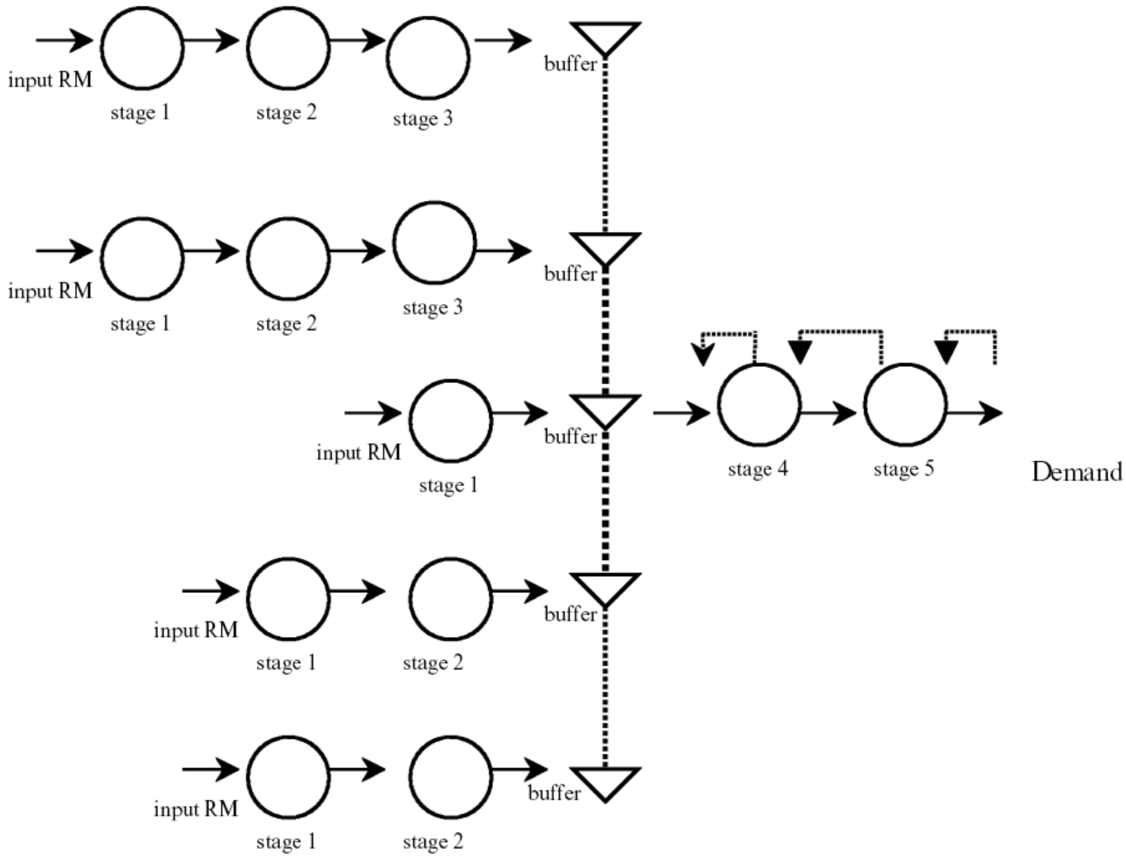

Figure 2.4 Combination Push/Pull System
Source: (Beamon & Bermudo, 2000)

2.2 Lean Enterprises and Supply Chains

Supply Chain Management (SCM) is managing the flow of goods and services throughout the supply chain (Russell & Taylor, 2003). Lean techniques should not be confined to one part of the supply chain. Companies should also have lean implemented in their entire organization. This involves using lean techniques in product development, accounting, and manufacturing of a company. Dr. Thomas Greenwood (2006) of Leanworks™ describes this concept of extending lean throughout one company's entire organization as having a lean enterprise. Each lean enterprise is then linked to their supplier and customer in order to convey information more smoothly and in a more timely manner. Langenwalter coined a new term, Total Enterprise Integration (TEI), which is “integrating all information and actions required to fully support a manufacturing company and its supply chain” (2000). TEI is necessary for a fully functional lean supply chain. In order for the enterprise to fully transition to lean, the correct information technology should be implemented that allows optimal communication between supply chain partners. In an integrated supply chain, each partner is linked, through information technology or other methods, to the same customer demand signal. The manufacturing plant may allow its supplier to have access to the production schedules. When this type of linking occurs, each partner in the supply chain is aware of the specific needs of the customer and can then build to demand (Aberdeen Group, 2006a; Ake, Clemons, & Cubine, 2004; Michel, 2002).

Having a lean supply chain will provide many benefits to all companies involved, including reduced paperwork, reduced waste and reduced costs between business partners (Langenwalter, 2000). However, members in the textile and other industries are not implementing lean concepts throughout the enterprise or supply chain (Aberdeen Group, 2006b). The Aberdeen Group’s Roadmap to Lean Success survey of 125 companies’ lean involvement conducted in June of 2006 shows in Figure 2.5 that only about one third of the survey participants have lean manufacturing programs and less than 20% of companies surveyed have yet to implement lean in their enterprise or supply chain (2006).

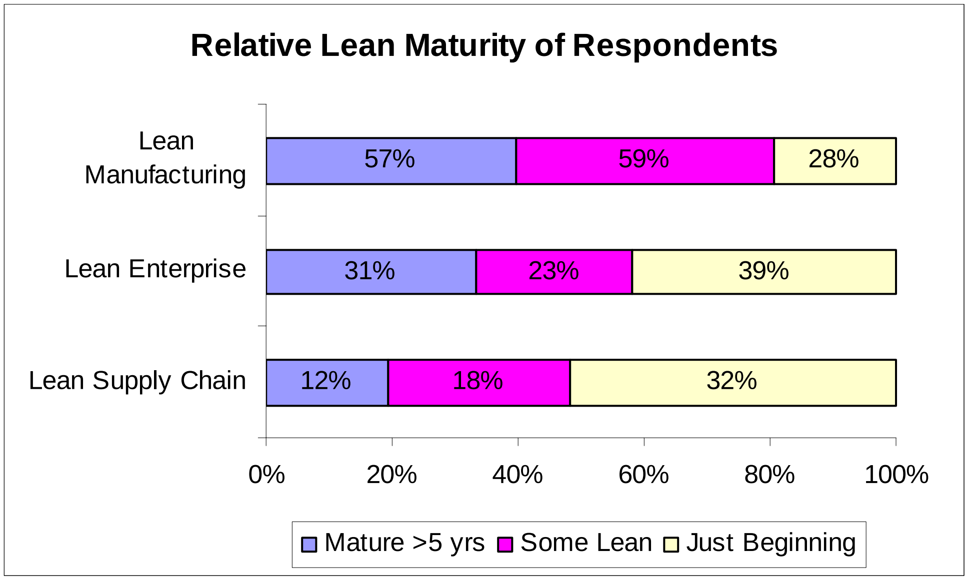

Figure 2.5 Relative Lean Maturity of Respondents
Source: (Aberdeen Group, 2006d)

The Aberdeen Group's Lean Supply Chain analysis of multiple industries says that many manufacturers are beginning to separate the lean philosophy from the tools and techniques used in manufacturing to apply the same philosophy with other tools and techniques in different parts of the supply chain (Aberdeen Group, 2006b). Still, there are limitations. In Figure 2.6, The Aberdeen Group's September 2006 Lean Supply Chain Report shows the top barriers to fully adopting lean principles throughout the supply chain (Aberdeen Group, 2006b). Many of these barriers are similar to those barriers seen when trying to implement lean on the shop floor.

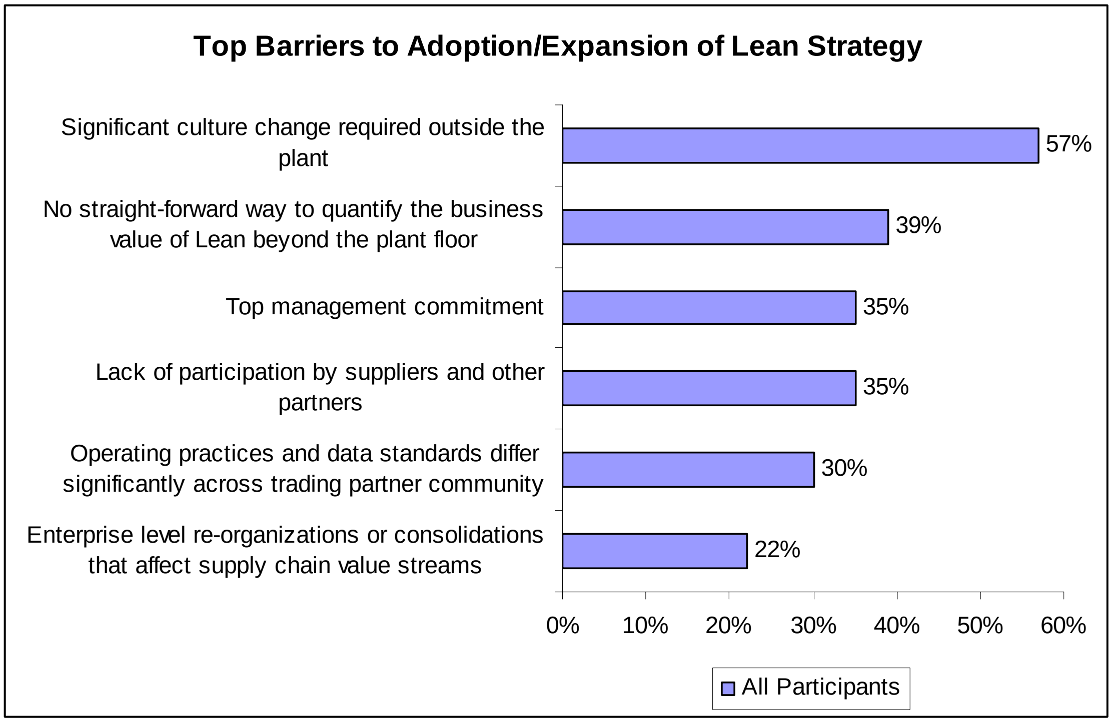

Figure 2.6 Top Barriers to Adoption/Expansion of Lean Strategies
Source: (Aberdeen Group, 2006b)

Lack of participation by suppliers is tied for the third most prevalent barrier. A company who has a lean manufacturing facility should not carry much inventory. Their supplier, however, if not lean, may have to carry extra inventory in order to provide what their customer requires. Suppliers may miss out on optimal business opportunities if they cannot promise their customers the products in an on-time manner, a task often made much easier with the implementation of lean manufacturing techniques. Companies involved in lean manufacturing have now begun to encourage their suppliers to also become lean and have begun helping them transform, while other companies are simply requiring their suppliers to be lean (Fabric manufacturing gets a new twist, 2003; Bacheldor, 2004a).

In addition to the planning and scheduling inside a plant, lean manufacturing also works best if the entire supply chain uses the same type of planning and scheduling system or one that is compatible with the other members of the supply chain's planning and scheduling systems. With similar and compatible systems in place, the fiber producer would be able to see what his customer's customer is ordering and prepare accordingly. Supply chain scheduling is used to integrate all of the various links of the supply chain together. An example of a textile supply chain is shown in Figure 2.7.

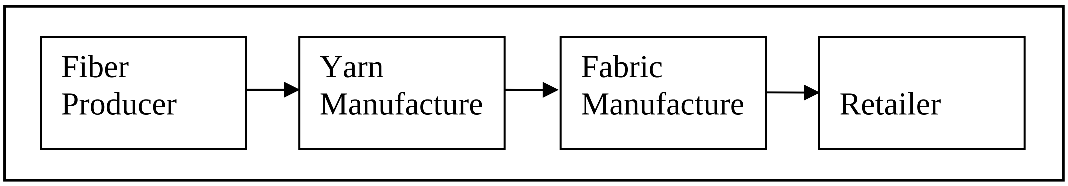

Figure 2.7 Textile Supply Chain

In each of these stages, information must be conveyed to ensure correct timing of orders. If a real-time relay of information is available to the suppliers regarding what their customer needs, there would not be a need for increased inventory waiting for a high demand period that may or may not come. For example, in order for the fabric manufacturer to be a lean organization, it may be necessary for the yarn manufacturer to hold extra inventory. This is useful to the fabric manufacturer, however costly for the yarn manufacturer. With the correct planning and scheduling systems in place, the need for holding excess inventory at one stage of the supply chain may be eliminated.

The following examples are of two integrated lean supply chains from the automotive industry. Guide, a manufacturer of automotive lighting systems, uses Factory Logic, a lean manufacturing software package that allows them to send their materials requirements directly to their suppliers (Bartholomew, 2003). With this system, Guide's supplier knows, in real time, exactly what the demand is, and can manufacture accordingly. Delphi Corporation is an automotive supplier who used lean manufacturing to decrease cycle times, improve on-time delivery, productivity and quality. Nelson, VP at Delphi Corporation, implemented a program which entitles their suppliers to their manufacturing secrets. Delphi helps their suppliers identify waste, map their manufacturing processes, and even helps with financial data and cost analyses. This sharing of information saved the company money and time involved in production stops from poor supplier quality, which improved by 34% (Bacheldor, 2004b). By ensuring Delphi Corporation's supplier was included in their lean program, as well as the information flow, the company's lean transformation was a success.

2.3 Information Technology

With the ever-improving ease, adaptability and speed of computers and programmable software, it is highly unlikely that any major operation does not use some type of information technology (IT). IT is a popular method for operations to assist in planning and scheduling as well as improve their processes (McClellan, 1997). Some lean leaders have once said that lean and IT are incompatible and should not coexist (Crabtree, 2005; Michel, 2002). Another opinion is that these technology solutions should be used together with lean concepts and that the technology solutions do not have to replace the traditional lean concepts (Aberdeen Group, 2006d; Bartholomew, 2003; Crabtree, 2005). Various methods of IT are used in the manufacturing industry; for example, the Internet, Computer Aided Process Planning, Management Information Systems, Automated Material Handling, Flexible Manufacturing Systems, and Computer Automated Manufacturing.

The Internet has greatly helped all industries through the use of web-based technologies. By utilizing the Internet and web-based technologies, companies are able to quickly respond to customers and suppliers, link or integrate automated systems with customers and suppliers and also provide access to information around the clock. With information and access so readily available to customers, companies need to be able to react quickly in order to meet the customers' requirements. Manufacturers are choosing to adopt lean concepts into their manufacturing practices and they require systems that can handle the flexibility, complexity, and urgency needed to satisfy the customer demands.

Computer Aided Process Planning (CAPP) is specialized process planning software that can be modified by an engineer when necessary for the production of new parts. A variant or generative system may be used, where the variant system allows for modification of the program and generative systems are created from scratch (Russell & Taylor, 2003). Management Information Systems (MIS) and Manufacturing Intelligence (MI) are used to move all types of information throughout an organization (Aberdeen Group, 2006c; Russell & Taylor, 2003). These systems are important for real-time data transfer, which is imperative for lean planning and scheduling systems. Automated material handling systems such as automatic guided vehicles (AGV) and automatic storage and retrieval systems (ASRS) are used to improve the flow throughout the manufacturing facility. Flexible Manufacturing System (FMS) uses programmable tools and machinery that enables the processes or routines to quickly change according to demand or the product manufactured. These systems are connected by the Automated Material Handling Systems and controlled by computer networks. Computer aided manufacturing (CAM) uses computers to aid in the manufacturing processes.

IT is able to help in lean manufacturing by aiding in sequence control, calculating and recalculating the supermarkets and kanban containers and sizes, creating direct links or integrating between sales, production and supply resources, and shipping, responding to changes in demand, implementing schedules and providing visual information which aids in decision making. Some software vendors have added lean modules into their existing packages and other have created lean-specific applications (Bartholomew, 2005).

2.4 Planning and Scheduling Systems

The terms planning and scheduling are often used synonymously; however, the two are quite different. Planning is the term used to determine the long range needs for manufacturing and takes into account the different conditions that may occur such as overtime, capacity changes, and changing due dates (Pekny, Dr. Joseph F., 2005). Scheduling is typically used to determine in what fashion the manufacturing will be accomplished by determining the timing and location of particular activities to meet a set of orders or customer demand. The two tasks are most effectively achieved using the same or closely related tools (Pekny, Dr. Joseph F., 2005). Planning and scheduling systems are not only important on the plant floor, but also throughout the entire supply chain. Some of these scheduling systems are custom made, tailored to the specific industry, or the software may be a generic package.

In their September 2006 supply chain study of 308 companies from the aerospace and defense (A&D), automotive, high-tech, industrial products and other industries, the Aberdeen Group has shown that more and more companies are using automated planning and scheduling systems. In Figure 2.8, The Aberdeen Group shows that around one third of companies involved in lean are still using MS Excel™ and about 10-15% are using pencil and paper methods for planning and scheduling the shop floor (Aberdeen Group, 2006b).

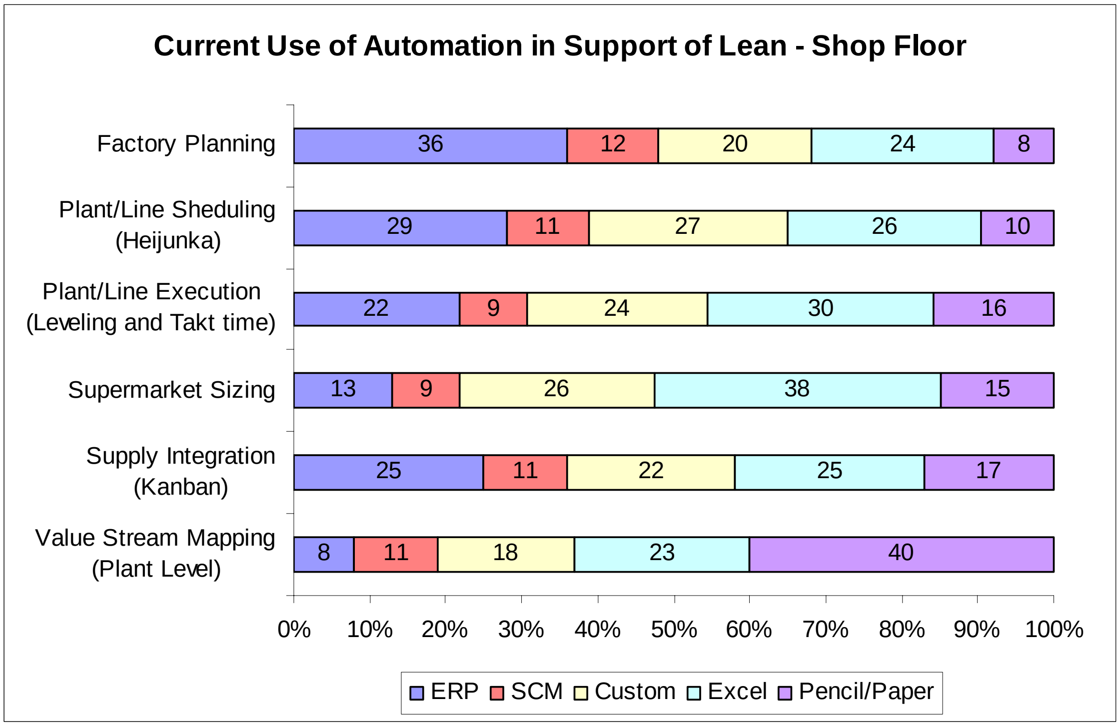

Figure 2.8 Current Use of Automation in Support of Lean - Shop Floor
Source: (Aberdeen Group, 2006b)

2.4.1 Automated Planning and Scheduling Systems

Electronic facility-wide planning and scheduling systems have evolved from the original Materials Requirements Planning (MRP) to Manufacturing Resource Planning (MRPII), and now to enterprise-wide Enterprise Resource Planning (ERP) systems. Although most companies now use MRPII or ERP systems, employees still refer to their systems as “MRP” (Cheng, 1997). The latest version of facility-wide terminology is Total Enterprise Integration (TEI) created by Langenwalter (2000) which is a fully integrated system that combines all information and actions necessary to maintain a manufacturing operation and its supply chain. Planning and scheduling systems that involve the plant floor use manufacturing execution systems (MES) and Advanced Planning and Scheduling (APS) systems. Ake, Clemons, and Cubine depict how each of these systems has some overlapping capabilities in Figure 2.9.

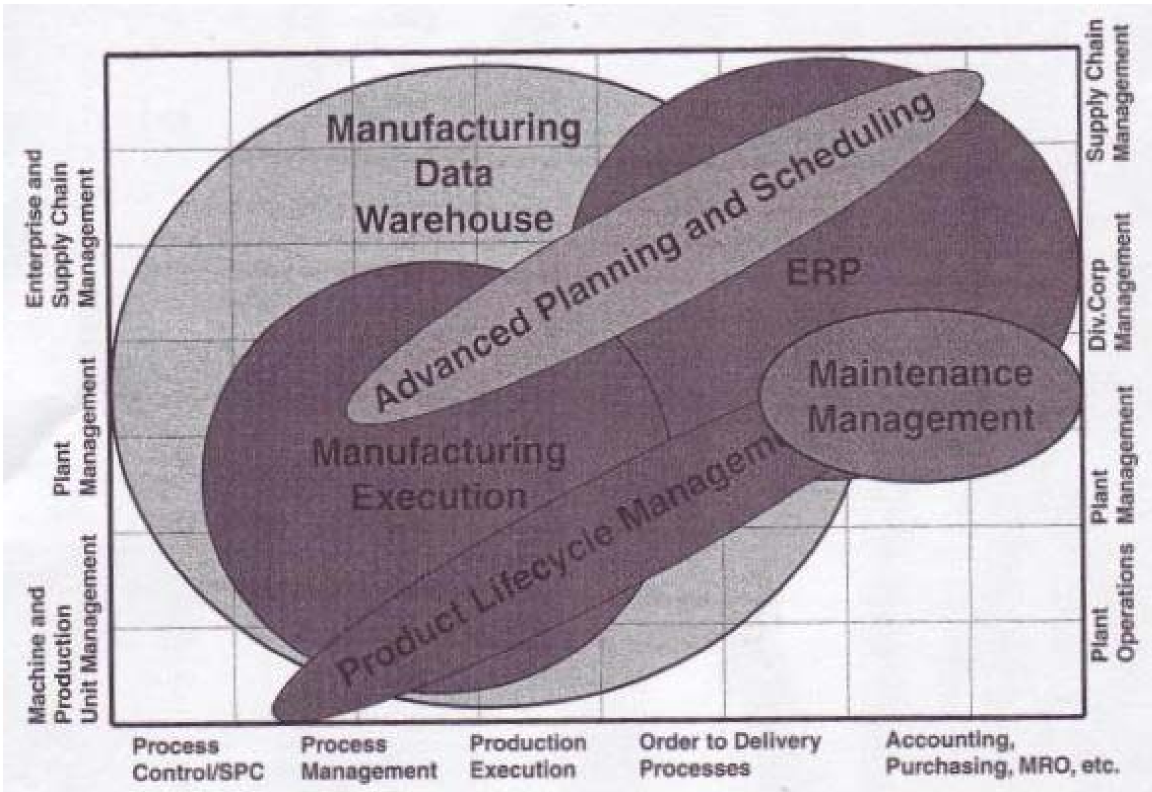

Figure 2.9 Overlapping System Capabilities
Source: (Ake, Clemons & Cubine, 2004 – Adapted from AMR Research)

2.4.1.1 Material Requirements Planning (MRP)

Material requirements planning systems were developed in the 1970s as inventory control and production planning systems that calculated the demand for component items of products while keeping track of their work orders and purchase orders (Russell & Taylor, 2003). By 1981 there were over 8,000 MRP production control systems available (Standard & Davis, 1999). Today, however, the majority of users are not satisfied with their system due to resulting parts shortages and late deliveries to customers. These shortcomings stem from companies using their MRP systems as a form of production control, rather to than plan materials (Standard & Davis, 1999). The MRP systems tell what product is on hand and how much is needed to fill the order and stay on schedule (Ake et al., 2004). MRP uses a Master Production Schedule for demand, inventory status, open orders from the shop floor, planned orders from the shop floor, and the Bill of Materials (BOM) to ensure the plant has the right quantities of the right parts at the right time and affects many functions of manufacturing (Langenwalter, 2000). Langenwalter uses a visual to describe all functions which are affected by MRP systems seen in Figure 2.10. One of the biggest weaknesses of MRP is that it assumes infinite capacity for both the company using the systems and its suppliers (Langenwalter, 2000). Infinite capacity scheduling loads resources with no regard to their capacity constraints (Russell & Taylor, 2003). One solution to this is for a company to use a Capacity Requirements Planning (CRP) module which predicts capacity problems. CRP does not handle any of the scheduling, but the planners and schedulers may use it to help make decisions (Langenwalter, 2000). In dynamic scheduling environments, a higher, more sophisticated level of scheduling that is not typically available in most MRP systems may be required (Russell & Taylor, 2003). Another solution is for companies to use Advanced Planning and Scheduling systems, which will be discussed in section 2.4.1.5.

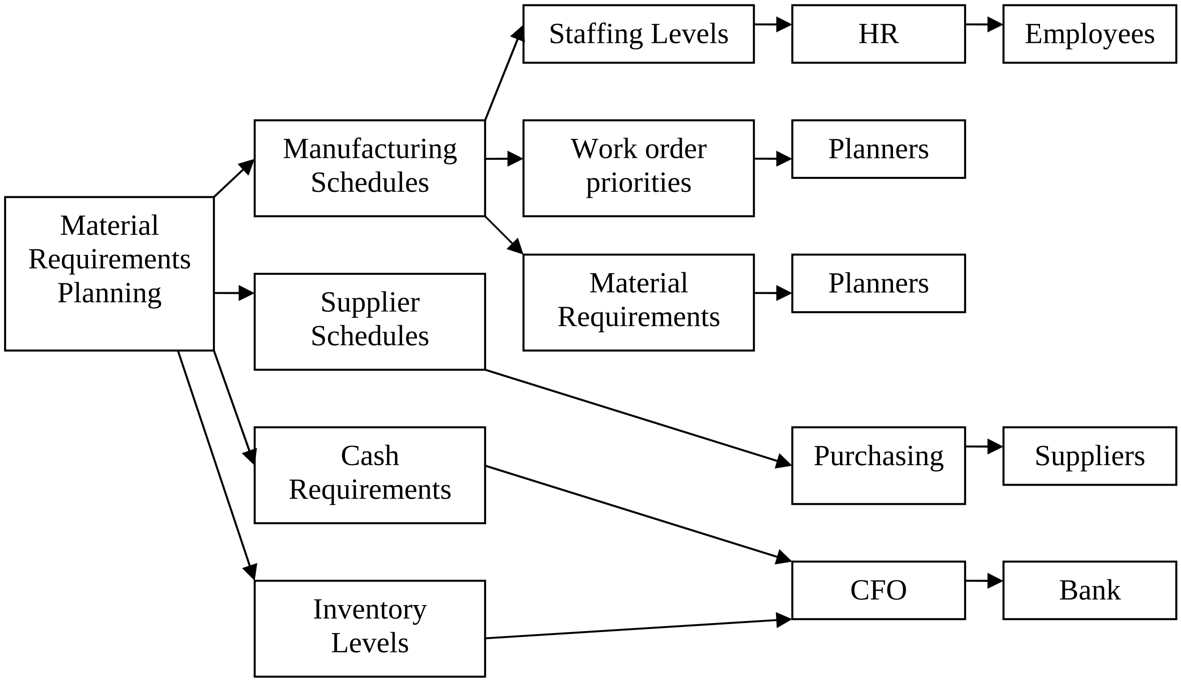

Figure 2.10 Functions Affected by MRP
Source: (Langenwalter, 2000)

2.4.1.2 Manufacturing Resources Planning (MRPII)

MRP evolved into Manufacturing Resources Planning II in the late 1970s and by the early 1980s, MRPII systems were being used to combine the material planning and the shop floor with the business functions such as accounting and purchasing (Ake et al., 2004; Langenwalter, 2000). MRPII systems soon evolved into ERP systems when additional functions were added. Many ERP systems encompass the functions included in MRP and MRPII systems. Figure 2.11 shows the functionality comparison between these systems.

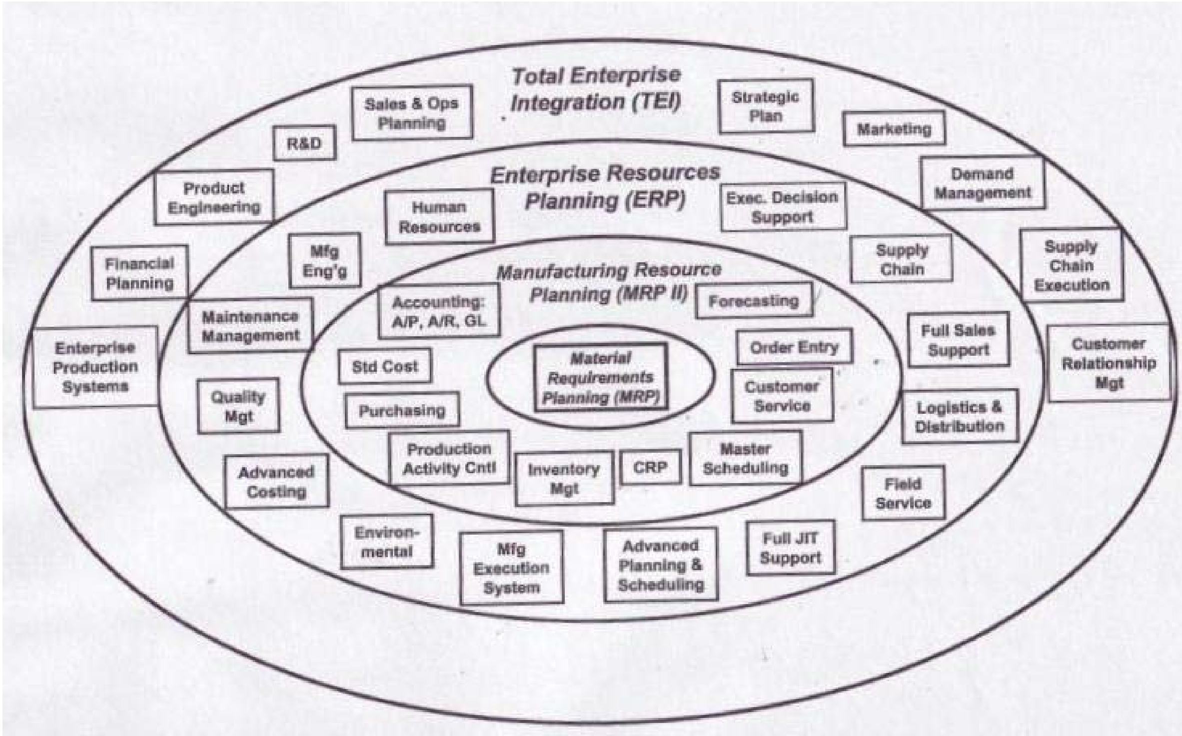

Figure 2.11 MRP, MRPII, ERP, and TEI Functionality Comparison
Source: (Langenwalter, 2000)

2.4.1.3 Enterprise Resource Planning (ERP)

ERP systems were developed in the 1990s and combined even more functions, such as logistics and distribution, human resources, manufacturing engineering, maintenance management, manufacturing execution systems and advanced planning and scheduling systems (Bartels, 2004; Langenwalter, 2000). Numerous systems are on the market and due to the popularity of the lean terminology, a large portion of ERP systems claim to use lean principles. Langenwalter (2000) proposed a list of capabilities ERP systems should have in order to be compatible with lean concepts, seen in Section 2.4.3. The benefit of having an ERP system is that companies achieve a high level of functionality. For larger companies, it is important that systems at the plant level and systems at the corporate level are able to integrate. This will allow information from the plant to be sent back to the ERP system and vice versa (Ake et al., 2004). Today, the MRP functions still exist but they are typically included in the ERP system's capabilities. They focus on individual plant operations, where the ERP systems manage the entire enterprise's resources.

2.4.1.4 Manufacturing Execution Systems (MES)

In the 1970s, the shop floor requirements from the MRP system were sent to the shop floor in the form of dispatch and priority lists from a shop floor system. Due to the MRP information being late or inaccurate, there was a large gap between the planning systems and the actual shop floor execution (Langenwalter, 2000). Manufacturing Executions Systems (MES) are used as on-line, integrated systems to communicate to the shop floor and to help make decisions about production. They manage work orders, maintain material use and material status information, and collect data to be put into the context for real-time decision making as well as historical analysis (Ake et al., 2004; Russell & Taylor, 2003). Because MES systems are real-time, they can relay minute-to-minute changes on the plant floor, where the traditional MRP or ERP respond less frequently. Langenwalter (2000) suggests that the MES systems are the optimal way to schedule operations which cannot use kanban or pull systems.

The difference between MRP systems and MES systems is that where MRP is more of a planning tool, MES may include changing order priorities, assigning and reassigning inventory, moving inventory to and from workstations, managing the production process, and scheduling and rescheduling machines (Langenwalter, 2000; McClellan, 1997). MES systems also have "exception management" where the systems have the ability to respond to raw material shortages and machine breakdowns. When an exception occurs, the MES system will reschedule orders or re-route the product flow.

Langenwalter discusses a new combination of plant floor systems which integrate the plant floor functions, control and the MES, called Enterprise Production Systems (EPS). This is similar to the evolution of the ERP systems which integrate many different planning functions (Langenwalter, 2000). For more information on MES, refer to McClellan in *Applying Manufacturing Execution Systems* (1997).

2.4.1.5 Advanced Planning and Scheduling (APS)

Advanced planning and scheduling systems are used to help manufacturers optimize schedules for either the plant floor of a single plant or they may have the ability to schedule multiple plants and warehouses. The latter, more advanced APS is typically called a Supply Chain Execution (SCE) system. APS uses finite capacity scheduling that assumes a fixed capacity for resources and will not load more than that resource's capacity (Russell & Taylor, 2003). These APS systems use many techniques such as linear programming, advanced mathematical formulas, heuristics and rules to create the best schedule for the manufacturing processes (Langenwalter, 2000; Russell & Taylor, 2003). APS systems have the ability to simultaneously take into account capacity and material constraints when generating the production schedule. Preactor, Taylor Scheduling Software, and DATATEX are examples of software vendors that provide APS systems specifically designed for textiles operating in a lean environment. Often, companies will either develop their own finite scheduling software, or purchase APS systems as an add-on to their current ERP systems (Russell & Taylor, 2003).

2.4.1.6 Aberdeen Group's Best of Breed Software Systems

Some of the basic principles of Lean/Flow Manufacturing Software include line design, demand smoothing, kanban management, engineering changes coordination, method sheets and product costing (Owen, 2000). Factory Logic, PeopleSoft and Pelion were three software vendors that were included in Aberdeen Group's Best Practices in Lean study (Aberdeen Group, 2005).

2.4.1.6.1 Factory Logic

Factory Logic, recently acquired by SAP in December of 2006, is an ERP system that has built their entire Factory Logic Lean Operations software suite around lean concepts. Factory Logic is often used in the Automotive, High-Tech, Aerospace & Defense industries for implementation during the early stages in the lean transformation as well as for companies who are already well defined in their lean transformation (Factory Logic, 2005). Guide Corporation is an automotive lighting company who uses Factory Logic's Streamline system in some of their plants to run the plant floor by monitoring their numerous kanban and generating schedules hourly (Bartholomew, 2003). Factory Logic has been referenced as lean software in Aberdeen's Best in Class Case Study (Aberdeen Group, 2005). The modules offered in the Lean Operations Suite are the Pacemaker Scheduler, the Production Synchronizer and the Supply Synchronizer (Factory Logic, 2005; Michel, 2002).

2.4.1.6.2 PeopleSoft

PeopleSoft has recently upgraded their EnterpriseOne software. EnterpriseOne is to be used in lean environments and now has tools which allow companies to build to demand, rather than build based on forecasts. The software is based on real-time inventory alerts and production schedule sharing from the supplier to the customer. Included in the upgrade is also a kanban lean manufacturing procurement module. This will allow for pull based replenishing during each stage of assembly. Also included is a demand scheduling execution application that works with manufacturers' and customers' forecasts and schedules (Bacheldor, 2004b; Michel, 2002).

2.4.1.6.3 Pelion Systems

Pelion Systems' answer to lean manufacturing software is the Collaborative Flow Manufacturing (CFM) package. The system comes with an ERP integration toolkit so that existing ERP, MRP and APS applications may be used with the package. Pelion is designed to work with current systems as not to replace or significantly customize them. They have designed the software to work in many different languages to respond to today's global community. The lean aspects of Pelion are Lean Metrics and Dashboards, Lean Six Sigma Data Management, and Lean Program Management. The Lean Metrics and Dashboards operate in real-time and track manufacturing lead-times, inventory control, labor cost reductions, delivery reliability and increased gross margins and market share. Lean Six Sigma Data Management performance manager allows the lean initiatives to be aligned with Six Sigma initiatives as well, including designing more capable processes. Lean Program Management operates in real-time using tools to streamline the processes and to eliminate waste and unplanned process problems, all to help increase the customer satisfaction level (Michel, 2002; Pelion Systems Inc., 2006).

2.4.2 Manual and Visual Planning and Scheduling Systems

In addition to the automated planning and scheduling systems, companies are also using manual and visual planning and scheduling systems (Aberdeen Group, 2006b). Manual systems include MS Excel™ spreadsheets or MS Access™ databases and scheduling with pencil and paper. Visual systems include kanban and visual production or scheduling boards. Kanban works as a pull system where tickets or cards are used to identify an upstream process that materials are needed (Santos et al., 2006; Womack & Jones, 2003). For more information on the implementation of kanban systems, refer to Section 2.1.2. Visual production boards are used to easily display to employees what has or has not been manufactured. Some visual tools may utilize Gantt charts to depict the information. Gantt charts, developed by Henry Gantt, are bar charts or graphs that contain bars which represent each production order and its length of time required for completion. These are typically used for scheduling and planning small projects with few activities (Russell & Taylor, 2003). Using manual and visual methods for scheduling becomes difficult for operations with a multitude of products, machinery, product mixes, and multiple routings for individual products. The task of updating product, process, customer, and supplier information should be carried out frequently in lean manufacturing, and this can be difficult using only manual and visual methods (Crabtree, 2005). Once a company grows out of their typical manual and visual planning and scheduling system, automated versions may be sought. Especially in lean environments, typical automated planning and scheduling systems may not be sufficient. The need for these upgrades and modifications are discussed in Section, 2.4.3.

2.4.3 Limitations of Implementing Lean

Various limitations exist for companies who choose to implement lean manufacturing techniques. In addition to the mental and physical limitations the company must overcome when implementing general lean manufacturing concepts, there are also limitations which exist specifically for lean planning and scheduling systems.

2.4.3.1 Mental and Physical Limitations

Part of the difficulty with implementing lean principles throughout a company stems from the mental and physical changes which are necessary to become lean. Most often, the mental roadblocks are what keep companies from successfully sustaining lean manufacturing. At all levels, employees must have faith in the lean philosophy and adapt to a new way of thinking (Detty & Yingling, 2000). Lean manufacturing is not only applying tools and techniques; it is a new way of thinking and involves a culture change. The culture change is said to be the most difficult part of lean manufacturing (Fabric manufacturing gets a new twist, 2003; Aberdeen Group, 2006a; Aberdeen Group, 2006c; Nicholas & Soni, 2006). The Aberdeen Group's Roadmap to Lean Success survey states that developing a lean culture involves setting goals, measuring the results and rewards for success (Aberdeen Group, 2006d).

The time involved in changing, both mentally and physically, the way a company runs its manufacturing processes and procedures is another challenge. Months may be spent in just trying to find the problem or source of the problem. Time is then added to improve the situation and even more time is spent trying to control the improvements (Trebilcock, 2004). This often results in a company becoming frustrated and finally giving up on the idea of becoming lean. Many have said that lean is a journey, not a day trip. Those companies who only look for the short-term solutions will not be successful in changing to lean manufacturing.

Companies which have top management who are resistant to adapt to new ideas have difficulty implementing lean (Aberdeen Group, 2006b; Nicholas & Soni, 2006). Employees at all levels must be willing to give the transformation a chance. Resistance is normal, but change is necessary. Human nature is resistant to change which is why companies are often hesitant to restructure the way their traditional manufacturing organization has been functioning for a number of years.

It often takes more than a leap of faith in the lean manufacturing philosophy (Detty & Yingling, 2000). Physical adaptations are another type of limitation to implementing lean manufacturing. They may include changing the layout of the plant, removal or addition of capacity, moving employees to different processes, or the addition of visual management tools. In continuous processing, large fixed assets and capital equipment make it difficult and expensive to rearrange a manufacturing line into cells or change the process of manufacturing. Equipment used for continuous manufacturing often limits the ability to see if products are flowing or stationary (Myers, 2005). This is especially true in highly automated processes where raw materials enter at one end and are not seen until they exit as a finished product on the other end of the manufacturing line. Continuous automation results in some difficulty in converting textile manufacturing facilities to lean, especially in the beginning stages of the supply chain. Often, there is a pipeline in which the fiber or yarn flows through large capital equipment where it is not touched by operators until the final product is made, whether it is sliver, roving or yarn ready for the next process. The only place where visible excess product is seen is either in the beginning with bale or stock fiber and at the end with excess yarn packages, cans of sliver, or rolls of fabric waiting to be shipped to the next stage of processing.

Although the following example is a non-textile case, the idea of converting massive continuous equipment to smaller pieces applies to the same continuous method of manufacturing in the textile industry. In this example, Meyers (2005) explains how he helped a large consumer products company covert to a lean process. This company used large high-speed equipment that manufactured and packaged products continuously, 168 hours a week. Operating this way was extremely efficient because the company used the following two measurements of productivity: overall equipment effectiveness (OEE) and cost per case. However, the company was left with large amounts of finished inventory, resulting in huge inventory costs. The large, inflexible high-speed equipment was the roadblock in the lean transformation. Meyers knew that purchasing smaller batch-sized machinery to better match demand would be the starting point in this company's change to a lean environment. Inventory costs would be reduced from not producing as much product, which justified purchasing smaller machinery. The decision of investing capital on machinery must be made wisely, and it is often smarter if the capital is invested on equipment that is flexible enough to meet changing demand so there are not excessive amounts of inventory left in the warehouses which is so often seen in the textile industry (Myers, 2005).

2.4.3.2 Lean Planning and Scheduling Limitations

Often, companies will already have their own planning and scheduling tools set up for their manufacturing processes, and often these tools do not support lean manufacturing. These may be ERP or MRP systems, MS Excel™ spreadsheets or other types of tools that are aging, out-of-date, or unable to integrate with each other (Aberdeen Group, 2006a; Aberdeen Group, 2006c; Bartholomew, 2003; Lynch, 2007). If the decision is made to install new software or apply new scheduling tools, training is always necessary and successful lean implementation must involve the correct training and guidance (Detty & Yingling, 2000). Unfortunately, training involves time and money, which may be a large barrier to smaller companies. Planning and scheduling departments are sometimes resistant to new systems due to the learning curve. Top management may be wary of the new software systems because they may have been around to see the previous systems fail or be underutilized. Others feel that the new technology will slow down the workers or that they will not be able to learn the systems (Ashbrand, 2003).

Authors and experts have also mentioned a large challenge in implementing lean planning and scheduling systems is the mismatch between the traditional lean concepts and automated planning and scheduling systems for various reasons. Traditional lean concepts are based on pull systems where most of the older, more traditional automated planning and scheduling systems are based on push systems and forecasts (Bartholomew, 2003; Crabtree, 2005; Gross & McInnis, 2003; Langenwalter, 2000; Womack & Jones, 2003). Automated systems are also typically controlled by only a few knowledgeable members of the company, while the purpose of having lean systems is to encourage control by all members of the company using manual and visual methods. With lean manufacturing, there is a great need to update information frequently, a task that becomes tedious and time consuming when done by hand. The inability to frequently update reduces real-time visibility, and thus, decision making may suffer (Crabtree, 2005).

The difficulty in creating planning and scheduling systems for a textile environment is due to various reasons. For example, customer demands for smaller lot sizes, seasonal raw materials, high finished goods inventory, and manufacturing constraints such as large lead times, large setup times and different processing speeds between work centers and machines are all reasons that make planning and scheduling for a textile environment challenging (Ahmed, 2004). Software vendors that offer solutions specifically for the textile and apparel industries, such as DATATEX, Taylor Scheduling Systems and Blue Fox Porini have recognized these challenges and have tried to build features into their software packages that can better handle them. Ahmed (2004), an advanced planning and scheduling consultant for industries including textiles, suggests that these types of constraints can be alleviated by conducting a profitable to promise analysis, grouping/breaking orders, and routing and sequencing WIP.

A profitable to promise analysis evaluates the orders according to profitability, customer service levels, and other goals of the company. Essentially, the system should have a way of rating the orders. Grouping orders helps with the customers' small order lot requests so less fabric, yarn or other raw materials will not be wasted. For large orders, it may be best to break it up into smaller orders where more than one machine can process it. Routing and sequencing and WIP with similar characteristics will minimize large setup times. Successful planning and scheduling software for the textile industry should be able to handle these types of situations (Ahmed, 2004).

These challenges are typical for companies who have chosen to implement lean, but many have overcome them and are enjoying the benefits of having a lean manufacturing facility. There will always be road-blocks and situations that arise in any company, but no one has said that this is an easy solution. Lean takes time and effort by everyone, at all levels.

2.4.4 Need for Lean Upgrades in Automated Planning and Scheduling Systems

In order to fully adopt lean principles for a textile manufacturing facility, applicable planning and scheduling systems will need to be able to handle lean concepts, run in real-time and show shop-floor activities or else lean implementation is unlikely to be successful. Companies interested in IT solutions that may help with their lean manufacturing journey must be fully aware of the functions and features in the planning and scheduling systems. Before a company chooses a software system it is important that they know what those specific functions and feature requirements are (Ake et al., 2004). Many ERP systems claim they are using lean principles and concepts with their software, but often lean is used merely as a buzz-word to attract attention. Some systems will support lean manufacturing and execution on the shop floor. Langewalter (2000) lists the capabilities that both repetitive and process manufacturing ERP systems should have in order to be integrated with lean manufacturing concepts. Langenwalter defines repetitive manufacturing as:

> "repeated production of the same discrete products or families of products. Repetitive methodology minimizes setups, inventory, and manufacturing lead times by using production lines, assembly lines, or cells. Work orders are no longer necessary; production scheduling and control are based on production rates. Products may be standard or assembled from modules. Repetitive is not a function of speed or volume" (Langenwalter, 2000).

Process manufacturing is where the material continually flows through fixed routings and the products are often in batches. Companies that combine aspects of both repetitive and process manufacturing are described as having hybrid manufacturing (Langenwalter, 2000; Russell & Taylor, 2003), and other authors call it mixed-mode manufacturing (Bell, 2006). Textile manufactures will most likely have a combination of manufacturing styles, therefore, capabilities from both repetitive and process manufacturing should be considered when developing a lean ERP system. With regards to planning and scheduling, the repetitive manufacturing capabilities are:

1. "Flexible scheduling without the use of work orders; scheduling should include shift, daily and weekly production;
2. Rate-based forward scheduling;
3. Identify production lines with products and rates per period; ability to schedule a product on more than one production line;
4. Overlap unit scheduling;
5. Mixed model scheduling for each product line;
6. Transfer units between repetitive lines; all costs are automatically transferred with units;
7. Work order BOM and routings created for the specific repetitive schedule from master BOMs and routings; ability to modify for a specific schedule;
8. Cumulative or continuous schedule for labor, burden and material cost; charges must be traceable to the repetitive schedule;
9. Close the continuous order for the financial reporting period and reestablish the order for the next period;
10. Set independent shop calendars for each production line;
11. Simulation workbench: Workbench or simulation capability to level load production lines with repetitive schedules;
12. Workbench simulation: Graphical line/load representation for workbench. Ability to manipulate the load directly from graphical screen; and
13. Workbench simulation: Sequencing algorithms to minimize steps" (Langenwalter, 2000).

With regards to planning and scheduling, the process manufacturing capabilities are:

1. Forward and backward scheduling from critical resource;
2. Constraint-based, with user's choice of constraint orientations (capacity, materials, both);
3. Ability to manage and prioritize materials in bulk and packs;
4. Sequencing of products and batches;
5. By-products and co-products;
6. Lot traceability
    - Complete forward and backward traceability
    - Automatic interface with quality measurement systems
    - Ability to mix or not mix lots in a batch or to a customer
    - Ability to support a recall or quarantine
    - Across entire supply/distribution chain
7. Shelf life;
8. "Soft allocation" of lots in various stages of production or storage to specific customer orders or forecasts, by quality specifications and delivery dates;
9. Adjustments for quantity usage variances due to humidity, temperature, acidity, and other factors;
10. Intermediate storage requirements;
11. Recycling scrap back into the process
    - Maximum or minimum percentages allowable
    - Shelf life of scrap" (Langenwalter, 2000).

MES and APS systems also need to have features and capabilities to support lean manufacturing. The MES system should have functions that include production management, performance metrics, workflow control, material tracking and genealogy, measurement and reporting, quality management, work instructions, and model-centric implementation design. The model-centric design is when the system is set up on a computer-based model of the plant so that production orders can be dynamically routed according to the best utilization of capacity. This will allow for reduced WIP, eliminating waste and the flexibility needed a lean manufacturing environment. The MES should also be constraint-based, capability-based, and run in real-time in order to make the best decisions (Ake et al., 2004).

The traditional textile supply chain is composed of more than one company, and often the supply chain partners will use different information technologies (IT). This is a problem that also arises with business mergers and acquisitions (Ake et al., 2004). The IT solutions between companies may be a mix of different packaged software systems and word processing spreadsheets. The various systems that are used throughout the supply chain must be able to integrate with each other and work together in real-time.

For example, ArvinMeritor Inc. is an auto supplier that recently switched to lean technologies by installing Oracle 11i. Before the Oracle 11i installation, plants in this organization used different types of software throughout their supply chain and lacked real-time information transfer due to the software barriers. The Oracle suite has a flow manufacturing module that will enable lean manufacturing principles to be applied to the manufacturing stages of their operation, such as build-to-demand or build-to-order rather than their current build by batch process (Bacheldor, 2004b).

Lockheed Martin Commercial Space Systems was using a mixture of best-of-breed MRP software systems that only allowed the company to produce in batches. The manufacturing replenishment schedule was limited to the frequency that the software was run. CIO Fred Musco explains that when Lockheed Martin would run the MRP software once a week they would only receive replenishment signals once a week. Once the company started using SAP, they could go real-time and receive signals for replenishments whenever necessary (Bacheldor, 2004a).

New lean planning and scheduling systems also need to be able to link to older existing information technology systems already in place in addition to integrating with customers and suppliers. As far as integration, the system should also be able to handle kanban systems for demand and material replenishments for production lines, and must be directly tied to the material requirements planning system (Langenwalter, 2000).

As mentioned in Section 2.1.2, a mismatch exists between the software and the lean principles already implemented in manufacturing facilities. Traditional MRP and MRPII systems were originally developed to handle job shop manufacturing and are based on push systems, while lean scheduling concepts operate on pull systems (Bartholomew, 2003; Crabtree, 2005; Gross & McInnis, 2003; Langenwalter, 2000). In order to be more compliant with lean principles, new systems or modifications and upgrades to the current systems are needed to create pull based schedules.

2.5 Lean Textile Company Case Studies & Success Stories

Numerous success stories exist for companies in industries other than textiles which have transformed their traditional manufacturing processes into lean manufacturing. Fewer success stories exist for the textile industry regarding lean manufacturing and still fewer for lean manufacturing principles being used in planning and scheduling. The first two case studies are on the implementation of lean planning and scheduling systems in textile facilities. Five additional case studies and success stories are included which were written about textile and textile-related companies' involvement with lean manufacturing.

2.5.1 Quaker Fabrics, Massachusetts

Quaker Fabric of Fall River, Massachusetts, is a manufacturer of woven upholstery fabrics and used to expend a lot of time and effort into making schedules that, when implemented, would rarely meet the customers' delivery dates. Quaker used to use an MRPII system which would produce a schedule that they felt they could never really use. This was due to their MRPII system's inability to handle the material and capacity constraints at the same time. Difficulty in scheduling also stemmed from the complexity of the process, where each of their 400 looms was an individual workstation that could handle various different products and run at different speeds. Changeovers also play a large role in the scheduling process. At Quaker, change-overs can be as little as 15 minutes or as long as eight hours. There is a cost associated to each change-over as well as a cost associated to being late to the customer. Quaker's solution to the scheduling problem was to install Adexa's Plant Planner and Shop Floor Sequencer, a supply chain planning system that runs off of advanced planning and scheduling technology. Adexa's Plant Planner and Shop Floor Sequencer produces the best schedule based on the lowest cost and also allows Quaker to modify the schedule if necessary. Adexa is different from Quaker's original MRPII system because the Plant Planner and Shop Floor Sequencer allows multiple constraints to occur at the same time in order to create the best production schedule. It creates a "finite forward schedule that is both capacity- and material- constrained" says Boltz, the directory of inventory and forecasting at Quaker who is also responsible for scheduling production. Now, Quaker has a 90% on-time delivery, an increase of 15% from where it was before Adexa was implemented, and the production scheduler does not have the previous complicated scheduling issues to deal with (Bartels, 2004).

2.5.2 Fountain Set, Hong Kong.

Taylor Scheduling Software Inc.'s Taylor Scheduler is used at Fountain Set, a vertical textile manufacturer in Hong Kong. Fountain Set had an advanced ERP system, but was still using manual scheduling processes. They now use Taylor Scheduler to schedule their yarn dyeing, fabric dyeing, and knitting processes. Like most other textile companies, many factors are taken into consideration when creating the production schedule, such as due date, resources, machine utilization, expedited orders, and machine failures. The Taylor Scheduler is able to be integrated with the pre-existing ERP systems at Fountain Set so when new sales orders are created by the sales team, the information is sent to Taylor Scheduler, which creates or modifies the schedule and then sends it back to the ERP system so that the data can be updated in the ERP system as well. An important note in the article was that the system was not used to replace people, but to help them do a better job for the company. What has helped Fountain Set are their "forward thinking" managers who know that changes must take place to keep up with the marketplace (Taylor Scheduling Software Inc., 2004).

2.5.3 National Textiles, North Carolina.

National Textiles (now part of HanesBrands, Inc.) is a textile manufacturer that has been working with the NCSU Industrial Extension Services (NCSU IES). A success story written by NCSU IES describes how the Yarn Division began implementing lean manufacturing concepts. They started in 2004 with the training of 30 managers, the purpose of which was to educate about basic lean principles and perform simulations so the trainees could learn through a hands-on approach. Comments from the lean trainees were made about all employees needing to be involved with lean and that lean needs to be adapted to the culture of the company. The Forrest City plant conducted a five day Kaizen event to improve the workflow in one area of the plant and they also created standardized operator workstations. Many other plants were conducting lean events and receiving lean training for VSM, 5s, continuous flow and standardized work (NCSU IES, n.d.).

2.5.4 SI Corporation, Tennessee.

SI Corporation manufacturers materials for erosion control, furniture, and road construction. In 2004, at the time the article was written, SI Corporation had implemented lean in each of the five facilities in order to combat the rising costs of health care, raw materials, and utilities. Members of top management understood that the transformation would require the employees to be adaptable and also require an understanding that transforming to a lean organization is a continuous process that will never end. Improvements were seen in increased safety, reduction in waste, decreased off quality goods, and increased productivity. SI Corporation implemented flow cells as part of their lean transformation. Structure, leadership, and moving from the mass production way of thinking are key for lean to be implemented (Dunn, 2004).

2.5.5 Absecon Mills, New Jersey.

Absecon Mills, located in Cologne, New Jersey, is manufacturer of contract seating. In an article from the December 2003 issue of Upholstery Design and Management, which is now Upholstery Manufacturing, the CEO, Randolph Taylor, mentions some key points for starting lean in a textile company. By attending a seminar held by the Business and Institutional Furniture Manufacturers Association, he was able to learn about a company that had been successful in lean and decided to apply some of those techniques to his fabric manufacturing business. Taylor says to ignore benchmarking competitors, due to the possibility that they may be more laggard than your company is. He also says to make sure that the employees know that lean does not mean getting rid of jobs and that it can actually help create jobs. This is important for the employees to understand because “they are the heart of the process” (Fabric manufacturing gets a new twist, 2003). David Adair, Executive Vice President, is in charge of Lean Thinking at Absecon Mills and took the following steps in implementing lean manufacturing:

1. Define all of the steps in the process from raw materials to shipping;
2. Create flow charts listing every step; and
3. Find low-hanging fruit to get a quick start on lean implementation.

Quickly, the company found 100,000 pounds of obsolete inventory. The benefits of this find include increased space, saved manpower, and less time wasted during inventory counts. Absecon Mills has also implemented 5s which helps to identify errors so that quality can be improved.

One challenge Absecon was faced with, as are many companies, was a communication barrier. Over half of the employees were Spanish speaking. To overcome this challenge, the company hired a lean consulting company that had consultants who spoke Spanish to help train the employees.

The results after only months of the lean implementation include a 23% reduction in inventory; their goal is to reach a 70% reduction in inventory. Lead times have decreased from four weeks to one, and the employees are taking ownership of what they do. Key points from Adair are to do things quickly at the beginning in order to see results and gain buy-in from the employees. Another key is that as the company makes improvements, it is vital that no one is laid off. Gain sharing is also important. Adair says, “Our feeling is at some point when gains are made, some of it will go back to the employees." The company also must recruit their customers and suppliers to implement lean practices (Fabric manufacturing gets a new twist, 2003).

2.5.6 Joseph Abboud Apparel Corporation, Massachusetts.

While most apparel companies are slowly closing their operations, New York based Joseph Abboud (JA) Apparel Corp has decided to open a new distribution center at their New Bedford, Massachusetts plant. JA Apparel Corporation manufactures high-end men's suits and is one of the last remaining US manufacturers of the kind. The reason for the new distribution center stems from the workers beginning to adopt lean manufacturing techniques. Instead of working alone, they now work in teams to build one complete garment. The workers are also cross-trained, which is particularly beneficial if one area gets backed up. Unlike most of the other companies in the literature, not all of the workers appreciate the new lean manufacturing techniques. Some employees feel too rushed by the new system, while others enjoy the faster pace and the ability to do a variety of jobs. Workers at this Bedford, Massachusetts plant are members of a union, UNITE-HERE and could have opposed the new manufacturing changes. However, union leaders agreed to work with management to sell the new system to the JA Apparel Corp employees. As many companies have stated before, most of the employees were wary and suspected lay-offs. The opposite occurred, however, and JA Apparel Corp began hiring additional employees. The union was more flexible after realizing that without changes, their jobs may eventually go overseas (Langfitt, 2007).

Benefits from the lean transformation include an increase in sales of 15%, an increase in production, and a decrease of a week in the time necessary to complete a suit. JA Apparel Corp is expecting this strategy to work for five years and predicts that further change will be necessary to stay competitive with the overseas market (Langfitt, 2007).

2.6 Conclusion

Much of what is known of planning and scheduling systems in lean manufacturing relates to non-textile industries. However, if these non-textile industries are able to successfully implement lean planning and scheduling systems, the textile industry should be able to adapt some of those techniques to suit their particular manufacturing style. The literature reveals that there are some companies which are having success with lean manufacturing and even planning and scheduling systems.

3 Methodology

Based on the literature in Chapter 2, a three phase methodology was created to determine how textile and textile-related companies are using lean techniques in their planning and scheduling applications. The literature did not reveal a large number of textile-specific cases, and the study would confirm the utilization of lean manufacturing in the textile and textile-related industries. The methodology section describes the purpose for the research, the research objectives, and how the goals were achieved.

3.1 Research Purpose

In order for a smooth lean transformation, companies must have planning and scheduling systems that operate well in a lean environment. The purpose of this research was to determine what planning and scheduling systems, both manual and automated, are applicable in lean environments in the US textile industry. The research identified the characteristics of advanced planning and scheduling systems available as part of the plant floor data collection systems, enterprise resource planning systems and supply chain management systems as well as the manual planning and scheduling systems used in the textile and textile-related industries. The incompatibility issues between traditional planning and scheduling system capabilities and lean concepts were addressed in the literature review. The research was conducted to see if those incompatibility issues were prevalent and also to determine what other challenges and barriers textile companies were facing when implementing lean planning and scheduling systems.

3.2 Research Objectives

The following are the specific research objectives that were examined:

RO1 Identify the degree to which US textile companies are using lean techniques in their manufacturing operations;

RO2 Identify what planning and scheduling systems US textile manufacturers are using;

RO3 Determine the barriers to using lean planning and scheduling systems in US textile companies;

RO4 Determine where the implementation of lean planning and scheduling systems would be best applied;

RO5 Determine the lean planning and scheduling software available to the textile industry and develop a systems directory; and

RO6 Determine the requirements of lean planning and scheduling systems and modify the existing Software Requirements Checklist.

3.3 Research Design

This research design was qualitative in nature. A qualitative approach involves open-ended interviews and the collection of emerging text or image data in order to develop a theme (Creswell, 2003). The Creswell model for the inductive logic of qualitative research is shown in Figure 3.1.

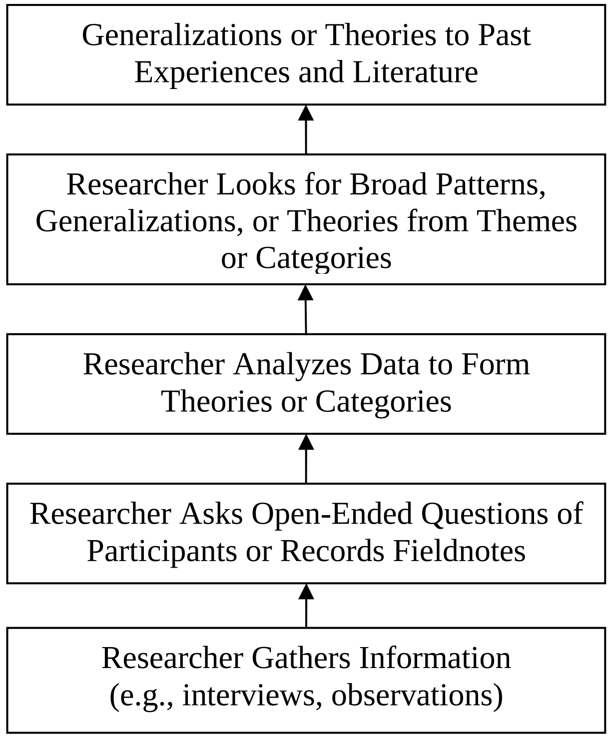

Figure 3.1 The Inductive Logic of Research in a Qualitative Study
Source: (Creswell, 2003)

An adaptation of Creswell's Inductive Logic Model was used for this research. The adapted model in Figure 3.2 shows that the initial data collection comes first from secondary sources. These secondary data form a foundation for the research and were used to develop open-ended questions for the interviews. Next, the information was gathered from the primary sources by asking open-ended questions during interviews and conducting case studies. The data was finally analyzed in order to form theories and look for patterns.

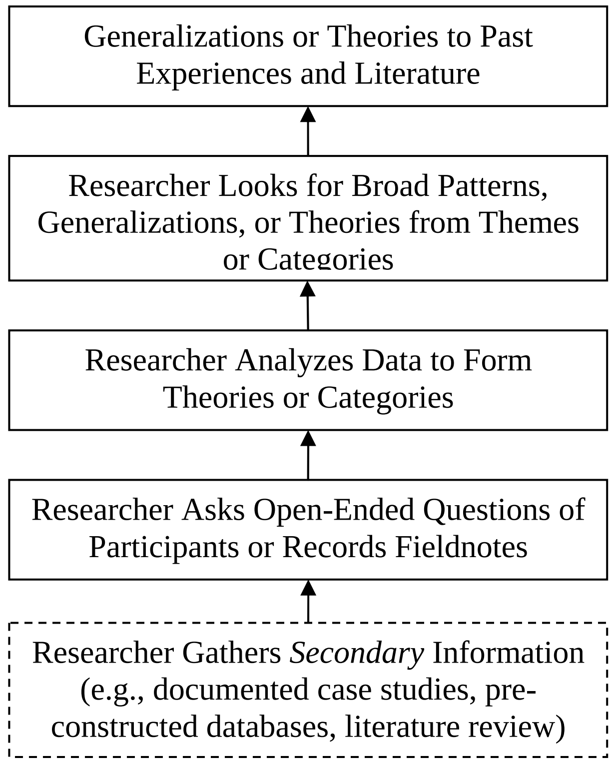

Figure 3.2 Inductive Logic Model Adapted from Creswell

This research was broken into three phases: Phase I for analyzing information from secondary sources, Phase II for analyzing information from primary sources, and Phase III for developing the systems directory and modifying the existing requirements checklist for planning and scheduling systems. Phase I was used to form an initial basis for achieving each of the six research objectives, while Phase II consisted of collecting data from primary sources such as interviews and case studies in order to add to research objectives one through four. After Phase I and Phase II analysis, the final results of both phases were combined. Phase III involved surveying a list of software vendors in order to form the Directory of Lean Planning and Scheduling Systems Software for Textile and Textile-Related Industries. Phase III is also when the modifications were made to the requirements checklist in Hodge's Software Requirements Evaluation Guide for Manufacturing

Planning and Control Systems (1998) to include planning and scheduling systems for lean environments. By completing Phase III, RO5 and RO6 were fully answered. After combining each of the three phases, all six research objectives were achieved. Figure 3.3 shows a visual depiction of the three phases of this research and which research objectives would be achieved in each phase.

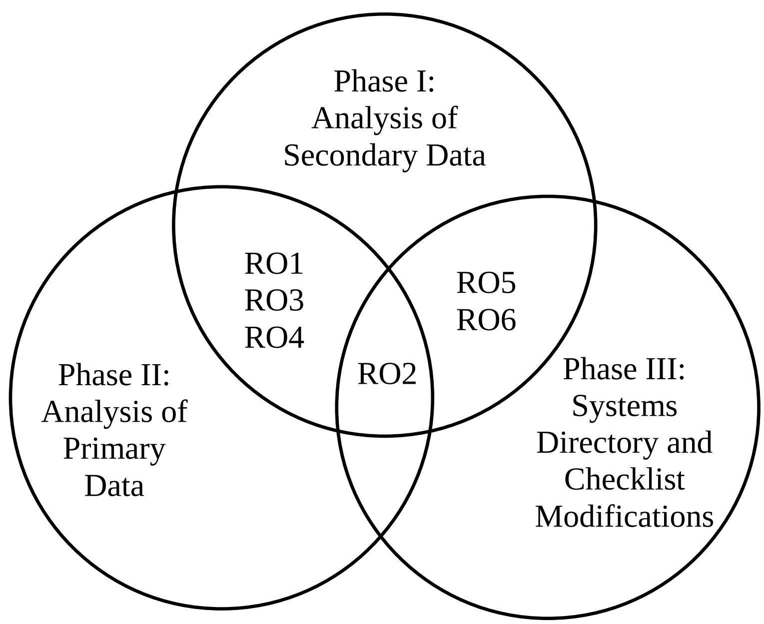

Figure 3.3 Conceptual Model of Research Phases

3.3.1 Phase I: Analysis of Information from Secondary Sources

In order to achieve the six research objectives, secondary sources were first analyzed in Phase I. This information provided a foundation for the analysis of the Phase II primary sources. Phase I helped to identify the degree to which some US textile companies were using lean techniques in manufacturing (RO1) and what types of planning and scheduling systems these textile manufacturers were using (RO2). The analysis also provided an initial listing of barriers to using lean planning and scheduling systems (RO3), helped determine the lean planning and scheduling software systems available to the textile industry (RO5) and the requirements of those systems (RO6). In addition, Phase I identified where lean concepts may be best applied in the textile industry (RO4). Each of the six research objectives were then further built upon with the analysis of the information obtained through the primary sources in Phase II and Phase III. The secondary sources analyzed in Phase I included:

1. Textbooks, trade and scholarly journals;
2. Research analyst, such as the Aberdeen Group, websites and whitepapers;
3. The Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry (Hodge, 2000);
4. Software vendors' websites, pamphlets and reviews;
5. Attendance at the 2006 Institute of Industrial Engineers Conference (May 20th-24th, 2006);
6. The North Carolina State University Industrial Extension Services' (NCSU IES) database; and
7. Internet Research.

Based on the revised Creswell Inductive Logic Model in Figure 3.2, the next step was to collect information from primary sources. Open-ended questions for the interviews were developed based upon the results of the Phase I and were used to construct an interview questionnaire rubric for use in Phase II. The rubric included a set of standard questions to be asked during each interview in order to help answer research objectives one through four. The interview rubric was also used to aid in organizing the responses from each interview and is included in Figure 3.1.

Table 3.1 Phase II Interview Questionnaire Rubric

Research Objective			Interview Question	Answers
RO1	Identify if US textile companies are using lean techniques in their manufacturing operations		Does your company use lean tools/concepts? If so, which ones?	
			What improvements have you seen?	
RO2	Identify what planning and scheduling systems US textile manufacturers are using	Manual/ Visual Systems	Do you use manual or visual plant floor planning systems? If so, what types? (Examples: planning boards or kanban)	
			What are the systems used for? (Example: raw materials, final products, in-process inventory, replenishment of supplies)	
			Do you use kanban? If so, what is the lot size, how is it determined? Does the size change? How often must the size change? How does demand affect variability?	
		Electronic/ Automated Systems	What are the systems used for? (Example: raw materials, final products, in-process inventory, replenishment of supplies)	
			How accurate is the system?	
			Is it reliable?	
			Is it custom built or a packaged program? If packaged, what is the brand?	
			How long has your company used the program?	
			Does it support lean manufacturing?	
RO3	Determine the barriers to using lean planning and scheduling systems in US textile companies		What was difficult about the lean transformation?	
			What complications did you have when installing the lean PS system?	
			What are the barriers to using lean?	
			Do you use automated P&S systems? If not, why not?	
			Do you use lean systems? If not, why not?	
RO4	Determine where the implementation of lean planning and scheduling systems would be best applied		What was easy about the lean transformation?	
			Where has lean worked best?	
			How many SKUs do you have? How are they defined? Does this affect kanban sizes?	
			If the systems are not lean, do you think they will work for your operations when you make the lean transformation?	

3.3.2 Phase II: Analysis of Information from Primary Sources

Phase II consisted of collecting primary data from open ended interviews and case studies. Through the analysis of the primary sources, Phase II identified additional companies using lean techniques in manufacturing (RO1) and what types of planning and scheduling systems these textile manufacturers were using (RO2). The primary sources also provided an additional listing of barriers to using lean planning and scheduling systems (RO3). Industry interviews also helped to form theories where lean concepts may best be applied in the textile industry (RO4). The primary sources for data collection in Phase II were:

1. Textile company interviews
2. Case studies
3. Meeting with software vendors at the 2006 Megatex & ATME Conference (October 30th , 2006)

3.3.2.1 Industry Interviews

The first part of Phase II was open ended interviews with the companies that met the specifications listed in Section 3.4. Interview topics of importance included the companies' interests and experiences with lean manufacturing in addition to the types of planning and scheduling tools or systems that were used for production scheduling. The interviews were conducted in person with open ended questions that allowed the participant to add additional comments or opinions. If applicable, the interviews were conducted on-site at the participants' company in order to tour the plant. The plant tour provided a visual to better understand the lean tools that were implemented. Due to logistics, one company interview was conducted over the phone. Based upon the results of the interviews, some companies were asked to participate in in-depth case studies to better understand lean manufacturing and its application in the textile industry.

3.3.2.2 Case Studies

The purpose of a case study is to collect detailed information regarding an in-depth program, event, activity or process using various data collection methods over an extended period of time (Creswell, 2003). The case studies provided a better understanding of lean techniques when applied to textile applications. After interviewing the textile companies, two were chosen based on their interest in participating in an in-depth case study. Each case study involved documenting the application of a specific lean tool, Value Stream Mapping, to an already existing textile process.

An additional case study involved evaluation of a lean planning and scheduling software package by DATATEX that was created for textile and textile-related industries and can be used in lean environment. The DATATEX MQM (Machine Queue Management) program was evaluated to better understand the functionality of the system in a textile weaving environment and to see what features were offered. The program was also used as a benchmark to evaluate other lean planning and scheduling systems for textile environments.

3.3.3 Phase III: Development of a Planning and Scheduling Systems Directory and Modifications to the Existing Requirements Checklist

Phase III consisted of combining the information gathered from Phase I, regarding the planning and scheduling systems and their requirements, the responses from the Phase II interviews regarding the lean planning and scheduling systems used at the textile companies interviewed (RO2), and the software surveys conducted in this phase to form a directory of automated planning and scheduling systems available to the textile industry and applicable in lean environments (RO5). Phase III was also for developing the modifications to the planning and scheduling systems' requirements in the Software Requirements Evaluation Guide for Manufacturing Planning and Control Systems (RO6) (Hodge, 2000).

3.3.3.1 Survey of Software Vendors

Leading software vendors were surveyed and evaluated to determine the benefits and applications of their software packages, if they have lean planning and scheduling capabilities for the plant floor, and if they were applicable in the textile industry. An original software survey was used to develop the Directory for Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry created in 2000 by Dr. George Hodge. The original survey is shown in Appendix A. Based upon the information gathered in Phases I and II regarding requirements for automated lean planning and scheduling systems, modifications were made to this survey to include applicable information. The modified survey that was emailed to the software vendors is shown in Appendix B.

Eighty-five software vendors were surveyed for the directory. The listing of the 85 vendors came from various Phase I sources including Apparel Magazine's 2006 IT issue, a previous Directory for Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry created in 2000 by Dr. George Hodge, vendors interviewed at the Megatex Conference, additional sources from the literature review, and conducting an Internet search. The information and answers from the returned surveys and vendor websites were used to compile a planning and scheduling systems directory applicable to lean environments which can be used in the textile and textile-related industries. All information included in the directory is directly from the vendor representative or from the vendor website.

Four textile companies were found in the literature that used a lean planning and scheduling system. Two additional lean software systems, not specific to textiles, were found in the literature. In addition to those six software systems, software vendors were further obtained in Phase I by evaluating Apparel Magazine's annual IT edition (2006). Apparel Magazine (formerly Bobbin Magazine) provides the textile and apparel industry with an annual listing of information technology providers. The Apparel Magazine's listing contained 103 software vendors that were listed in the "ERP and Supply Chain Collaboration & Materials Inventory Control" category. The survey was sent to 36 of those vendors who fell under the ERP or MRP sections. Additional software vendors were obtained through the Aberdeen Group's research on Best in Class lean companies. Eight software vendors who were not previously mentioned in other sources were added to the list of companies to survey. A previous study in which the Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry directory was created that included 46 textile software vendors of manufacturing planning and control systems (Hodge, 2000). Of those 46 vendors, 26 were either still in business or had merged with another software company. Fourteen of the 26 companies were already listed in Apparel Magazine's IT issue or the Aberdeen Group, which leaves a total of 12 additional software vendors provided by Hodge's directory that were surveyed. An internet search on the Managing Automation website for lean planning and scheduling systems for the textile industry was conducted that provided an additional 23 companies not previously mentioned in the literature (Managing Automation, 2006).

Phase II did not provide additional companies to be included in the survey that were not already mentioned in the literature. However, additional information was gathered for 4 lean planning and scheduling companies that market to the textile industry by attending the 2006 Megatex Conference. Each of the four vendors at the conference, DATATEX, Jomar, Network Systems and Blue Fox Porini, were either previously included in Hodge's directory or listed in the Apparel Magazine IT issue and, therefore, already included in the list of vendors to survey for this research.

3.3.3.2 Development of the Directory and Modifications to the Requirements Checklist

By compiling each survey completed by the software vendors, a directory was created with vendors that provided planning and scheduling systems that can be used in lean environments in the textile and textile-related industries. The directory included the company name, the software system and specific program if available. Also included was a brief description of the system that was obtained from the website or promotional information and the hardware requirements. In addition, the lean capabilities and features were also included for each vendor. Examples of lean features are kanban management and replenishment, demand smoothing, line design and balancing, mixed-model production, and real-time inventory management.

Modifications to Hodge's *Software Requirement's Evaluation Guide for Manufacturing Planning and Control Systems* were created to include relevant requirements for planning and scheduling systems in a lean environment. To prepare the modifications to the original requirements checklist and systems directory, the information gathered from Phase I secondary sources was evaluated. Additional sections were added to include MES, APS and ERP requirements.

3.4 Sample Selection for Interviews

The sample for the industry interviews was a convenience sample which included members of the textile and textile-related industries. Members of the Institute of Textile Technology (ITT) were first asked to participate in the research study. After the interested companies were contacted, contacts for remaining textile companies outside of ITT were found using the help of the North Carolina State University Industrial Extension Services (NCSU IES). All companies interviewed fell under the following criteria:

1. Company must have one of the following NAICS codes:
    a. NAICS 313: Textile Mills Manufacturing
    b. NAICS 314: Textile Product Mills
    c. NAICS 315: Apparel Manufacturing
2. Plant location must be no more than 5 hours one-way from the College of Textiles for an on-site interview. If the company was more than 5 hours away, a phone interview was conducted.
3. Company must be participating in some aspect of lean manufacturing.

3.4.1 North Carolina State University Industrial Extension Services Database

The NCSU IES was contacted to obtain a listing of potential companies that may be chosen to participate in this research. NCSU IES provided a database with 146 various manufacturing improvement projects they had completed with companies in various industries. The companies were separated into seven clusters: metal working and automotive transportation, information technology, computers and communications, services/pharmaceuticals, furniture/non-furniture wood products, food processing, and textiles. A query was performed to extract all of projects listed under the textile cluster. Out of the 34 projects listed under the textiles cluster, 15 projects were identified where some type of lean manufacturing event occurred. These 15 different projects were with 9 individual companies in 15 different locations where lean events have taken place. Each company fell under the criteria defined previously. Of these 9 different companies, 6 agreed to an interview and plant tour.

3.5 Data Collection

Data was collected throughout Phase I to form initial listings of companies participating in lean manufacturing (RO1), planning and scheduling systems currently being used by textile companies (RO2), barriers to lean planning and scheduling systems (RO3), where lean planning and scheduling systems might be best applied (RO4), planning and scheduling software available to the textile industry (RO5), and the requirements necessary for a planning and scheduling system to be considered lean (RO6).

Data was collected throughout Phase II using an interview questionnaire to complete RO1, RO2, RO3, and RO4. Ten interviews with textile and textile-related companies were conducted in Phase II. Nine companies were interviewed on-site at ten different locations and one company was interviewed over the phone. The interviews were scheduled based on a time and place most convenient to the participant. Additional information was obtained in Phase II by interviewing software vendors at the Megatex Conference and conducting three case studies. Two case studies evaluated the implementation of a particular lean tool in two different textile manufacturing operations, and one case study evaluated an automated planning and scheduling system specifically designed for textile applications and is applicable in lean environments.

3.6 Data Analysis

For each of the three phases of this research, the results were analyzed in order to achieve the research objectives. Phase I included an analysis of the secondary sources, and Phase II included analysis of the primary sources: ten interviews, three case studies and interviews with software vendors at the Megatex Conference. The results from Phase I and Phase II were then combined to give the final listings of companies participating in lean manufacturing, the planning and scheduling systems currently being used by textile companies, the barriers to lean planning and scheduling, where lean planning and scheduling may be best applied, the software available to the textile industry, and the planning and scheduling requirements for lean manufacturing software. The listing of software available to the textile industry combined from Phases I and II was used in Phase III to contact vendors in order to create the directory of lean planning and scheduling systems available to the textile industry.

3.7 Limitations of the Research

The sample for this research is small and is also a convenience sample, and therefore warrants caution in evaluation. The results may not be appropriate to generalize to the entire United States textile industry. While a cross-section of companies in several different sectors of the textile industry was interviewed (for example knitting, flooring, weaving, yarn manufacturing), there still exists textile industry sectors that were not interviewed (for example wet processing). For this reason, only companies who have operations similar to those companies who chose to participate in the research interviews may be able to generalize the research results to their own operations.

4 Results

Results for this study were broken into results for each of the three phases. The results from Phase I and Phase II were analyzed according to Figure 3.2. First the secondary information was gathered in Phase I and then primary information was gathered in Phase II. Each phase was analyzed separately and then combined together to form the conclusions in Section 5.2.

4.1 Phase I Results: Analysis of Secondary Sources

In Phase I, all information was obtained through secondary sources such as attendance at seminars and workshops at the Institute of Industrial Engineers Lean Manufacturing Conference, the exploration of scholarly and trade journals, research analysts' websites and whitepapers, and Internet research. The results from Phase I were used to initially answer all six research objectives stated in Section 3.2.

4.1.1 RO1: Textile Companies' Use of Lean Manufacturing

In answering the first research objective, a list of 16 textile and textile-related companies that are using lean was compiled and is shown in Table 4.1. The list was compiled by performing an Internet search (IS) with search engines using variations of "lean manufacturing" and "textiles" and utilizing commercial databases to which NCSU subscribes (Textile Technology Index (TTI), Business Source Premier (BSP), World Textiles (WT)).

Table 4.1 Textile and Textile-Related Companies Using Lean from Secondary Sources

Company Using Lean	Operation	Location	Lean Tools, if applicable	Source
National Textiles	Yarn Mfg	Forrest City & Gastonia, NC	VSM, 5s, Visual management, Kaizen events, Standardized work, Continuous flow	IS (NCSU IES, n.d.)
SI Corporation	Carpet Mfg	Chickamauga, GA	Flow cells	TTI, BSP, WT (Dunn, 2004)
Performance Fibers	Industrial Fiber & Yarn Mfg	Richmond, VA	Kaizen events to reduce inventory and improve flow, work cells in quality testing labs	TTI, WT (Norberg, 2005)
Victor Innovatex	Contract Fabric Mfg.	Saint-Georges, Quebec	Updated machinery and product development to become more efficient and faster	IS (McDonough & Braungart, 2002)
Collins and Aikman	Automotive Textiles Mfg	TN facility	VSM, 5s, Visual management	IS (IndustryWeek, 2002)
Absecon Mills	Weaving	Cologne, NJ	5s, Flow charts	WT (Fabric manufacturing gets a new twist, 2003)
Joseph Abboud Corp	Apparel Mfg	Bedford, MA	Cross-trained work cells	IS (Langfitt, 2007)
Simmons	Bedding Mfg	Atlanta, GA	NA	TTI (Simmons names new exec VP of operations, 2005)
Flynt Fabrics	Vertical Knitting	NC	Kaizen events, Simplified product lines, Installed i2 Technology's Automated Rhythm Planner	TTI (McCurry, 2000)

Table 4.1 Continued

Company Using Lean	Operation	Location	Lean Tools, if applicable	Source
Hickory Springs	Furniture & Bedding Mfg	Hickory, NC	VSM, Lean Six Sigma	IS (Aberdeen Group, 2006d)
Russell Corporation	Athletic Apparel Mfg	GA, AL	Uses Workbrain software to schedule lean factory floor labor	BSP (Workforce optimization apps extend lean endeavors, 2006)
Partex Apparel	Apparel Mfg	El Salvador	NA	TTI, BSP, WT (Speer, 2004)
INC Corporation	Textile Mfg	Australia	NA	TTI (The INC way: The challenge of change at INC corporation, 2006)
Sunskins	Apparel Mfg	Australia	NA	TTI (Sunskins, 2001)
Quaker Fabrics	Woven Upholstery Fabrics	Fall River, MA	Installed Adexa's Lean Planning and Scheduling System	IS (Bartels, 2004)
Fountain Set	Vertical Textile Mfg	Hong Kong	Installed Taylor Scheduling's Lean Scheduling System	IS (Taylor Scheduling Software Inc., 2004)

4.1.2 RO2: Planning and Scheduling Systems used by Textile Industry

There are very few publications on textile companies using lean planning and scheduling systems that are found in the literature. Table 4.2 is a list of systems that are currently being used by members of the textile industry and documented in the literature. Four automated lean planning and scheduling systems were found and references to companies using proprietary and manual systems were also found. The systems list was created by searching the NCSU library's databases including Textile Technology Index (TTI), Business Source Premier (BSP), and World Textiles (WT), conducting an Internet search (IS), and the literature review.

Table 4.2 Planning and Scheduling Systems Currently Used

Planning and Scheduling System Used	Company, if applicable	Source
Adexa	Quaker Fabrics	IS (Bartels, 2004)
i2 Technologies' Rhythm planning system	Flynt Fabrics, Vertical knitting	TTI (McCurry, 2000)
Oracle (Formerly JD Edwards)	Hickory Springs, Furniture and bedding mfg	IS (Aberdeen Group, 2006d)
Taylor Scheduling Software	Fountain Set, Vertical textile mfg	IS (Taylor Scheduling Software, Inc., 2007; Taylor Scheduling Software Inc., 2004)
Proprietary Automated Systems	NA	IS (Aberdeen Group, 2006b; Bartholomew, 2003)
Manual (MS Excel™ spreadsheet, paper and pencil)	NA	IS (Aberdeen Group, 2006b)

4.1.3 RO3: Barriers to Lean

One of the top barriers found in secondary sources was the fact that lean manufacturing requires a significant culture change (Fabric manufacturing gets a new twist, 2003; Aberdeen Group, 2006a; Aberdeen Group, 2006c; NCSU IES, n.d.; Nicholas & Soni, 2006). Top management commitment and the integration with current systems are also common barriers to lean planning and scheduling implementation (Aberdeen Group, 2006a; Aberdeen Group, 2006c). These and additional barriers to lean found in the literature are listed in Table 4.3.

Table 4.3 General Lean Barriers from Secondary Sources

General Lean Barriers	Source
Culture change	(Fabric manufacturing gets a new twist, 2003; Aberdeen Group, 2006a; Aberdeen Group, 2006c; NCSU IES, n.d.; Nicholas & Soni, 2006)
Top management commitment	(Aberdeen Group, 2006a; Aberdeen Group, 2006c; Nicholas & Soni, 2006)
Large fixed assets, capital equipment	(Myers, 2005)
Long/involved process	(Dunn, 2004; Nicholas & Soni, 2006)

Additional barriers exist for implementing lean planning and scheduling systems. The Aberdeen Group suggests additional challenges and barriers with the combination of plant floor scheduling and an ERP system as being difficult to integrate with the existing system, no unifying manufacturing architecture, multiple applications to support, aging and proprietary systems that do not support lean, and providing business users with information necessary to make decisions (Aberdeen Group, 2006c). Ashbrand (2003) mentions in Managing Automation that in many different industries, a common fear is that top executives are wary of new software systems. These and additional lean planning and scheduling barriers are listed in Table 4.4.

Table 4.4 Lean Planning and Scheduling Barriers from Secondary Sources

Lean Planning and Scheduling Barriers	Source
Top management wary of new software systems	(Ashbrand, 2003)
Integration with current systems	(Aberdeen Group, 2006a; Aberdeen Group, 2006c)
No unifying architecture	(Aberdeen Group, 2006c)
Multiple applications to support	(Aberdeen Group, 2006c)
Aging/proprietary systems do not support lean	(Aberdeen Group, 2006c; Lynch, 2007)
Information for decisions unavailable	(Aberdeen Group, 2006c)
Complexity of products	(Bartels, 2004; Bartholomew, 2003)
Technology will slow down workers	(Ashbrand, 2003)
Excessive manufacturing lead times and setup/change-over times	(Ahmed, 2004; Bartels, 2004)
Different processing speeds for work centers	(Ahmed, 2004; Bartels, 2004)
High finished goods inventory	(Ahmed, 2004)
Mismatch between traditional lean concepts and automated systems	(Bartholomew, 2003; Crabtree, 2005; Gross & McInnis, 2003; Langenwalter, 2000; Womack & Jones, 2003)

Long lead times and setup times for textile materials, as well as different machine processing speeds can make creating planning and scheduling systems difficult (Ahmed, 2004; Bartels, 2004). Ahmed (2004), a consultant for advanced planning, scheduling and optimization techniques in manufacturing, says that due to the constraints and barriers found in the textile industry, difficulty arises when developing software to plan and schedule textile materials. Therefore, creating successful scheduling software would be difficult for someone who is not familiar with the textile industry (Ahmed, 2004).

4.1.4 RO4: Implementation of Lean Planning and Scheduling Systems

Limited success stories were found for the implementation of planning and scheduling systems at a textile company. Most were success stories found on software vendors' websites. However, one company, Quaker Fabric, was discussed in an article by Nancy Bartels (2004) in *Manufacturing Systems*, now *Manufacturing Business Technology*, as having much success with an advanced planning and scheduling system. Taylor Scheduling Software Inc.'s Case Studies section of their website discusses a successful implementation of their Taylor Scheduler at Fountain Set, a vertical textile manufacturer in Hong Kong (Taylor Scheduling Software Inc., 2004). For additional details on these success stories, refer to section 2.5.1 and 2.5.2. Two additional companies were referenced in the literature about their use of lean planning and scheduling systems, however a detailed account of their successful implementation was not available. These two companies are Hickory Springs Manufacturing Company which uses Oracle's lean automated products (Aberdeen Group, 2006d) and Flynt Fabrics which uses i2's lean automated products (McCurry, 2000).

Researchers have claimed that where automated planning and scheduling is concerned, a hybrid approach is best. Simulations, not specific to the textile industry, have been created to show that the implementation of a hybrid system that combines both push and pull systems are useful and successful (Beamon & Bermudo, 2000; F. T. S. Chan, 2001; F. T. S. Chan & Tang, 1996). Product Development Senior Director of ERP vendor Epicor also says that the newest approach is to create hybrid systems that combine JIT with long-term planning (Bartels, 2004).

Regarding manual planning and scheduling, the Aberdeen Group has shown through their research in other industries that around one third of companies involved in lean are still using MS Excel™ and about 10-15% of companies are using pencil and paper methods for planning and scheduling the shop floor (Aberdeen Group, 2006b). Others feel that combining manual or visual approaches with information technology is the best way to successfully implement the lean planning and scheduling systems (Bartholomew, 2003; Crabtree, 2005; Gross & McInnis, 2003; Langenwalter, 2000; Womack & Jones, 2003).

4.1.5 RO5: Determine Lean Planning and Scheduling Software Available to the Textile Industry

Eighty-five vendors of software solutions were included in the list of companies to survey in order to find the lean planning and scheduling software applicable to the textile and textile-related industries. As listed in Table 4.2, there were four instances of textile companies using lean planning and scheduling software previously found in the literature. These automated systems are Adexa, i2 Technologies, Inc., Oracle, and Taylor Scheduling Systems. Two additional lean software systems, not specific to textiles, were found in the literature: Glovia and Workbrain (Bacheldor, 2004b). The remaining software vendors were found through Apparel Magazine (2006), the Aberdeen Group (2006), the Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry (Hodge, 2000), and additional secondary sources.

4.1.5.1 Apparel's Guide to Software and IT Solutions

The first source was the September 2006 issue of Apparel, which was the special edition annual software directory (Apparel's Guide to Software and IT Solutions, 2006). There were a total of 164 software and IT vendors, and suppliers to the apparel and soft goods industries. Of these 164 companies, 103 of them were provided in the ERP, Supply Chain

Collaboration & Materials Inventory Control section. Thirty-six vendors, who were not previously found in the literature, were identified to be surveyed because they fell under the specific categories of "Mid Market ERP," "Large Market ERP," or "MRP or MRPII." The magazine included contact information and operating system requirements. The companies are listed in Table 4.5.

Table 4.5 Apparel Magazine Software Vendors
Source: (Apparel's Guide to Software and IT Solutions, 2006)

Apparel Magazine Software Vendors		
Advanced Systems Integration	Epicor	Metamor Enterprise Solutions
Apparel Business Systems	Exact Software Co. Inc	Momentis Systems Inc
ApparelMagic	FDM4 America Inc	Network Systems International
AS/AP Apparel Software	GCS Software LLC	New Generation Computing Inc
BlueFox Porini	IDEA LLC	Polygon Software
Centric Software	Indigo8 Solutions Limited	Prescient
Cognizant Technology Solutions	Infor Global Systems	REACH Technologies
Computer Care	JDA Software Group	SAP
Computer Generated Solutions	Jesta I.S.	SAS
DATATEX TIS Inc	Jomar Softcorp Int'l	TSI Systemgroup Inc
Demand Solutions	Jonar Systems Inc.	TXT e-solutions
Ensemble Business Software	Lawson Software	Xperia

4.1.5.2 Aberdeen Group

The Aberdeen Group also mentioned several lean software vendors in their Best in Class Case Studies from the research titled Best Practices in Lean: The Momentum Builds

(Aberdeen Group, 2005). The eight Best in Class companies, not previously found in the literature, and their lean software solutions listed in Table 4.6 were mostly in industries outside of the textile industry; however, they were still included in the list of vendors to survey. Infor Visual Easy Lean was the only vendor that was used in the textile industry in this limited study. This textile company was The Marena Group, Inc who manufactures surgical compression clothing; however, Infor was already included in Apparel Magazine's listing and therefore not included in the Aberdeen Group listing below.

Table 4.6 Aberdeen Group Software Vendors
Source: (Aberdeen Group, 2005)

Software Vendor	Best in Class Company	Products
Axapta Lean Enterprise	WIKA Instrument Corp	Pressure and temperature gauges
Bristlecone	Mahindra & Mahindra, Ltd	Farm Equipment
Brooks Automation	Unnamed: Major defense contractor	Electronic guidance systems
eBECS	WIKA Instrument Corp	Pressure and temperature gauges
Factory Logic	Unnamed: Multi-tier automotive supplier	Automotive supplier
JRG	Pilkington North America	Automotive glass and glazing supplier
Pelion Systems	Husqvarna, division of Electrolux	Turf care products
Rockwell Automation	Integram	Automotive supplier

4.1.5.3 Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry

The Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry was created by Hodge (2000) that included 46 textile software vendors of manufacturing planning and control systems. Of those 46 vendors, 26 vendors remained that were either still in business or had merged with another software company. Fourteen of the 26 companies were already listed in Apparel Magazine's IT issue or by the Aberdeen Group, which leaves a total of 12 additional software vendors provided by Hodge's directory that were surveyed, shown in Table 4.7.

Table 4.7 Additional Software Vendors from Original Directory
Source: (Hodge, 2000)

Software Vendor	
Application Consultants, Inc.	Principles and Applications, Inc.
Greycon	Ramco Systems Corporation
Hanford Bay Associates, Ltd.	Smart Software, Inc.
International Systems, Inc.	User Solutions, Inc.
MCBA	Waterloo Manufacturing Software
Micro-Analysis & Design	Winman (formerly TWW, Inc.)

4.1.5.4 Managing Automation Website Software Search

Twenty-three vendors that were not previously mentioned on any of the above lists were found on the Managing Automation website software search and are shown in Table 4.8 (Managing Automation, 2006). In the search field, the term "lean manufacturing" was used to search for lean software systems. A total of 51 vendors were returned from the software search. For each vendor, Managing Automation provides a list of industries for which the software is applicable. Only the 23 companies who had textiles mentioned in the industries category were added to the list of companies to survey.

Table 4.8 Vendors from Managing Automation Website Software Search
Source: (Managing Automation, 2006)

Vendors from Managing Automation Website Software Search			
3M	GE Fanuc Automation	Matrikon, Inc.	Softbrands
Apriso Corporation	Giraffe Production Systems	nMetric	Synchrono
CIMNET Inc.	Global Shop Solutions, Inc.	OpenPro, Inc.	Technology Group International
DataCraft Solutions	Horizon Software, Inc.	Plexus Systems	Visiprise Inc.
Enterprise Logix	LAMAR	Preactor International	Xdata Solutions, Inc.
Factory DNA Inc.	Lean Manufacturing Systems, Inc.	QAD	

Therefore, evaluating each of the previously mentioned secondary sources resulted in a total of 85 software vendors to survey in Phase III.

4.1.6 RO6: Determine the Software Requirements for Lean Planning and Scheduling Systems

Capabilities, features and functions are required for specific applications, such as ERP, APS and MES, to be applicable in lean manufacturing environments. Based upon the secondary sources, the list of requirements for lean planning and scheduling systems are shown in Table 4.9.

Table 4.9 Lean Planning and Scheduling Software Requirements

MES Additional Functions	Source
Production management	(Ake et al., 2004)
Performance metrics	(Ake et al., 2004)
Workflow control	(Ake et al., 2004)
Material tracking and genealogy	(Ake et al., 2004)
Measurement and reporting	(Ake et al., 2004)
Quality management	(Ake et al., 2004)
Regulatory compliance	(Ake et al., 2004)
Work instructions	(Ake et al., 2004)
Model-centric design for routing capability	(Ake et al., 2004)
Runs in real-time	(Ake et al., 2004)
Constraint and capability based	(Ake et al., 2004)
Integrates with other IT systems	(Ake et al., 2004; Langenwalter, 2000)
APS Additional Functions	**Source**
Ability to group and split orders	(Ahmed, 2004; Ake et al., 2004)
Rate or assign priorities to orders	(Ahmed, 2004; Ake et al., 2004)
Routing and sequencing capabilities to ensure the best utilization of capacity	(Ahmed, 2004; Ake et al., 2004)
Simple/graphical/user-friendly interfaces	(Ake et al., 2004)
Kanban for pull based replenishing	(Ake et al., 2004)
Ability to work in build-to-demand environments	(Ake et al., 2004)
Real-time inventory alerts	(Ake et al., 2004)
Integrate with other planning and scheduling systems	(Ake et al., 2004)
Production schedule sharing from supplier to customer	(Ake et al., 2004)
Demand scheduling	(Ake et al., 2004)
Handles varying process/manufacturing/lead/change-over times	(Ake et al., 2004)

Table 4.9 Continued

ERP Additional Functions	Source
Flexible scheduling should include shift, daily and weekly production	(Langenwalter, 2000)
Forward and backward scheduling from critical resource	(Langenwalter, 2000)
Constraint-based scheduling, with user's choice of constraint orientations (capacity, materials, both);	(Langenwalter, 2000)
Ability to manage and prioritize materials in bulk and packs	(Langenwalter, 2000)
Identify production lines with products and rates per period	(Langenwalter, 2000)
Ability to schedule a product on more than one production line	(Langenwalter, 2000)
Sequencing of products and batches	(Ahmed, 2004; Langenwalter, 2000)
Lot traceability across entire supply/distribution chain; ability to mix lots	(Langenwalter, 2000)
"Soft allocation" of lots in various stages of production or storage to specific customer orders or forecasts, by quality specifications and delivery dates;	(Langenwalter, 2000)
Mixed model scheduling for each product line	(Langenwalter, 2000)
Transfer units between repetitive lines	(Langenwalter, 2000)
All costs are automatically transferred with units	(Langenwalter, 2000)
Ability to modify for a specific schedule	(Langenwalter, 2000)
Set independent shop calendars for each production line	(Langenwalter, 2000)
Workbench or simulation capability to level load production lines	(Langenwalter, 2000)
Graphical line/load representation for simulation workbench	(Langenwalter, 2000)
Recycling scrap back into the process	(Langenwalter, 2000)
Intermediate storage requirements	(Langenwalter, 2000)
Ability to manipulate the load directly from graphical screen	(Langenwalter, 2000)
Sequencing algorithms to minimize steps	(Ahmed, 2004; Langenwalter, 2000)
Ability to link to customers and suppliers	(Aberdeen Group, 2006a; Ake et al., 2004; Langenwalter, 2000; Michel, 2002)
Ability to integrate with older systems	(Langenwalter, 2000)

4.2 Phase II Results: Analysis of Primary Sources

The primary resources analyzed in Phase II were interviews with four lean planning and scheduling software vendors for the textile industry at the 2006 Megatex/ATME Conference, ten textile industry interviews and three case studies.

4.2.1 Lean Software Vendors from 2006 Megatex Conference

Four software vendors were spoken with at the Megatex Conference which offered lean solutions to textile and textile-related industries. These four vendors were already included in the list of software vendors to contact in Phase III for the directory and are shown in Table 4.10.

Table 4.10 Lean Vendors at Megatex

Planning and Scheduling Vendor System	
Blue Fox Porini	Jomar
DATATEX	Network Systems

4.2.2 Open Ended Interviews

Ten interviews were conducted with nine different textile and textile-related companies which have begun implementing lean manufacturing. The interview results were used to answer research objectives one through four. One additional interview with a lean manufacturer in the automotive industry was conducted as a comparison between a company which has implemented lean principles since the company's start-up and companies who are newer to lean manufacturing.

4.2.2.1 Interview 1

Company A has manufacturing facilities located in the southeastern United States, which perform warping, slashing and weaving functions. The company makes woven PET, PET/cotton and cotton greige goods for a variety of end uses including industrial and apparel. 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. The tools used thus far are 5s, Kaizen and process improvement, and standard operating procedures. The company had also recently begun quick change-over in the weaving operations. The improvements that have been seen include a drastic decrease in waste and employees taking pride in their workplace. Currently, lean efforts have been successful in the slashing but have been slow in weaving.

The planning and scheduling systems at Company A were strictly manual. One person was responsible for creating the daily schedule. The scheduler would compile information on paper from each process as well as an email with open orders from corporate, and then use collective knowledge in scheduling the plant's slashing machines. The scheduling process goes upstream throughout the plant. The weave room first assigns the looms and then tells the scheduler what has been assigned, and the scheduler then creates the slashing schedule.

The opinions of the executives at Company A were that the scheduling process was a very complex and difficult task and there is too much time and clerical work spent on creating it. The company had tried once before to apply a packaged automated scheduling system to the operations but the attempt failed due to complexity of the numerous SKUs. Currently, Company A is interested in finding an easier way to schedule their plant operations but is unsure of where to start.

4.2.2.2 Interview 2

Interview 2 was conducted at Company B, a large flooring manufacturer located in the United States. The interview was conducted on a day trip where four participants were interviewed: the Director of Manufacturing, the Manager of Manufacturing Resources, the Manager of Rug and Broadloom Planning, and a Process Engineer who is a member of the lean initiative.

Company B has been implementing lean since the summer of 2005. They began by benchmarking a lean company which manufacturers file cabinets. They next utilized the NCSU Industrial Extension Services (IES) to train 70 employees and 15 hourly workers. Company B has worked with Value Stream Mapping (VSM) and plans to use the VSM as a guideline for the remaining lean initiatives.

The improvements seen at Company B have come from streamlining their rug manufacturing process and also by creating smaller lot sizes. The raw materials consumption has decreased and the company is working on reducing complexity by reducing the number of colors. The hourly employees have become excited about lean. Company B is trying to keep them involved as much as possible and continues to encourage them to volunteer ideas for improvements. The company provides the hourly employees with resources and tools needed to be successful and then management tries to stay out of the picture.

Company B used to use an automated scheduling system but their opinion was that the process was still too manual. The old system was an MRP system from Pansofic (now Computer Associates) which runs on an IBM AS400 system. The old system was missing the information from the shop floor which required additional manual work to plan and schedule. Company B also said that there was difficulty in lot size collaboration with their old Pansofic system.

Currently, Company B uses a proprietary Report Program Generator (RPG), developed in the 1990s, that has access to the company's AS400 system. RPG used to stand for Report Program Generator which is a programming language for business applications that runs on the IBM i platform, but has evolved into many different forms of the original.

Other forms include RPG II, RPG III, RPG/400 and RPG IV (aka RPG LE). They look at a manufacturing forecast and tweak it with current manufacturing data. Their current system is adequate at handling the shop floor routings and process sequences, which are reported at each step. The software is not specifically designed for lean, but Company B feels that it will be able to handle the concepts once they are implemented into their operations.

An opinion of Company B on automated planning and scheduling software that deals with customizable software is that most companies feel they have to buy and use the software the way that it is when it comes out of the box, but that every company feels that they are different and requires customized software. Their concerns with the planning and scheduling system with regards to lean manufacturing include the compatibility of the systems with rugs, measured in feet and square yards, and carpet, measured in inches.

Company B is attempting to get marketing, sales, product development and design on board with the idea of lean. Company B feels that other members of their enterprise have the wrong idea of lean manufacturing in that it means less marketing and less design. The company is also in the process of evaluating additional lean projects to tackle, including 5s and Six Sigma.

4.2.2.3 Interview 3

The third interview was conducted at a large textile and apparel manufacturing company (Company C), which is a vertical manufacturer of knitted textiles. The interview was conducted on a day trip to the company's Headquarters. The three interviewees included a member from Strategic Capacity Planning, a member from the Lean Implementation team and the Director of Lean and Quality Management.

Company C began lean about four years ago because management wanted to become a lean enterprise, meaning lean in every aspect of the supply chain. They decided to start a pilot pull system 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. The company uses many lean tools that include Value Stream Mapping (VSM), process mapping, 5s, standardized work, and quick change-over. Company C commented that the VSM did not work particularly well in their textile mills because no improvements were made to them. Other barriers included getting past the traditional ways of thinking and implementing lean techniques before a process was stable and in control. Company C mentioned that they feel a lot of textile companies have the mentality that the assets are losing money if they are not running so they must run it faster and longer to get their money's worth.

Benefits from implementing lean techniques included an inventory decrease of 50% while achieving continuous gains in demand. What once took 1.5 days for a change-over now takes only 45 minutes, and labor is leveled. The company now has work centers that can manufacture over 50 styles, where before the lean implementation they could manufacture less than ten.

Headquarters at Company C uses a combination of i2, SAP and a proprietary system interlinked together for planning and scheduling. The long-term goal is to move to only SAP. Specifically, capacity planning is done in monthly buckets so machines can be moved in and out of the warehouses based on the capacity requirements. Because of this, set-up time and change-over times are critical. Company C has a forecast-driven schedule that is created in monthly or weekly buckets passed down from headquarters to the individual plants. Employees at the plants then create daily or hourly schedules from the originals using manual tools such as MS Access™ databases or MS Excel™ spreadsheets. The goal is to produce the production required at the end of the week. Difficulty Company C finds in scheduling is that they are unsure how the different process schedules relate to each other and the complexity of products. Also, some divisions use different bucket sizes and headquarters must decide how to split it up when creating the schedule for a particular division. An additional barrier is that the measurements are mismatched. Sewing measurements are in dozens or bundles and textile measurements are in pounds.

Kanban are used in the pull system facilities of Company C. The kanban lot sizes are determined based on the criticality of the item and a kanban calculation. While the specific calculation for kanban was not revealed, it is based on lead time and usage of product, and is then tweaked through experimentation. The difficulty Company C sees with using kanban is that the inventory accuracy must be almost perfect and if it is not, the efforts are a waste of time.

Currently, Company C is working on implementing lean in all aspects of the supply chain, including finance, internal auditing, product development, and design. Even though they have been implementing lean for about four years, they still believe they are in the early stages. They currently have a fully functional pull replenishment system in their apparel division. What has helped the pull replenishment in its success is that the management team is extremely positive and is willing to try whatever it takes for the plant to remain running. Company C also has a lean and quality division located at their headquarters that visits each plant to help implement lean and control quality issues.

4.2.2.4 Interview 4

Interview 4 occurred at Company D, which is the same company as Company C, but at a different location. While the interview with Company C was conducted with interviewees at the headquarters, the interview with Company D was conducted with interviewees at one of the company's textile manufacturing facilities that produces spun yarn. Participants were the Lean Manufacturing Manager and an Industrial Engineer. Company D has been extensively involved in lean manufacturing for three and half years. They knew that in order to be survivors in this global economy, money had to be saved and everyone had to be involved in doing just that. In order to stay competitive, this plant began implementing lean manufacturing techniques. The company has Kaizen Teams that meet for 30 minutes each week where they discuss lean projects, such as 5s, Total Productive Maintenance (TPM), standardized work, and Zone Control throughout the plant.

Key points from the Lean Manufacturing Manager on 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 and not an overnight success. This plant took nearly three years for the lean thinking to completely catch on. Each new employee gets a lean handbook that was created by their Lean Manufacturing Manager which covers the basics of lean manufacturing in easy to understand terms.

As mentioned in Interview 3, the planner, who is also an industrial engineer (IE) at this plant, gets the weekly production schedule from headquarters. Using an MS Excel™ program, the IE schedules the necessary frames to meet production requirements. Before lean, the plant would get the production schedule at the end of the week and have the next week to meet the requirements. Now, due to lean, the plant has the ability to be more flexible. Headquarters can now call the plant with a specific request and give a window of six to seven hours for the request to be met. This change came about when the planning department at headquarters decided to begin scheduling by the hour, not by the day. This particular plant at Company D had already completed lean events which made it easier and quicker for the workers to make frame changes in order to meet headquarters' quick requests. Company D has also learned to be more flexible with the shipping load sizes in order to satisfy customer requirements. Before, they would only ship out full truck loads. Because of lean thinking, however, the company is more focused on the customer's schedule and will ship less than full loads if necessary in order to better satisfy the customer.

4.2.2.5 Interview 5

Company E is a large textile manufacturer that produces cotton and cotton blended yarns using the latest technologies and automation. The interview was conducted on a day trip to one of the company's manufacturing facilities as well as the headquarters. The participants of the interview were a Vice President, the Six Sigma Manager and the 5s Coordinator.

Company E began implementing 5s in many of their plants about one year ago after two employees attended a 5s seminar held at North Carolina State University. The initial training began with one employee from ring spinning and one employee from open-end spinning. The goal was to train employees at each individual plant. One person now covers both spinning departments and is in charge of overseeing the training for all facilities. What made this successful for Company E was that the trainers began using common language that was easily understood by all employees and hourly workers. When there was an issue of a foreign language, pictures were used in addition to words. Company E also has a small team that implements Six Sigma projects. What enabled the 5s implementation to be such as 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. Rewards are very helpful. Plants where the managers work with the employees instead of keeping away from the project are also helpful in sustaining the improvements. Value stream maps were attempted, but Company E said they were not very helpful and felt they were not the right tool for them. They said the VSMs did not show the projects or opportunities that needed to be worked on.

Barriers to implementing Six Sigma were that the projects were often too narrowly defined and that most employees and hourly workers did not understand the statistics and terminology. Company E also does not use the Japanese terminology commonly associated with lean manufacturing. Instead, the trainers use direct, English terms as to not scare off employees and hourly workers. Other barriers included the fact that some people continue to "slack off," and there can sometimes be difficulty in the sustaining step of 5s due to the time it takes for the project to be completed.

In regards to planning and scheduling, Company E does the majority of that at their headquarters. After switching from i2 in March of 2005, DATATEX was selected as the planning and scheduling system chosen by Company E. The modules used are the DATATEX TIM (Textile Integrated Manufacturing) for their ERP system and MQM (Machine Queue Management) for plant scheduling. They have the ability to pull information off of the AS400 system that is already in place. It took about 14 months for Company E to completely install the DATATEX and integrate it into each individual plant. The current software allows many users to have accounts, but only allows one at a time to be modifying the schedule. Company E says that DATATEX lets them make quick decisions, handles the complexity of their products fairly well, and allows for more description of the products than before. The company tries to plan off of its top customers to produce a forecast. There is one planner for each plant that once a week receives a new schedule for the upcoming week. The fact that there are a large number of plants in various locations requires good communication between headquarters and the plant facilities. Inside some of the plants, Company E uses visual scheduling cues such as tape and rods on the wall to determine how much of the finished, raw, and in-process inventory is needed at any given time. Company E still uses a push system where they build to inventory, however, they are able to keep less than a week's worth of inventory on hand in the warehouses.

4.2.2.6 Interview 6

Company F manufactures textile materials that are used in recreational products. This interview was conducted on a day trip where the Vice President of Operations was interviewed. As a result of large customers demanding lower prices, Company F was forced to begin importing some of their materials. In addition to importing, the company chose to apply lean concepts to further reduce costs. Company F is successfully using 5s and work cells in their operations. They started applying lean concepts about two years ago when 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 E said that the concepts were too complex for some employees to understand.

Company F has an MRP system from Harris Data Systems based in Minnesota that links to their AS400 system. They use the MRP for planning, inventory management, order management, creating the bill of materials and the master production schedule.

Company F has also begun to let the vendors see the MRP requirements. Their current vendors are not lean but are in batch mode of manufacturing. Therefore, this visibility allows them to have on-hand the raw materials that Company F needs. The goal is to allow customer visibility so they can eventually place their own sales orders. The company planner uses a MS Excel™ spreadsheet to import information from the MRP system such as capacity requirements and product requirements by type, item, and area of production. The planner then meets with the production manager on a daily basis to discuss the shop floor requirements.

One of the barriers Company F 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 who were 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 F is currently working on becoming a make-to-order facility.

4.2.2.7 Interview 7

Interview 7 was conducted in person but away from the company's facilities. The Quality Control/Engineering Manager met the research committee on NCSU College of Textiles' campus to discuss their involvement in lean manufacturing. Company G is a small manufacturer of a variety of woven and knitted fabrics for industrial and medical end uses. Company G first began implementing lean techniques in the beginning of 2006 by using the NCSU IES. They rearranged the work flow, introduced visual scheduling and used VSM. The visual scheduling board was used to inform the operators of the open work orders and the orders' priority.

Barriers to lean scheduling for Company G include complexity of product and expense of training and implementation. Communication problems or language barriers between workers has also been a challenge. However, the largest challenges are the culture change and resulting lack of enthusiasm from some employees. The warping process is one area where Company G is interested in implementing lean techniques due to the fact that it is their biggest bottleneck and has less than 50% current run-time.

Benefits included a 17% increase in throughput and the knowledge of how to carry over the lean implementation into other areas of the plant. Decreased work-in-process was also a benefit from the lean implementation. Company G used to have up to six weeks of a work-in-process backlog at any given time. Currently, Company G is in the process of working with IES to help implement other lean techniques and lean training at their plant.

4.2.2.8 Interview 8

Due to logistics, Interview 8 was conducted on the phone with Company H, a medium sized manufacturer of contract upholstery fabrics used in the hospitality market. The Executive Vice President was the participant for this interview. Company H has been implementing lean for about 3 ½ to 4 years. Their lean transformation began when the company's CEO became inspired after attending a seminar on lean manufacturing with a Key Note Speaker from Wire Mold, a successful lean manufacturing company. Soon after, Company H's largest customer, a lean organization which desired to cut back on their numerous suppliers, asked them to go lean. As seen in the literature, many customers are asking their suppliers to become lean. Not only did Company H's customer ask, they also helped them become lean by acting as a mentor for their lean transformation. The interviewee mentioned that one of the critical aspects of successful lean implementation is to put lean into practice throughout the supply chain. Company H has also helped a downstream member of their own supply chain, a finishing operation, in becoming lean by creating daily shipments. Their shipping truck was modified with racks that now categorize the fabric rolls according to which type of finish will be applied. These modifications help Company H's fabric finisher spend less time sorting through the fabric rolls so that they can get the finished product to the customer sooner.

At Company H, the Executive VP formed an implementation team and began training employees and implementing lean techniques throughout the facility. One task for Company H that saved a rather large amount of money was getting rid of the entire obsolete yarn inventory. This amounted to $275,000 worth of yarn inventory that, although may have looked bad on the financial books for the year, freed up much space in the warehouse to add staging areas and to better implement the pull systems and supermarkets.

Company H has used Value Stream Maps, performed set-up reductions, implemented pull systems, held Kaizen events, and implemented 5s as part of their lean transformation. They also use a kanban system for the weave room production. Company H said implementing the kanban system was difficult at first because of the complexity, and it involved a lot of in-house modeling before the process was ready. The interviewee noted that Company H mocked up every possible aspect of the process including each loom in the weave room with set-up times, beam types, the supermarket with the required styles, kanban cards, and kanban posts in both the weave room and production office. A modified kanban formula was used to determine the number of warps required by the system. Company H also used a 50% safety stock factor in the beginning with the goal of reducing the inventory levels by reducing the number of kanban as the company became more comfortable with the system. Company H then created a supermarket, based on the kanban formula, where a certain number of warps were made for each style and loom configuration. For those styles where customer demand was inconsistent, Customer H made an estimated guess on the number of kanban required and adjusted the number when necessary.

Each loom was set up on the kanban system with the warp supermarket. The supermarket is color coded with red and yellow areas to visually alert employees when a particular style is getting low on warps. However, if there is no customer demand for a particular style of warp, no warps are made. Each warp receives a kanban card and when a new warp is placed on the loom, the kanban card is taken off of the warp and placed in a kanban post. Cards in the kanban post will go back to the production office when the loom runs out of the warp to alert production that another warp needs to be produced in order to replenish the supermarket. If the supermarket is functioning properly, there will be a warp available to be immediately tied in to the remaining warp on the loom. New warps are sent to replenish the supermarket and are then ready to be placed on the looms as needed.

As an example for the kanban/supermarket system, Company H may have 30 kanban cards coordinating a warp for a particular type of warp style and loom configuration. The supermarket may always need to carry ten warps. There may be six cards in the supermarket, one card at each of the 20 looms on which the fabric is being woven, and four kanban cards at production where new warps are being made to replenish the supermarket. If the situation arises when an order must be expedited, a common occurrence with most companies, the warp request is placed at the top of the warp schedule and then moved to the top of the supermarket. If the system is running smoothly, in four hours from the customer's expedited request, the warp will be made, tied in, and will have begun production.

There were people who thought that implementing lean in Company H's textile facility would not work, but Company H has enjoyed the challenge. Currently, Company H would not classify themselves yet as having a "lean culture" as they believe that takes a long time to achieve. Some of the challenges they have faced, as with many companies, is communicating to a multi-lingual workforce. To help alleviate this problem, Company H used a grant to hire a bi-lingual lean trainer who worked with the foreign language speaking employees. They also feel that the lean implementation would be smoother, quicker, and easier to sustain if they had a full-time employee whose job was to implement, sustain, and train employees on lean manufacturing.

4.2.2.9 Interview 9

The ninth interview was conducted at a small company that manufactures textile auxiliaries under government contract at three manufacturing facilities. The interview was conducted at one of Company I's North Carolina manufacturing facilities with two members of upper management, the Director of Manufacturing and the Production Manager.

Company I first started lean in February of 2005 by utilizing the NCSU IES. Their purpose for beginning lean was to keep their pricing competitive and to be able to keep up with the marketplace. Their most current lean implementation was in May of 2006. Company I has implemented one-piece flow for one of their products, kanban systems to help lower their finished goods inventory, 5s throughout the facility, TPM, and VSM.

The actual manufacturing is controlled by the kanban system implemented at the finished goods inventory area. When the inventory gets below a certain point, the kanban card is placed in a bin where, twice a day, the production manager will see what products should be made to refill the inventory. Based on prior knowledge, the shift manager will schedule the manufacturing floor according to which kanban cards he receives. Company I also implemented a flag system for the employees to use when they start to get low on work. Once an employees' in-process work reached a predetermined level, the employee would raise a flag so the shift manager would see that they were getting low on in-process work.

Company I uses Great Plains' MRP system called Horizons for ordering their raw materials, which they run twice a week. They do not use it to schedule production. When the finished goods are completed, they are entered into the system, and the MRP will recalculate how much raw material is left. The planner has a five week lead time pre-set in the system and when the raw materials fall below a five week inventory level, an order is automatically generated. The company used to create the orders by hand every day, and having the MRP system has freed up that time for the planner to work on something else.

One of the biggest benefits from the lean implementation includes a major increase in floor space, which Company I now uses for temporary contract business as well as leasing out to outside companies. Additional benefits stemmed from the implementation of one-piece flow which eliminated storage and reduced the material travel by 72%. This was achieved by moving machines closer together which decreased the footage the materials had to move from 124 feet to 29 feet. Production also increased for Company I. Before lean, the production on one of their products used to be 1500 units for each ten hour day, however, now the company can produce the same 1500 units in an eight hour day. Cost savings were also seen in one of the cutting operations where 1.5 inches of waste fabric was saved each time. This equated to $2,400 worth of savings for Company I. Their customers have even said that their on-time delivery and quality have increased as well.

4.2.2.10 Interview 10

Interview ten was conducted on-site at Company J, a manufacturer of industrial textiles. Three executives were present during the interview, the Manufacturing Manager, President of Manufacturing and the Lean Manufacturing Coordinator. Company J began their lean transformation in February of 2005 with the help of the NCSU IES. They began with Lean 100 classes to train all employees on the ideas and concepts of lean manufacturing. Company J also had the NCSU IES come in and train the management on Value Stream Mapping so they can create Value Stream Maps of their own. In addition to the NCSU IES, Company J asked LeanWorks, a lean manufacturing consulting company to come in for additional training and experience.

Company J uses VSM, one-piece flow, production scheduling boards, and 5s. The benefits from implementing lean have been improved flow and increased floor space. Also, the WIP inventory has been greatly decreased. No automated planning or scheduling system is used for the company, only manual techniques. Company J uses a production board to keep track of the plant floor schedule and an MS Excel™ spreadsheet to aid in inventory control.

Company J faced some initial barriers when first beginning the lean transformation. One was not having belief in the lean philosophy and thinking that it will be another manufacturing flavor of the month. In order for the top executives to believe that lean would work for their company, the company visited Eaton, a transmission manufacturer for heavy duty vehicles, which is the first North Carolina plant to receive the North Carolina Shingo Prize for Excellence in Manufacturing for their efforts in lean manufacturing. Because most of the products at Company J are high mix and low volume, some of the executives there felt that lean manufacturing would not work for their manufacturing environment. Soon after they attended some seminars and visited other lean companies, the idea began to catch on.

They realized that lean is much more than just implementing different tools and techniques. It is a company culture and a new way of thinking. Still, applying this lean thinking throughout the enterprise is currently where Company J is headed. They are also scheduled for more Kaizen events and lean training through NCSU IES.

4.2.2.11 Automotive Industry: Interview 11

Interview 11 was conducted at a company in the automotive industry. Company K is a Japanese owned engine parts supplier for a major automotive company. This particular plant opened in 1998 and implemented the Toyota Production System (TPS) and lean principles as part of their company culture. The company was chosen to interview because of their long involvement with lean principles. Although Company K is not part of the textile industry, it was important to see how a true lean manufacturing plant operated. The interviewee was a Manufacturing Manager at Company K’s first United States manufacturing plant.

The tools used at Company K included kanban, musical and lighted andon (signals), TPM, Kaizen, standard operating procedures, and 5s. The Japanese are very quality-conscious; therefore, Company K had numerous quality check stations throughout the plant. Every hour, an employee would place one part at the quality check stations to make sure the line was continually manufacturing quality products.

The facility operated on a pure pull system. The process began when the computerized scheduling system printed out tickets, in batches of five, for the automotive parts. E-carts are electric hauling trucks with carts attached on the back and are used to haul parts around the plant. An E-cart employee would then pick up the printed tickets and take them to the first step in manufacturing. At that first step, another employee would pull the correct amount of parts to begin manufacturing, place the ticket on the parts, scan the ticket to signal production, and the process would begin. From there, the manufacturing process moved in an assembly line. At each station of the assembly line, the worker had visual cues for when to pick specific parts and at what sequence the parts should be used. These cues were blinking lights that were attached to the parts buckets. This would ensure that each employee was following the standard operating procedures for making any particular product. Company K also used retractable tools so that the work station would stay clutter-free.

Kanban were also used throughout the plant for replenishing the parts used during the shift. One person for each line was responsible for checking the kanban containers. Every time two kanban containers were used, meaning two empty bins were visible, the employee would send a signal across the plant to the receiving area that meant they needed replenishment. Located at receiving was a board with kanban tickets that were color coded for each assembly line process. These tickets were round, plastic and had the part number and storage location engraved on the front side. The board had retractable pegs that were electronically integrated with the assembly lines. One kanban ticket was hung on each peg. When the employee sent a signal for replenishment, the peg for that particular kanban retracted into the board and the plastic, round kanban ticket dropped down into a trough. The tickets rolled to the end of the trough where they would accumulate if the receiving area employees were short-staffed or working too slow. There was a yellow warning line and a red danger line on the trough. If the tickets accumulated enough to where they got to the red danger line, a light began blinking on the kanban board to tell the receiving area employees that there was a back-up on parts needed. With this kanban system, the line only was replenished when the parts were used. The receiving area employees had ten minutes from time the kanban ticket was dropped to locate the part and get it to the assembly line.

The takt time for making the automotive parts was at less than one minute and the employees knew exactly how long it took to conduct each step of their particular process. Posted in each employee break area was a list of each task for any given process and the number of seconds it should take to accomplish that task.

The interviewee for Company K said that there were not any major barriers to implementing lean due to the fact that the company trained the employees from the very beginning of their employment. Also, employees at Company K who are new were fairly familiar with the TPS system because they had come from similar plants or manufacturing facilities. Not all of the tools used at Company K would be useful in the textile industry. However, the lighted and musical andon, kanban systems and visual management would be useful.

4.2.3 Comparison of Textile Company Interviews Pertaining to Each Research Objective

Although each company interviewed is quite different and is in different stages of their lean transformations, similarities in thought process and methodology of conducting lean initiatives are seen. Table 4.11 shows the comparison between each of the ten textile industry interviews and one automotive industry interview and their responses regarding research objectives one through four. The company in the automotive industry, Company K, was not included in the actual analysis of interview answers. The company is included in Table 4.11 to show a comparison between a company which has been implementing lean from the initial start-up and companies who are newer to lean implementation.

Table 4.11 Comparison of Company Interviews

Company Interview # (# of Executives)	Began Lean	Lean Techniques (RO1)	Planning and Scheduling Systems Used (RO2)	Barriers to lean (RO3)	Application of lean planning and scheduling (RO4)
Co. A Interview 1 (6 Execs)	2 yrs	5s, Process Improvement Standardized operating procedures, Quick change-over	Manual: Pencil and paper	Complexity of products, time consuming and complex scheduling Company's attempt at implementing automated system failed due to complexity and numerous SKUs	No lean planning & scheduling: Need better system to replace manual scheduling,
Co. B Interview 2 (4 Execs)	1.5 yrs	VSM, Streamlining manufacturing process	Automated: Proprietary RPG system but still too manual	Difficulty with lot size collaboration and measurement metrics (feet versus sq. yards)	No lean planning & scheduling: Proprietary system not lean, but Execs feel it will handle the concepts once they are in place
Co. C Interview 3 (3 Execs)	4 yrs	VSM, 5s, Pull system, Kanban, Standardized operating procedures, Quick change-over	Automated: i2, SAP, Proprietary linked together, kanban at pull facility	Getting past traditional ways of thinking, trying lean before process was in control, differing measurements (dozens versus pounds), complexity of products	No lean planning & scheduling: MS Excel™ or MS Access™ used at plant level, kanban for pull system facilities
Co. D Interview 4 (2 Execs)	3.5 yrs	5s, Kaizen teams for TPM, Standardized operating procedures, Zone control	Manual: Receives schedule from headquarters and modifies with MS Excel™	Culture change requires time	No lean planning & scheduling: MS Excel™ or MS Access™ used for weekly production schedule at plant level
Co. E Interview 5 (3 Execs)	1 yr	5s, Six Sigma, VSM not very successful	Automated: DATATEX MQM	Language barriers, large number of plants requires good communication between headquarters and manufacturing	Uses MQM to schedule plants

Table 4.11 Continued

Company Interview # (# of Executives)	Began Lean	Lean Techniques (RO1)	Planning and Scheduling Systems Used (RO2)	Barriers to lean (RO3)	Application of lean planning and scheduling (RO4)
Co. F Interview 6 (1 Exec)	2 yrs	5s, Work cells, VSM not very successful	Automated: Harris Data Systems MRP, Planner uses MS Excel™ to schedule plant	Resistance to change, complexity of some lean concepts, integration with suppliers and customers	No lean planning & scheduling: MS Excel™ used to schedule plant
Co. G Interview 7 (1 Execs)	1 yr	VSM, Streamlined work flow, Visual scheduling boards	Manual: Visual scheduling board for one department, pencil and paper for all else	Complexity, expense of training and implementation, language barriers, culture change and resistance to change	Visual scheduling boards for packaging department, manual scheduling everywhere else
Co. H Interview 8 (1 Exec)	4 yrs	VSM, 5s, Kanban, Pull systems, Setup reductions	Manual: Kanban system for weave room and warping	Disbelief in lean principles, culture change, language barrier, complexity of weave room for implementation of kanban	Kanban for weave room production
Co. I Interview 9 (2 Execs)	2 yrs	VSM, 5s, One-piece flow work cells, Streamlined work flow, TPM	Manual and Automated: Kanban for finished goods, MRP for raw materials	No real resistance to lean concepts	Kanban at finished goods which controls manufacturing
Co. J Interview 10 (3 Execs)	2 yrs	VSM, 5s, One-piece flow work cells, Streamlined work flow, Production scheduling boards	Manual: Production board and manual scheduling	Disbelief in lean principles, thought it would be a “flavor of the month”	No lean planning & scheduling: Manual schedules but are looking for a better way
Co. K Interview 11 Automotive Industry (1 Exec)	9 yrs	5s, Kanban, Pull system, Kaizen events, Standard Operating Procedures, Production Boards, TPM, Quality-check stations, Andon	Automated: Scheduling system prints kanban tickets that starts the Manual Pull system and kanban for assembly	No major barriers due to employees being trained from the beginning	Lean pull system and kanban for part replenishment on assembly lines

***RO1**: Identify if US textile companies are using lean techniques in their manufacturing operations.*

All companies interviewed were using some type of lean tool. The number of companies using any particular tool is shown in Figure 4.1. Eleven different tools were mentioned during the interviews. The most widely used tools were 5s and Value Stream Mapping used at eight and six companies, respectively. The manual lean planning and scheduling tools mentioned in the interviews were scheduling boards and kanban/pull systems. However, there were only five instances of companies using some form of manual lean planning and scheduling tool that were mentioned, shown in Figure 4.1 with yellow bars. Some of the top lean tools used, e.g., 5s, VSM, streamlining work flow and work cells, all help in lean planning and scheduling, but they are not used specifically to schedule production.

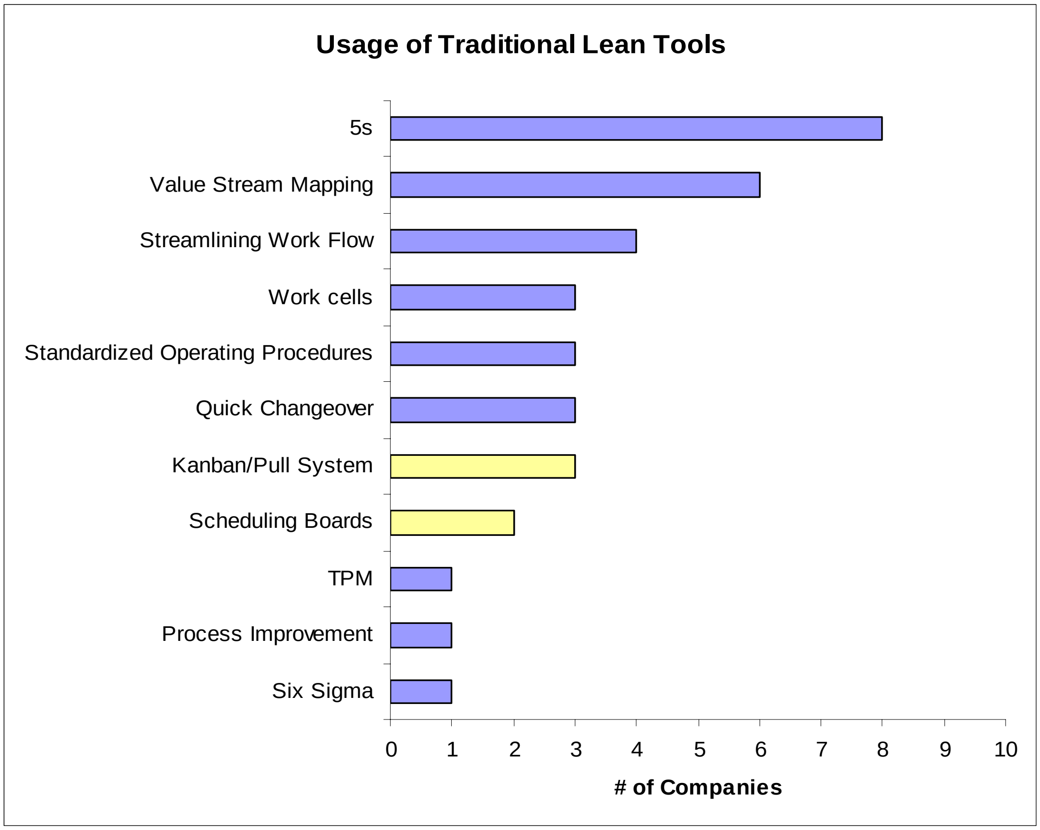

Figure 4.1 Usage of Lean Tools

While the VSM was particularly popular, some companies did not find it useful in their organizations. Either the VSM improvements were not carried out or the company felt that the VSM did not show the opportunities that needed to be improved at the time.

All companies interviewed are relatively new to lean manufacturing. The most mature lean manufacturers have been using lean for four years. Regardless of their time involved in lean, all of the companies interviewed have seen improvements from applying these lean tools. These improvements include decreased inventory, decreased raw materials, and an increase in employee involvement and pride in their workplace. Several companies acquired additional floor space that was used for additional business, to further implement lean pull systems, or even to lease out to other companies as temporary storage space.

RO2*: Identify what planning and scheduling systems US textile manufacturers are using.*

Fifty percent of the companies interviewed used combinations of various planning and scheduling systems. Sixty percent of the companies still use the manual methods of paper and pencil or MS Excel ™ spreadsheet to schedule the plant floor as one of their scheduling tools. Figure 4.2 shows that the interviewed companies used varying combinations of tools. However, Companies G and J were similar in their planning and scheduling methods. Both used pencil and paper in addition to their scheduling boards. Both G and J were small manufacturers that had one manufacturing facility. Company C used four different types of planning and scheduling methods; however, it is a large organization with many different plants. At Company C, automated systems are used to plan at the corporate level, and at the plant level MS Excel ™ is used. The kanban system is used at only one of their facilities in which a pilot pull system was implemented.

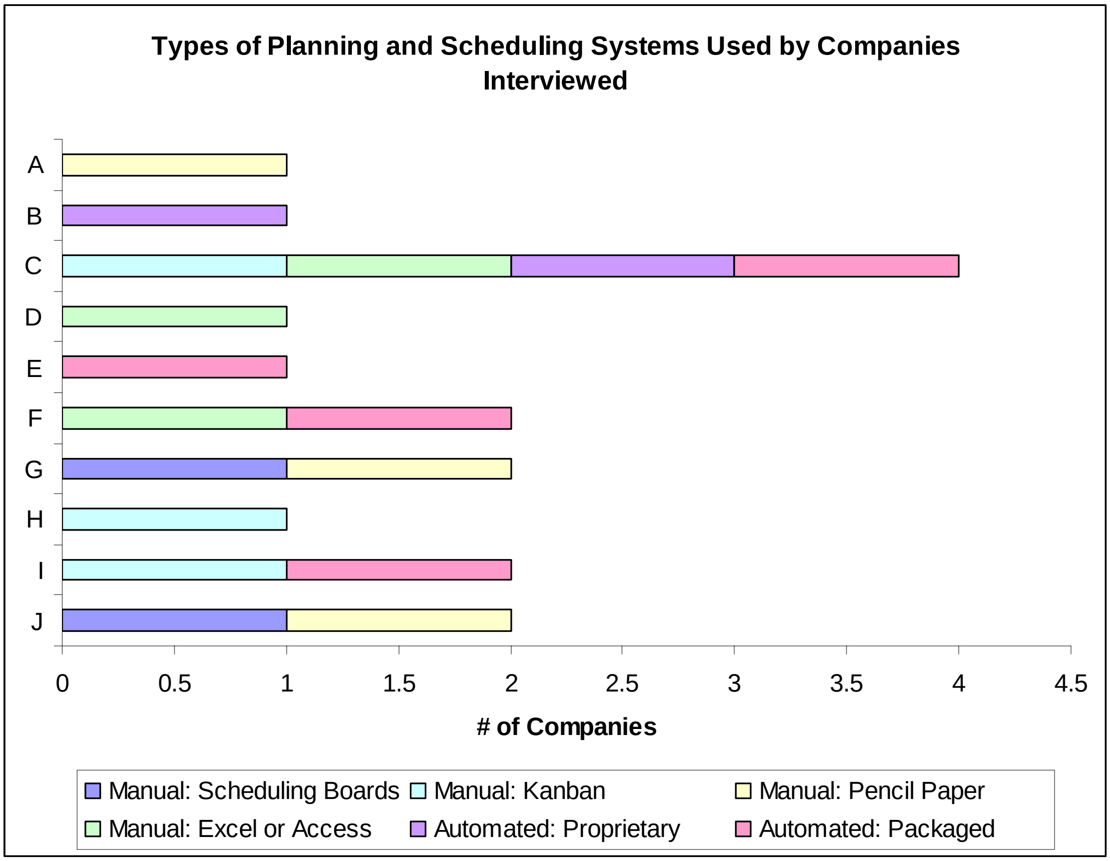

Figure 4.2 Types of Systems Used by Company

Table 4.12 shows that a majority of systems used to schedule the plant floor were still partially manual. Seventeen total planning and scheduling instances were reported during the interviews and almost 65% (eleven out of seventeen) of those were manual. According to the opinions of the executives at the interviews, manual planning and scheduling at the plant level is a very tedious and time consuming task, and they would prefer a quicker, easier method of accomplishing it.

Regarding whether or not the planning and scheduling systems were lean, only 41% (seven out of seventeen) of the total instances were reported as being lean systems. Results in Table 4.12 show that only two out of ten, or 20%, of the companies interviewed were using automated lean planning and scheduling systems (i2/SAP and DATATEX), 30% of the companies interviewed were using kanban/supermarket/pull systems for the production control, and 20% were using a visual scheduling board. Of the three companies to use kanban, one company used the kanban system throughout an entire pull process, and the remaining two companies only used the kanban systems in portions of the manufacturing process, i.e., finished goods inventory and the bottleneck process. The visual scheduling boards were used to inform employees of what orders are open and how much is left to produce.

Table 4.12 Companies and Their Planning and Scheduling Systems

System		Company										Total
		A	B	C	D	E	F	G	H	I	J	
1	**Lean Automated: Packaged**			X		X						2
2	**Lean Manual: Scheduling Boards**							X			X	2
3	**Lean Manual: Kanban**			X					X	X		3
4	**Manual: Pencil Paper**	X						X			X	3
5	**Manual: Excel or Access**			X	X		X					3
6	**Automated: Proprietary**		X	X								2
7	**Automated: Packaged**						X			X		2

RO3*: Determine the barriers to using lean planning and scheduling systems in US textile companies.*

Five companies mentioned that one of the top barriers included complexity of the product and/or product mix. Additional barriers were the expense of the lean training and implementation and the complexity of the current scheduling process. Other human challenges were getting top management to commit to the lean transformation, resistance to change, getting past traditional ways of thinking, and adapting to the culture change. Failure to overcome these challenges makes it difficult to succeed in the lean transformation. These barriers are consistent with the barriers found in the secondary sources regarding other industries. The complete list of barriers and challenges faced by the industry executives is shown in Table 4.13.

Table 4.13 Barriers and Challenges from Primary Sources

Lean Barriers and Challenges	
• Product and product mix complexity & numerous SKUs	• Current scheduling process too complex/manual
• Language barriers	• Culture change
• Unmotivated/unenthusiastic employees	• Multiple plants require good communication
• Resistance to change	• Integration with customers and suppliers
• Top management not committed	• Difficulty sustaining
• Uncertain where to start	• Complexity of lean concepts
• Getting past traditional ways of thinking	• Differing IT systems
• Expense of lean training and implementation	• Planning and scheduling system compatibility with differing product measurements

RO4: *Determine where the implementation of lean planning and scheduling systems would be best applied.*

Few companies were using lean planning and scheduling systems. Only Companies C and D were using lean automated systems. Both companies are large and have multiple plants. Only three companies were using kanban for production control, and only two used some type of visual scheduling board. The companies who used the scheduling boards were smaller companies. The kanban were used by small, medium and large companies. The small and medium companies used the kanban system in only one portion of the manufacturing process, and the larger company used the kanban system in a pull pilot facility.

4.2.4 Case Studies

This section covers three case studies conducted to better understand how lean planning and scheduling tools can be applied to textile companies. The first case study was conducted to create a Value Stream Map (VSM) for a textile manufacturing company who has recently begun lean manufacturing. The second case study involved a three day VSM session with the NCSU IES at a small textile manufacturer. The third case study evaluated an automated planning and scheduling system created specifically for textile environments.

4.2.4.1 Case Study A

The first case study conducted for this research was to apply a lean tool to a company's already existing process. The participating company, Company 1 is a small textile manufacturer located in the southeastern United States that has already had some experience in lean manufacturing, although they are in the beginning stages. The case study involved a three day visit to the plant in which a Value Stream Map (VSM) would be created for the warping, slashing, and weaving processes for a given product. Based upon the literature and speaking with lean experts, conducting a VSM should be one of the first things a company does when beginning lean. Not only does the VSM session teach the participants how to correctly construct the map, it also creates a brainstorming session where the participants are forced to think outside of the box (Nicholas & Soni, 2006). As previously mentioned in the literature review, VSM includes both information and material flows. The focus for this particular research was the information flow.

The researcher spent three days at this manufacturing facility. The first day was used to become familiar with the material flow of Style A through warping, slashing and weaving and the information flow for scheduling those operations. Company 1 had a manual scheduling system where the scheduler's main task each day was to use information gathered from various departments to create daily schedules for the slashing machines. Figure 4.3 shows that the Scheduler receives a large amount of information in order to create one daily slasher schedule.

The Scheduler receives the following pieces of information:

1. "Yards remaining to be put up" from corporate to determine how many yards of fabric are needed to finish an order;
2. Beams per set report created daily in a MS Access™ database by the scheduler to aid in the scheduling process;
3. Warp room run-out which tells how many and on what day the loom beams on the weaving machines will run out;
4. Slasher report which gives information on how many loom beams for any given style were created the day before;
5. Inventory counts for the available warp beams created from either warping at the plant or warps received from outside the plant; and
6. Loom schedule sent from corporate which tells the plant how many looms they want running for a particular order per week.

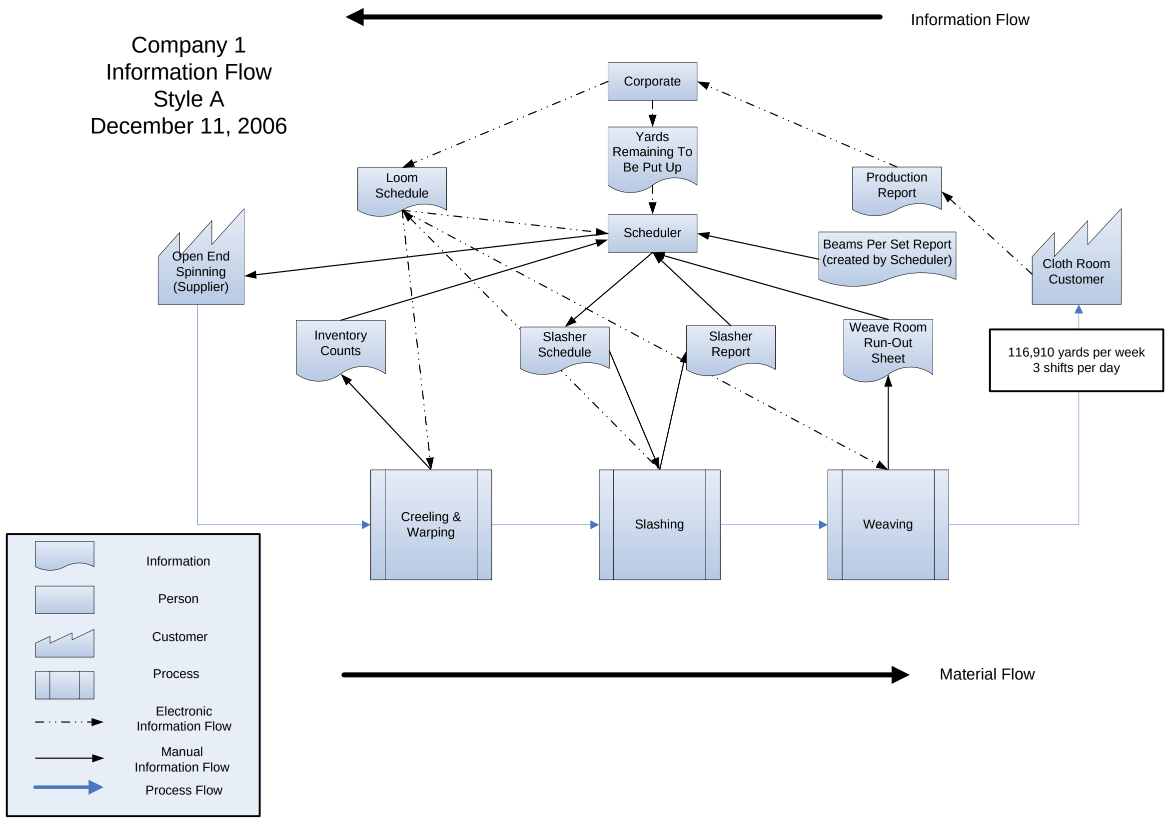

Figure 4.3 Case Study A Information Flow for a Weaving Operation

The complexity of this particular situation is not uncommon to other textile facilities. Many companies, especially smaller operations, have situations similar to this where one or more people are responsible for creating a manual schedule for the plant. The process is involved, time consuming and tedious, and many companies are looking for other options to help simplify the scheduling process.

After the material and information flows were better understood, the researchers collaborated with management in order to find a product that was fairly high volume and currently running in the plant so that data could be collected. The second and third days were used to gather the information and create the current state VSM.

The data required to create the entire VSM included the cycle time, machine setup time, uptime, waste, and takt time. The cycle time is the time it takes for a machine to produce one good piece to the next good piece. The machine setup time is the time it takes for the machine to change over from the last good piece of product A to the first good piece of product B. The uptime is the percentage of time the machine is running per shift, and the waste is the percentage of waste typical for that process and product. The takt is the customer's demand and the takt time is defined as the amount of time it takes to produce each part to meet customer demand. Takt time is found by dividing the total amount of actual working time per shift by the customer requirements per shift (Rother & Shook, 2002; Standard & Davis, 1999). The customer for this VSM is the Cloth Room which requires 116,910 yards per week. This value is the takt for this company.

After finding the inventory counts and the other required calculations, the current state VSM shown in Figure 4.4 was created. The map shows the value added and non-value added time and the percentage of the value added time for the processes. The percentage of value added time is calculated as follows:

$$\%VA = \frac{\text{VA Time}}{\text{Total Time}} * 100$$

Total time is found by adding the value added time to the production lead time. The equation for calculating Company 1's %VA follows:

$$\%VA = \frac{2.041\text{min} * 1\text{hr}/60\text{ min} * 1\text{day}/24\text{ hr}}{(2.041\text{min} * 1\text{hr}/60\text{ min} * 1\text{day}/24\text{ hr}) + 1.68} * 100 = 0.0843\%\text{ VA Time}$$

The percentage of value added time for this company's VSM was low due to the quick cycle times of the machinery.

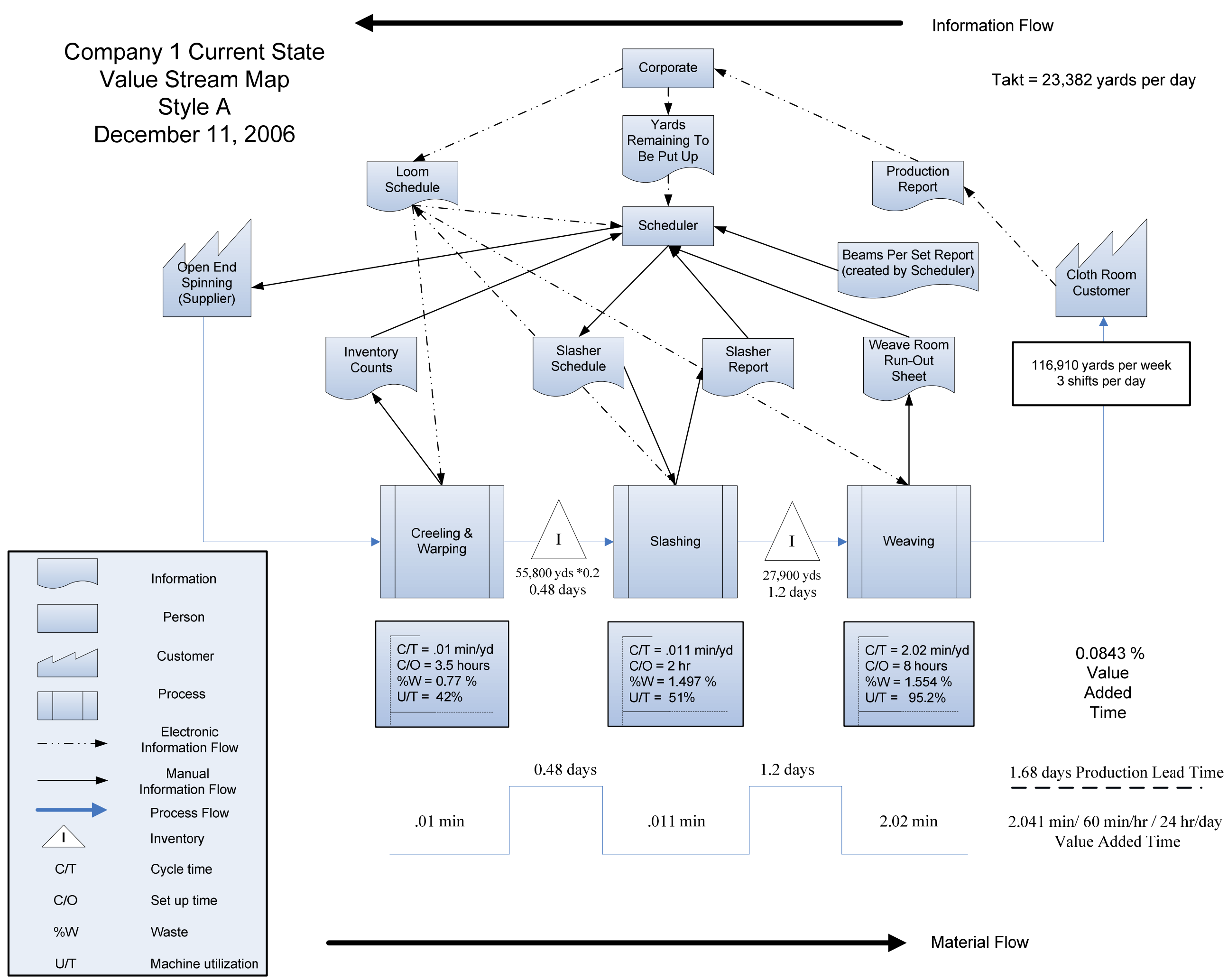

Figure 4.4 Case Study A Current State Value Stream Map

The next step would be to conduct a Future State Map for this company. In order to create the Future State Map, the management would need to brainstorm ideas for improvements that can be made to the existing process. The ideas should then be turned into projects where Kaizen teams would work on specific actions, for example, to reduce setup times, decrease inventory or improve the flow through the plant.

4.2.4.1.1 Key Points from Case Study A

- Information and data is somewhat difficult to gather for first-time VSM creation
- Attending a hands-on VSM session makes the process easier
- A complicated information flow, such as this, creates a difficult scheduling process
- The percentage of Value Added Time is much lower than expected
- Future state maps are important to complete the VSM process

4.2.4.2 Case Study B

Case Study B was conducted by attending a Value Stream mapping session with the NCSU IES at Company 2. This case study was a three day event where the researcher assisted in creating a current and future state map for one of Company 2's products. The VSM session was composed of a cross-functional group of employees from many levels of management and hourly employees. Participating members, shown in Table 4.14, included the CEO, the President, the CFO, the Plant Manager, the Weaving Manager, the Quality Manager/Engineer, the Finishing Supervisor, a member from Expediting/Customer Service, and a member from Maintenance.

Table 4.14 VSM Session Members

Member	Experience at Plant
CEO	30+ yrs
President	--
CFO	< 1 yr
Plant Manager	4 yrs
Quality Manager/Engineer	13 yrs
Finishing Supervisor	--
Weaving Manager	30+ yrs
Expediting/Customer Service	21 yrs
Maintenance	11 yrs
Kelly Goforth (Graduate Student)	NA
April Wagoner (Graduate Student)	NA
NCSU IES VSM Leader	NA

It was important to have a cross-sectional VSM team with members from different levels, different departments, and different levels of experience throughout the company in order to get ideas from all departments and also to ensure that the map was created as accurately as possible. Having participating members who had been there for different amounts of time was especially helpful because the newer members were not biased or influenced from spending a long amount of time at the plant, and the more experienced members knew how the plant currently functioned and how it functioned in the past.

The first day of the session was used for initial training and education of the process of Value Stream Mapping. Each participant at the training session received a Value Stream Mapping Workshop workbook created by Mike Rother and John Shook (2002) of the Lean Enterprise Institute in Massachusetts. The IES session leader went through PowerPoints and explained the VSM process. The VSM team first learned the basic principles and terminology, then gathered information in order to create the Current State Map, and finally brainstormed for ideas and improvements in order to create the Future State Map. The process of creating a VSM would help Company 2 to better see the flow of their materials and information throughout their plant and also enable them to see where improvements to the process could be made.

4.2.4.2.1 Principles and Terminology

As the session began, the session leader explained the concept of waste. At IES, the concept of eight forms of waste is used, rather than the original seven forms of waste identified by the Toyota Production System. The eighth additional waste is employee underutilization. The session leader introduced an easy way to remember these eight wastes by spelling D-O-W-N-T-I-M-E as follows:

Defects

Overproduction

Waiting

Non-value added activities

Transportation

Inventory (excess)

Motion (excess)

Employee underutilization

Other principles and terminology covered were the concepts of lead time (L/T), cycle time (C/T), value added (VA) and non-value added time (NVA), and takt time. The lead time is the total time from starting the product to shipping the finished goods. The cycle time is the machine cycle time or assembly cycle time to make one good piece to the next good piece. As mentioned in the Literature Review, the value added time comes from the processes that the customer is willing to pay for, for example employee break time and reworks. The non-value added time comes from the processes that the customer is not willing to pay for, for example transporting the loom beam across the plant to be loaded onto a weaving machine. There are also non-value added but necessary processes which do not necessarily add value to the product, but must be carried out in order to complete the process, for example transporting beams, doffing the beam, and cutting the fabric. The session leader mentioned that in World Class manufacturing facilities, value added time typically only accounts for 30% of the total lead time it takes to produce a product. In typical manufacturing facilities, less than 5% of the total lead time is value added and the remaining 95% of lead time is non-value added or necessary non-value added. That is a large amount of time spent on processes the customer is not willing to pay for. The takt time is the total time available to produce the product divided by the customer demand. If the customer demand is daily, then the daily time available to produce the product should be used in the calculation. If the customer demand is weekly, then the weekly time available to produce the product should be used. This equation results in the time it should take to produce one item for the customer. Also important for a VSM is inventory counts, planned capacity (PC) or up-time which is the percentage of time that the machine is running during a shift, and the change-over time (C/O) which is the amount of time required to change from the last good quality Product A to the first good quality Product B. The session leader also covered the fact that the material flow is shown on the bottom going from left to right and the information flow is shown on the top, going in the opposite direction from right to left (Rother & Shook, 2002).

For a VSM, a company should focus on one product or one product family that has similar process steps. Company 2 chose a product, Product 2, for four important reasons. Mapping Product 2's process was reasonably simple, Company 2 was currently producing Product 2 in the plant, Product 2 had a fairly stable demand pattern, and it was a larger volume product. The processing steps for Product 2 were Preparatory (Warping), Weaving, Heat Cleaning (Oven), Dyeing, Blocking (Finishing), Packing, and Shipping.

Each VSM needs a VSM manager to have responsibility for implementing the improvements or Kaizens to the Current State Map. The VSM team at Company 2 chose a VSM manager for Product 2. Each Value Stream needs a manager, and the same person does not have to be the manager for all Value Streams. The Value Stream manager does not have to be the CEO or the Plant Manager, but it has to be someone who can take the time to see that the implementation is followed through and someone who can be held accountable for the VSM Future State Map. The VSM manager should always report to a top manager to keep them informed of the changes and of the progress being made (Rother & Shook, 2002).

Value Stream Maps can be created at different levels. At the lowest level is the process. The next highest level is at the plant level (Rother & Shook, 2002). Rother and Shook (2002) recommend starting at the plant level and mapping the process from door to door, or from when the materials first enter the building until they finally leave the building. The next highest level is mapping a process across multiple plants, and the final level is mapping the value chain across companies.

4.2.4.2.2 Current State Map

The Current State Map (CSM) is created to fully understand how the plant floor operates. The CSM is a snapshot in time of the information flow and the process flow for one particular product or product family. It is important to remember that all of the information and data gathered only represents that one moment in time. This concept is sometimes difficult to understand at first. For the VSM session, a fictitious company called "ACME Stamping" with accompanying data was used to show the process of creating a CSM. After the fictitious CSM for "ACME Stamping" was created, Company 2 was ready to start the CSM for Product 2. Tips for creating a CSM were given in the workbook. They included:

1. Review the basic processing steps and calculate the takt time in the team breakout room;
2. Have everyone draw while gathering data on the shop floor and be sure to draw both material and information flows;
3. Make sure the operators know what you are doing and let them see the drawings. After all, they are the ones who know the process best;
4. Select a "scribe" to combine each members' drawing into one complete CSM;
5. Calculate the total lead time versus the processing times; and
6. Post the CSM and select presenters to explain the process to the group;
7. All team members should be at the front with the presenter. Mention the product family and the takt;
8. Keep presentation to less than 5 minutes;
9. Start with the customer and information flow into the facility;
10. Mention the lead time versus the processing time;

11. Mention the problem areas and anywhere the group found push and overproduction; and
12. Share any future state thoughts (Rother & Shook, 2002).

In order to create the CSM, the information and data had to be gathered throughout the plant. The VSM team divided into two groups. One group gathered the information for the process flow and the other group gathered the information for the information flow. This case study will focus on the information flow. For more information on the process flow, refer to the thesis *Adapting Lean Principles for the Textile Industry* (Goforth, 2007).

The information flow started with the customer, Customer 2, which required Company 2 to have 20,000 yards of Product 2 a month. The product was typically shipped on a pallet containing about 10,000 yards. The plant operated on two shifts, five days a week. Company 2 shipped on average once every two weeks. Total working time per month was assumed to be 4 weeks or 20 days. Often the takt is calculated as pieces or products per minute; however, for Company 2's Value Stream Map, finding the takt per day was more appropriate since the customer's demand was monthly and could more easily be broken into days. The equation to find the takt time for Company 2 was:

$$\text{Takt time} = \frac{\text{Total working time available}}{\text{Customer's demand per month}} = \frac{20 \text{ days}}{20{,}000 \text{ yards}} = 0.001 \text{ days/yard}$$

The maximum amount of time available to produce one yard of fabric and meet customer demand was 0.001 days. However, for simplicity, that value was inverted to obtain a production goal of 1,000 yards per day. The final takt time was 1,000 yards per day required by the customer. The current state map in Figure 4.5 shows Customer 2 would send a four week forecast to Company 2 with a listing of products and the quantities they would expect to order. This forecast was sent electronically to Production Control where a member from customer service would input the order into the AS400 MRP system. A Production Order was created from Production Control which was then sent once a week to the Weaving and Preparatory stages. The order would follow the product from Weaving through the Oven and then to Dyeing. The supplier, Supplier 2 received the same Production Order through email. Production Control sent a daily Shipping Order Report to the Shipping department through email and updated the production board with the Open Order Report at the Packing department. The Open Order Report was also sent to Finishing. Production Control has a Weekly Schedule Meeting where members from all departments gather to go over the orders which have not been processed yet or any other important information.

The %Value Added time was calculated by adding the Value Added time to the Production Lead Time. The equation to find Company 2's %VA time follows.

$$\%VA = \frac{\text{VA Time}}{\text{Total Time}} * 100$$

$$\%VA = \frac{1.3045 \text{ min} * 1\text{hr}/60 \text{ min} * 1\text{day}/24 \text{ hr}}{(1.3045 \text{ min} * 1\text{hr}/60 \text{ min} * 1\text{day}/24 \text{ hr}) + 48.8 \text{ days}} * 100 = 0.00185 \text{ \% VA Time}$$

Any company can create a VSM and make improvements to the current state. One of the reasons for doing a VSM, however, is to help the company become more lean. In order to become more lean, a company should try to implement the lean flow throughout the process.

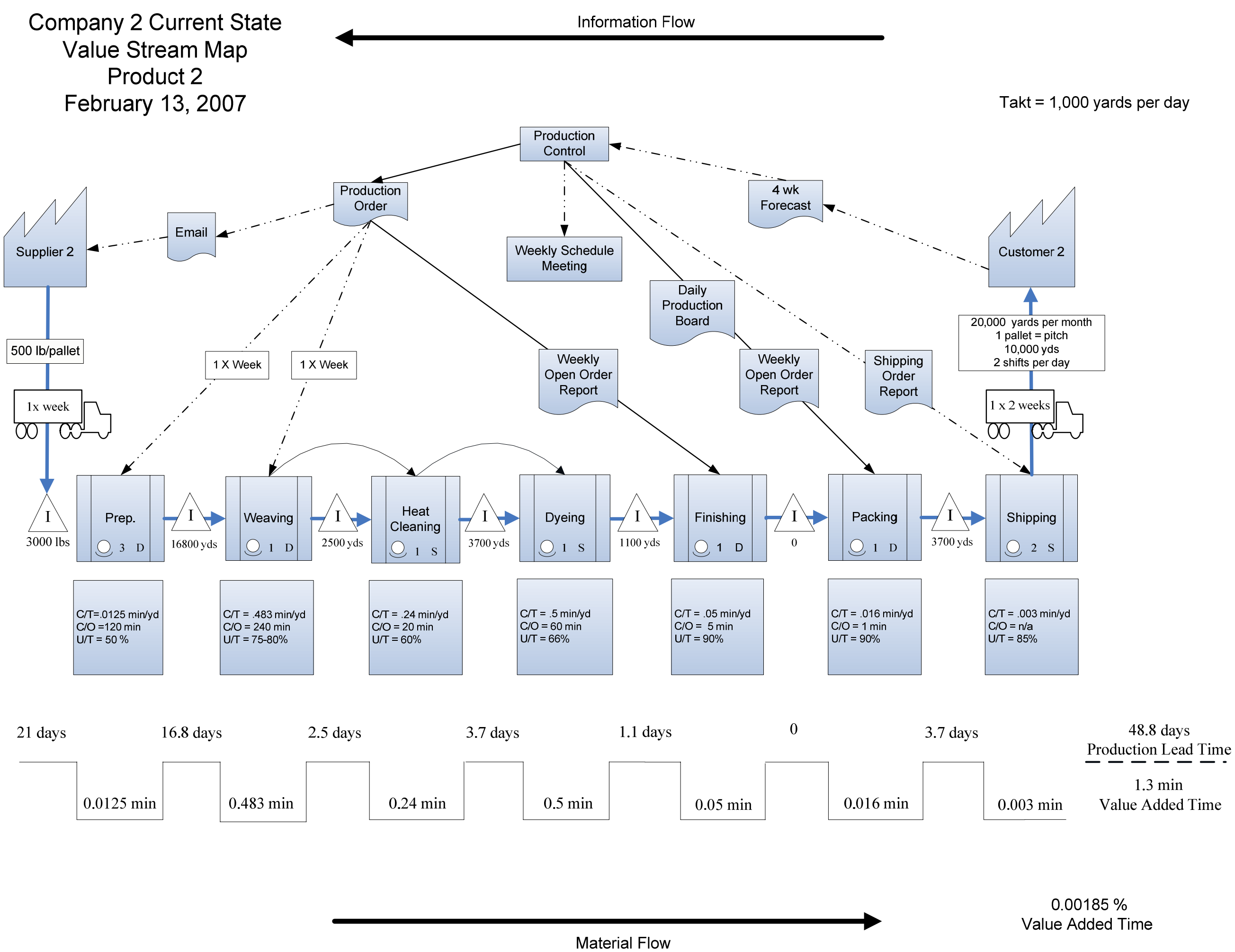

Figure 4.5 Case Study B Company 2 Current State Map

4.2.4.2.3 Future State Map

The second and third days of Case Study B were spent creating the Future State Map (FSM) shown in Figure 4.6. Due to time constraints, only the process flow was thoroughly evaluated. Portions of the information flow were examined, but the full evaluation of the information flow would have to be conducted at a later VSM session. The FSM was created by evaluating the CSM and brainstorming Kaizen events that could take place. As depicted, the information flow is less cluttered and there is less inventory between processing steps. While the %VA Time is still low, it is twice the %VA Time in the current state map. The calculation for the FSM %VA time follows:

$$\%VA = \frac{1.3045 \text{ min} * 1\text{hr}/60 \text{ min} * 1\text{day}/24 \text{ hr}}{(1.3045 \text{ min} * 1\text{hr}/60 \text{ min} * 1\text{day}/24 \text{ hr}) + 23.8 \text{ days}} * 100 = 0.003793 \text{ \% VA Time}$$

The objective of the FSM was to depict where Company 1 felt they should realistically be in the future and was a goal to work towards achieving.

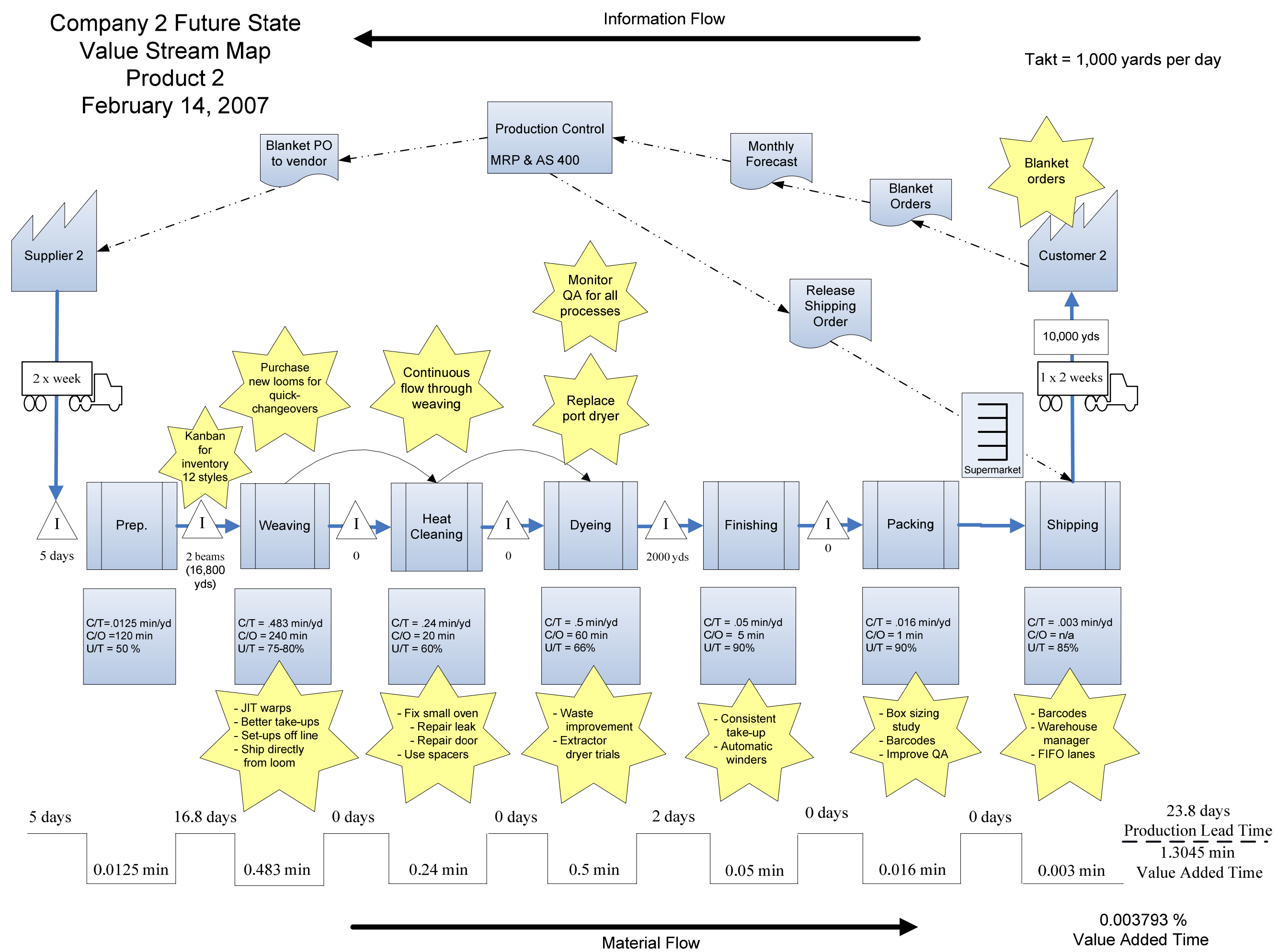

Figure 4.6 Case Study B Future State Map

Once the Future State Map was created, a scribe typed in each Kaizen event and along with the VSM team, assigned groups to each event and included the actions that would occur in order to successfully implement the Kaizen. Some of the suggested Kaizens included:

- Monitoring QA throughout all processes
- Look into purchasing newer looms for quick change-overs
- Implement kanban/supermarket for the warping process to control inventory
- Continuous flow through the Oven to Dyeing by utilizing a smaller oven
- Have blanket orders from the customer for a more stable demand
- Reduce the numerous SKUs by eliminating outdated or obsolete SKUS

Case Study B provided a wealth of information on how to create a Value Stream Map. It was also interesting to see the dynamics and suggestion differences between recent employees and those who had been with the company for quite some time. On the third day, after the FSM was finished, the session leader from IES sat down with the VSM manager, the Plant Manager, and the CFO to discuss the economic impact of the VSM and its subsequent improvements. In the future, IES will continue to monitor Company 2's progress and aid with implementing the Kaizen events created for the FSM.

4.2.4.2.4 Key Points from Case Study B

Listed below are some important key points that were learned from this Case Study.

- VSM sessions are used to both inform companies about how to create a VSM, but also to teach about lean tools, lean principles and to encourage a new way of thinking.

- VSM creates a beneficial brainstorming session for improvements to the current state of the company
- Having a cross-functional VSM work group will benefit the company by enabling ideas from various departments.
- Person(s) from the outside or newer employees are able to “think outside the box”
- Some people are resistant to changes in their work environment
- When top management is involved, the process will seem to go smoother
- The percentage of Value Added Time is much lower than expected
- Creating the Information Flow identified processes and steps that were not needed
- VSM sessions are sometimes stressful, but very helpful in identifying problems and opportunities for improvement as well as promoting positive change throughout the organization.
- Every company is different, so each VSM will be different. Therefore, it is acceptable for the VSM to be constructed differently each time.
- VSM is an important tool to use when first beginning on the lean journey.

4.2.4.3 Case Study C

Case Study C involved evaluating one of the planning and scheduling systems that can be applied to lean environments in a textile company. The purpose for this case study was to assess and demonstrate that planning and scheduling the production process of a textile operation can be successfully optimized and maintained by an automated system. This case study evaluated the DATATEX Machine Queue Management (MQM) module in a fictitious textile company that performs warping, slashing and weaving operations. Members from

DATATEX provided data for the MQM program and training on use of the software.

MQM can help to alleviate the following types of situations, in addition to many others, that production planners and schedulers typically face:

1. Where can I schedule this rush job?
2. Will the supplier will be late with our raw materials?
3. Will we miss our order ship dates?
4. How do I schedule around this unexpected machine breakdown?

4.2.4.3.1 Introduction to DATATEX

DATATEX is a provider of ERP, planning and scheduling, and automated data collection software to the textile and apparel industries. They are staffed with employees who come from textile backgrounds so they have first-hand experience in the industry. As Ahmed (2004) stated in his article Production Planning and Scheduling Software for the Textile Industry: Unknown Frontiers, planning and scheduling is a difficult task for textile environments, especially if the developer is unfamiliar with textiles. Creating the software becomes less of a challenge when the developers are familiar with the textile industry and the way it works in order to help alleviate the challenges of raw material concerns, manufacturing constraints, orders, and inventory (Ahmed, 2004). DATATEX recognized that current solutions for planning and scheduling the production floor for the textile industry were unsatisfactory. Their answer to this problem was software that is able to handle the typical constraints seen in the textile industry. This software is called Machine Queue Management (MQM) and it is a finite planning and sequencing tool. MQM is able to optimize the production schedule by minimizing setup times, minimizing WIP, and optimizing on-time delivery. MQM is structured in the form of a Gantt chart which can be updated in real time. With MQM, the tool handles all of the initial sequencing of production orders and the planner or scheduler handles the exceptions that are not automatically placed into the sequence.

MQM can be customized to handle numerous textile environments, for example, spinning, yarn dyeing, warping, beam dyeing, weaving, knitting, and finishing. For this case study, a warping and weaving operation was chosen.

4.2.4.3.2 Customizing MQM

Specialists from DATATEX spend time with the production planners and schedulers to customize the MQM program to suit the specific production process as well as customize the program to suit the individuals responsible for planning and scheduling. The program requires specific information, such as production orders waiting to be scheduled, that comes from a host system, such as an ERP or MRP system. DATATEX offers fully integrated ERP software with various different modules, one of which is the MQM program. The MQM program, along with other modules, can be integrated with a company's pre-existing ERP or MRP systems. If a company does not have an MRP or ERP system, the planned orders can be transferred from a manually created MS Excel™ spreadsheet. As previously mentioned in the literature review, an ERP system is the expanded version of the MRP systems and will most often contain the MRP functions and capabilities. MRP provides information such as the Bill of Materials (BOM), materials planning, and inventory control. These functions are now part of most current ERP systems which also has the ability to handle more complex functions such as Master Production Scheduling, order processing, project management and maintenance, and human resources (Langenwalter, 2000). The ERP information that is transferred to MQM includes the BOM, routings or process flows, work centers, calendars, and machine speeds. The MRP results are also transferred which provide additional important information such as product IDs, delivery dates, runtimes, setup times and properties or attributes for each step of the process flow. All of these characteristics, data, and information are used to create DATATEX's MQM finite capacity sequencing tool that is displayed on the scheduler's PC. This transfer of information is shown in Figure 4.7. The MQM scheduling screen shows three main components of the program which are the bin that contains the production orders, the resources or machines, and the Gantt chart.

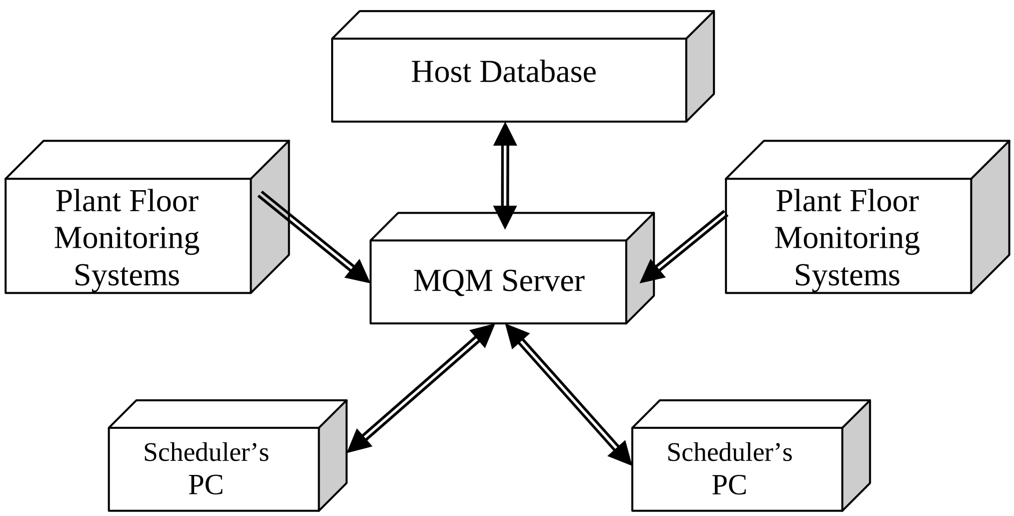

Figure 4.7 Data Transfer for MQM

4.2.4.3.3 Production Orders

The MQM scheduling screen shows production orders in a bin at the bottom of the screen, as seen inside the green box in Figure 4.8. All of the information in this bin is obtained through the results of the MRP system and is completely customizable by size, name, sequence and type, according to what information the planner wishes to show on the screen. The bin will also allow more than one view of information. For example, the planner can have a tab for orders already scheduled and another tab for orders yet to be scheduled, as well as another tab for orders that may run on only one type of machine. Each production order is shown as a bar on the Gantt chart when it is placed on the schedule.

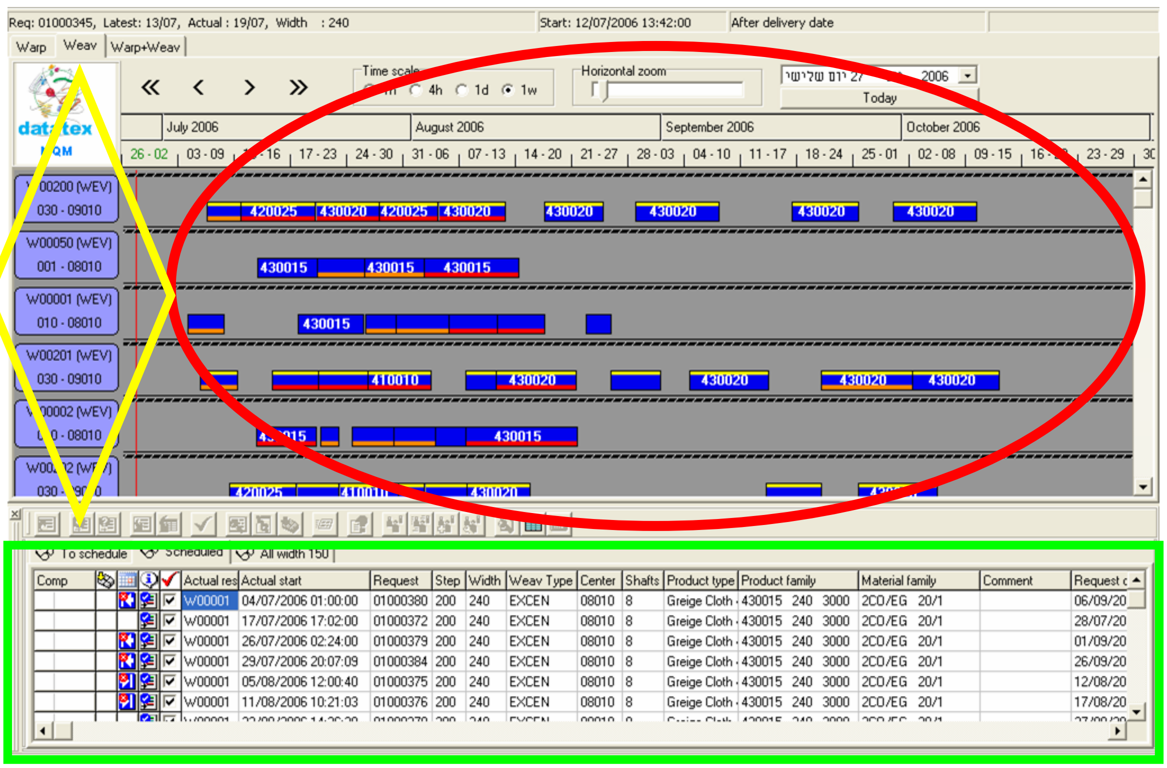

Figure 4.8 MQM Scheduling Screen

4.2.4.3.4 Machine resources

The machine resources are set up for each specific textile environment. The location of the machine resources is shown in the yellow diamond in Figure 4.8. The information needed to create these resources includes run speeds, setup times, names, and machine IDs. MQM also allows for alternate resources. A job scheduled on a particular weaving machine may have an alternate weaving machine resource in case the original machine has an unexpected breakdown.

4.2.4.3.5 Gantt charts

The Gantt chart is where MQM visually depicts the sequenced production orders and is circled in red in Figure 4.8. MQM allows the user to have "drag and drop" type functionality with the resources in order to optimize the schedule. Similar to the production orders, the Gantt chart is completely customizable to suit the individual, and the scheduler has the ability to define multiple Gantt views. For example, one view may be created for one set of resources and another view may be for a particular work cell. This feature is helpful when creating "what-if" scenarios. The information written inside the production order bars is also customizable, the colors on the screen are customizable, and the visual appearance of the Gantt chart screen is also able to be modified to show more or less production orders or more or less days.

The bars on the Gantt charts represent the production orders and have three colored parts to them: the background, the top colored bar and the bottom colored bar. The background bar tells the scheduler if the job is confirmed. The top bar will turn yellow to inform the scheduler if there are not enough materials and tools to complete the job. The bottom bar will turn red if the order is going to be late.

4.2.4.3.6 Attributes and Properties

For MQM, there needs to be predefined properties for the resources. The job information will come from the MRP, ERP system, or the MS Excel™ spreadsheet. The materials, manpower and tools are all additional pieces of information that need to be defined in order for MQM to sequence the production orders. For a weaving operation, example properties may be the number of shafts, the weave width, the loom type, or the weft colors. MQM will then use these properties to determine how compatible one production order may be as compared to another, and it will also determine the best machine resource on which to place the job.

Once all of the information is gathered from the MRP or ERP system and all of the resources and properties are defined, the scheduling in MQM can be handled in two different ways: automatic sequencing or manual scheduling.

4.2.4.3.7 Compatibility Case

The MQM program optimizes the schedule according to the compatibility rating, or “case”. The compatibility rules are custom defined and MQM evaluates the properties of each routing step by comparing job to job, job to machine, job to capacity reservation and job to job for grouping. The compatibility scores are computed where a low score of 01 being the most compatible and a high score of 99 is not at all compatible. MQM will show the most compatible job with the lowest case value at the top of the list, as shown in Figure 4.9. The two scenarios with a case 1 are on the top of the list and below them is a case 21 scenario.

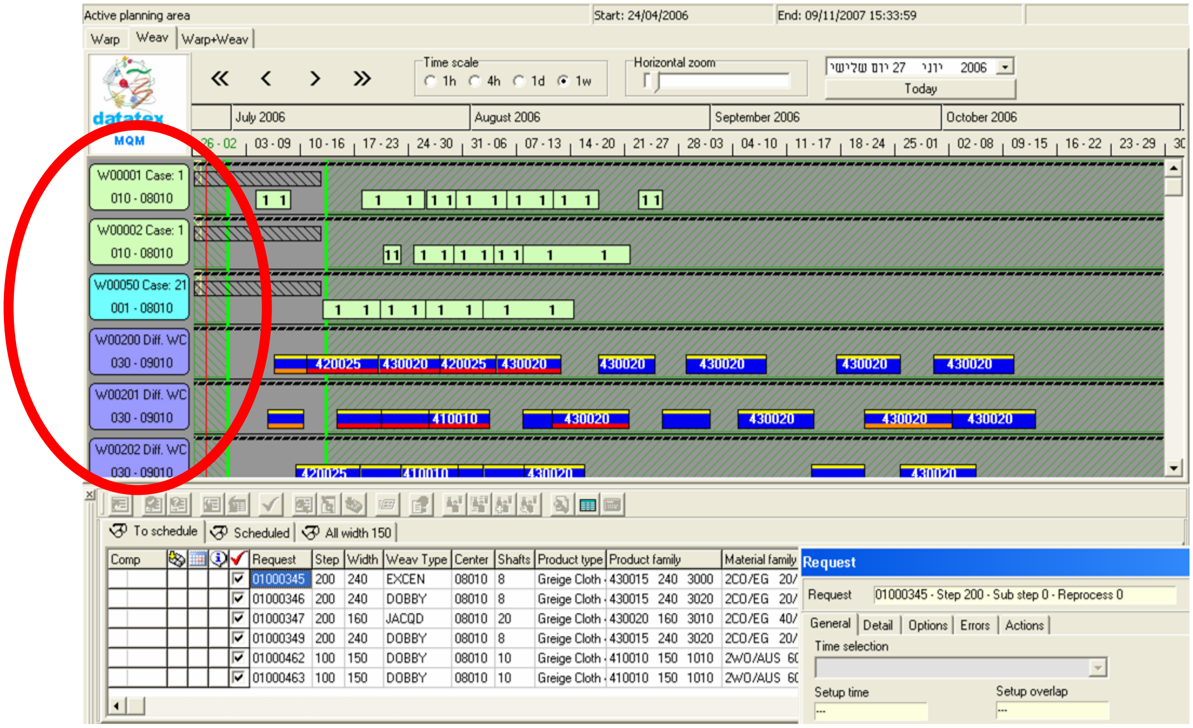

Figure 4.9 Compatibility Cases

For each machine, the planner can right click to see the details about why the case may or may not be compatible. As shown in Figure 4.10, right clicking on the case with a compatibility rating of 21 provides information that the weave type was different and therefore the suggested work order placement received a lower score. These compatibility ratings come from the scheduler's properties and priorities that are typically used to schedule the production orders. In addition to compatibility between machines and jobs, the tool takes into account the materials, tools, and manpower available.

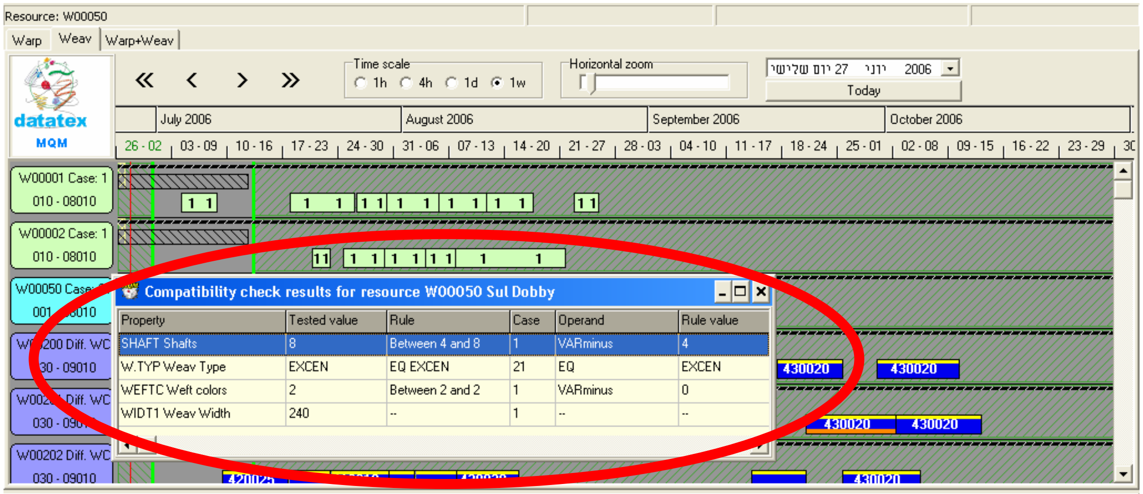

Figure 4.10 Compatibility Details

MQM will give a compatibility score for before and after scenarios as well. Right clicking will show the details of the compatibility scores. As shown in Figure 4.11, the compatibility score of 41 was given because the number of shafts on the weaving machines was not equal.

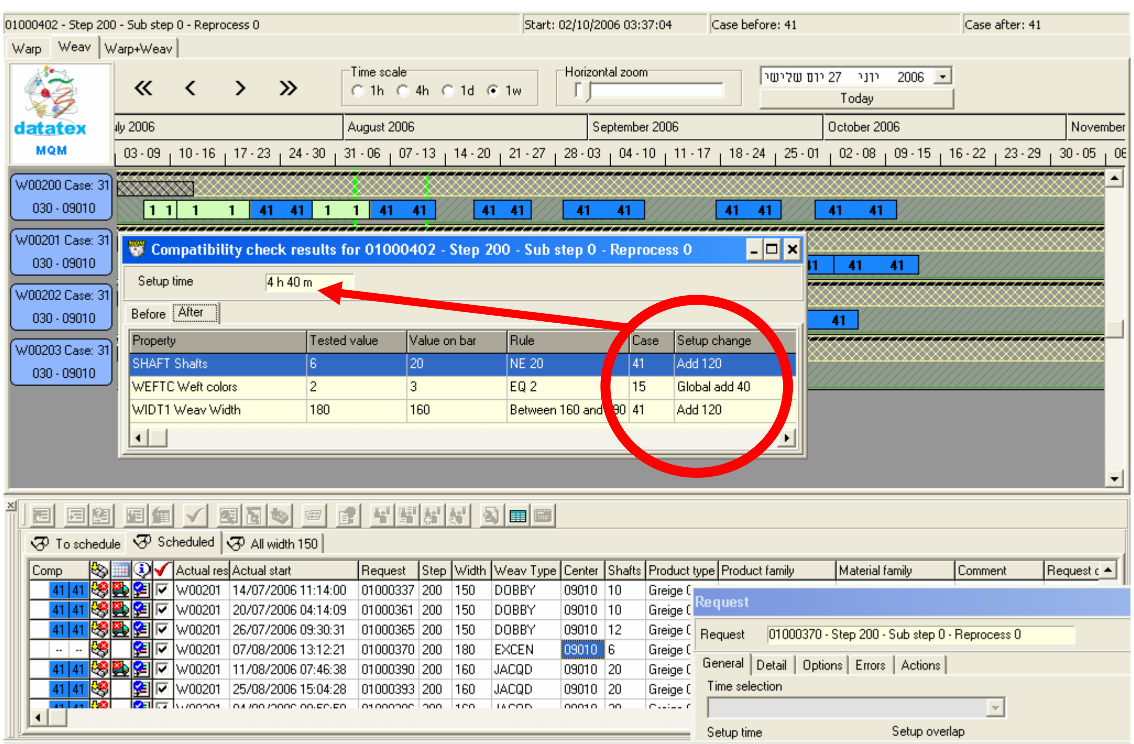

Figure 4.11 Before and After Compatibility Scores

The total setup times are also computed with each scenario created. Inside the red circle in Figure 4.11, the setup times are calculated for each step, and then summed at the top of the box. This will let the scheduler see how long it will take one job to be setup according to where it is positioned on the schedule.

4.2.4.3.8 Automatic Sequencing

MQM has an automatic sequencing function in which the tool creates the schedule according to the rules or priorities given, such as dates, materials, compatibility and priority. Penalty points are assigned to the rules and the rules are weighted to show importance. For example, if two critical rules are on-time due dates and high compatibility, but due date was the most important, the auto sequencer will create the optimal schedule according to the due dates first. Based on the rules and priorities, the MQM auto sequencer will schedule all of the typical orders and the scheduler will then tackle the individual exceptions. As the rules are tightened, the MQM auto sequencer will be able to successfully sequence fewer orders and the scheduler will have to handle more exceptions, i.e., production orders that cannot be scheduled by the automatic sequencer. Conversely, the more relaxed the rules, a larger percentage of orders will be sequenced by MQM and fewer exceptions will need managing by the scheduler.

In the automatic sequencing function of MQM, the scheduler can re-sequence or un-schedule as needed. The auto sequencer can be used to sequence specific jobs or all of the jobs. The scheduler has the option to keep all scenarios and then choose the best option. When the scheduler chooses not to use the automatic sequencing tool, or the automatic sequencing tool can not schedule some production orders due to tight rules, the production orders will be scheduled manually. The automatic sequencer can also be used to schedule the bottlenecks first and then schedule the rest of the processes from there.

When running the automatic sequencing tool, the scheduler has the ability to control how much compatibility is allowed by adjusting the compatibility limits. The scheduler will set the limits for how compatible the order is from job to job, job to resource, and job to capacity reservation, from 1 to 99. Whatever the compatibility limits are set at, the auto sequencer will only schedule those orders which have that compatibility score or lower. As mentioned, the lower the compatibility scores, the more compatible.

The balance between two properties can also be modified. In this example, the date score weight is at 80% and the compatibility discrepancy score weight is at 20%. If making the due dates is the highest priority for a company, MQM will schedule the production orders in the optimal sequence to ensure the order due dates are met by placing less importance on the compatibility of the jobs. This may mean that a lengthy change-over or setup must occur in order to get the product to the customer on time.

4.2.4.3.9 "Manual" Scheduling

With "manual" scheduling, the production scheduler uses the MQM program to assist in finding the best case scenarios according to the priorities and rules predefined by DATATEX and the production scheduler. Specific functions of MQM are used to help the production scheduler optimize the sequence of the production orders in the best way possible. These functions include compatibility cases, colored lines to visually depict important dates, and status bars that display information.

4.2.4.3.10 Visual Cues

MQM uses colored lines and nets to visually cue warnings, cautions, important dates, and additional information. The colors can be customized according to the company's preferences. The green colored lines show the earliest and latest dates for a particular setup. The nets are used to show cautions or additional information.

- Green Net: Open to schedule
- Red Net: Indicates problems with additional resources such as tools, people, etc.
- Yellow Net: Shows when the raw materials for this step will be available or unavailable
- Black Net: Shows a problem with a preceding or succeeding step

4.2.4.3.11 Grouping and Splitting Jobs

MQM has the ability to group small jobs or split large jobs into smaller jobs in order to create the best schedule. Just as a typical weaving operation may group several orders for different customers together because of their similar properties, the MQM module will do the same. Grouping jobs together will minimize the setup and change-over times. A job may be more efficiently produced if it is split into several smaller jobs. Perhaps there is a situation where there are three openings where smaller jobs can be run in between orders with similar characteristics. Splitting the larger job may help to decrease the downtime of the machines in between the production orders.

4.2.4.3.12 Other Options

Another interesting function of MQM is that the tool allows capacity to be reserved for special customers, special orders or specific products. MQM will also show ten confirmation levels. The scheduler can place confirmation levels on the orders already in sequence from level one (meaning the job is unable to move, it is important and needs to stay scheduled where it is) to ten (meaning the job can be moved or delayed).

4.2.4.3.13 Integration

The MQM software can integrate with a variety of different systems. DATATEX has created MQM to integrate with their own ERP system, TIM (Textile Integrated Manufacturing), and their NOW (Network Oriented World) product family, or it can integrate with other ERP or MRP systems in order to extract information. If no MRP or ERP systems are in place, MQM can extract information from a spreadsheet such as MS Excel™. MQM will also integrate with monitoring systems for looms and knitting machines. Information about machine breakdowns or problems is sent to MQM so the next sequence will take those updates into account.

In MQM, the schedule can be predefined for when the tool should update itself. The scheduler can also create a report in HTML or MS Excel™ that can be easily printed out and given to the plant floor. An example of the HTML report is shown in Figure 4.12. The reports can be customized to include or exclude any particular bin column or row. These reports can be sent to production so they will know the best order to manufacture the products. When the jobs are confirmed, if MQM is integrated with an ERP system, the information is sent back to the ERP so all systems are updated. This keeps all systems on the same page so that updates and changes can be made across the board.

Bin View

From: 3/16/2007To: 3/16/2007 11:59:59 PM

Production req.	Step	Sub step	Re-process	Step group	Actual work center	Actual work center description	Actual process	Actual process description	Planned work center	Planned work center descr.	Planned process	Planned process description	Product type	Product type description	Production line
01000338	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000345	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000347	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000344	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000346	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000348	100	0	0	-1	01000	S.Warping	001	Warping +	01000	S.Warping	001	Warping +	4	Greige Cloth 4	----
01000345	200	0	0	-1	08010	Weav A. (Zul.)	0020	Weaving	08010	Weav A. (Zul.)	0020	Weaving	4	Greige Cloth 4	----
01000346	200	0	0	-1	08014	Weav A. (Zul.)	0020	Weaving	08010	Weav A. (Zul.)	0020	Weaving	4	Greige Cloth 4	----
01000344	200	0	0	-1	09010	Weav Dor.A.jet	0010	Weaving	09010	Weav Dor.A.jet	0010	Weaving	4	Greige Cloth 4	----

Figure 4.12 HTML Report

4.2.4.3.14 "What If" Scenarios

Several of DATATEX's MQM users enjoy the ability to use the tool to perform "what if" scenarios for scheduling rush jobs or to see what will happen when a machine goes down for preventative maintenance. A scheduler may use the program to see if a new job can fit in the schedule, and MQM will show if there is available capacity or materials by creating the colored netted areas. "What if" scenarios can also be used to see what would happen to the schedule if, for example, another loom change-over crew was added to the floor or for determining the best schedule for those production order exceptions that the auto sequencer may not have been able to sequence.

4.2.4.3.15 What Do Others Do?

Other vendors also have functions and features similar to DATATEX's MQM, for example the ability to run "what if" scenarios, create additional original rules or priorities, customize the package to fit the company, and order grouping and splitting capabilities. Blue Fox Porini (Italy) is the sister company of NedGraphics and develops software solutions for the textile and apparel industries. Porini is an example of another vendor which offers a planning and scheduling system similar to DATATEX. Their Processing Planner and Loom Planner can be used to schedule dyeing, finishing, printing, weaving, and knitting operations. The Porini Planners have Gantt charts that show visual scheduling and also allows splitting and grouping of production orders. Porini Planners are customizable, "what if" scenarios can be run, and customizable reports can be displayed.

Jomar Softcorp International, Inc is another software vendor that offers planning and scheduling similar to the DATATEX module. Jomar's Schedule Board allows for "what if" scenarios, drag and drop features, splitting orders on multiple machines or grouping multiple orders on one machine, and is integrated with ERP, MRP and Capacity Planning.

4.2.4.3.16 Key Points from Case Study C

The MQM tool can be used to minimize the WIP, increase on-time completion, minimize the setup and change-over times, and utilize the optimal resources. The tool allows the scheduler to only focus on the exceptions so they can be more productive in other areas of their job. Multiple schedulers across departments are able to use the same program; however, they can only sequence their particular machines and will have read-only access to all other departments. DATATEX's MQM program is a planning and scheduling tool that can be used in lean environments and was created specifically for the textile and textile-related industries.

DATATEX's MQM program will help textile companies who are trying to become lean and also those who want to continue on their lean journey for several reasons:

- Has the capability to make-to-stock and make-to-order
- Can balance production lines
- Allows you to minimize the WIP in between steps by sequencing at the latest possible time;
- Minimizes the setup and change-over times by grouping or sequencing orders on the most compatible resources;
- Maximize labor and capacity resources by sequencing the orders on the best machines available;
- Integrate and link to other IT systems; and
- Link to customers and suppliers to ensure better customer service.

4.3 Phase III Results

The objective of Phase III was to develop the software systems directory of lean planning and scheduling systems that are applicable in textile and textile-related industries, and modify the current software requirements checklist found in the Software Requirements Evaluation Guide for Manufacturing Planning Control Systems created by Hodge (1998). This relates to RO5: Determine the lean planning and scheduling software available to the textile industry and develop a systems directory and RO6: Determine the requirements of lean planning and scheduling systems to modify the existing Software Requirements

Checklist. The initial list of 85 software vendors was created using the secondary sources in Phase I and is found in Appendix C.

4.3.1 Directory of Lean Planning and Scheduling Systems Software for the Textile and Textile-Related Industries

An exploratory survey of the 85 software solution vendors was conducted to determine if the software packages in Table C.1 could handle lean concepts and were applicable in textile and textile-related industries. Examples of the specific features of interest were if the software can track real-time data, handle kanban scheduling and if it offers visual scheduling, demand smoothing, line balancing, and line design. Using Hodge's initial survey conducted for the Directory of Manufacturing Planning and Control Systems Software for the Textile and Apparel Industry, shown in Appendix A, modifications were made to incorporate items and features applicable to lean environments. The modified survey for this research was emailed to each vendor and is shown in Appendix B. The vendors were emailed once and any emails which were returned due to mailbox or email address failure were resent using another address if available so that each vendor was initially contacted one time. The responses from the vendors were then evaluated. Only those vendors who had planning and scheduling software for the plant floor, applicable to lean environments, and marketed to the textile and textile-related industries were included. Using the responses from the survey, a directory page was created for each vendor using the template shown in Figure 4.13.

Company Name ← 1

2 → **Product Name** (Product Category) ← 3

Address
Address ← 4
Webpage

Contact Person
Phone Number ← 5
Email

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	
Real-time inventory management	
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	
Ability to create original rules	

Integrates with

MRP	
MRPII	
ERP	
MES	
SCM	
CRM	

Import/Export with

Excel	
MS Access	

6

Operating Systems	**Hardware**	**Databases**
		DB2/Unix, Informix, MS SQL Server, Oracle, and Sybase

7

Key:
1. Company Name
2. Product Name
3. Product Category: MRP (Materials Requirements Planning), MRPII (Manufacturing Resource Planning)
4. Vendor Address and Web Page
5. Contact Person, Phone Number and E-Mail Address (if available)
6. Product Features- Data about the Software as provided by the vendor or derived from website
7. Company and product description- Provided by the vendor or derived from website

Figure 4.13 Template for Vendor Evaluation

The directory was created with fourteen vendors of lean plant floor planning and scheduling systems for the textile and textile related industries. The fourteen vendors are listed in Table 4.15.

Table 4.15 Lean Planning and Scheduling Systems for Textile and Textile-Related Industries

Lean Planning and Scheduling Software Vendors	
Apriso Corporation	AS/AP Apparel Software
BLUE FOX Porini, Inc.	DATATEX TIS – USA, Inc.
eBECS	Giraffe Production Systems
JOMAR SOFTCORP INTERNATIONAL, Inc.	LAMAR Software, Inc.
Network Systems International, Inc.	Pelion Systems
Preactor International	SAP
Taylor Scheduling Software, Inc	User Solutions, Inc.

A total of seventeen vendors responded to the survey. Seven of those seventeen vendors that responded could not be included in the directory because they did not market to the textile industry, they did not use lean concepts, or they did not have planning and scheduling systems for the plant floor. Ten vendors responded to the survey with all of the correct criteria for the directory. One vendor, SAP, responded by saying they did offer lean planning and scheduling solutions to the textile industry; however, the researcher was asked to fill out the survey for the vendor using the vendor's website information. Three additional vendors were added to the directory because they were known to offer lean planning and scheduling systems to the textile industry. These three companies were Apriso, BLUE FOX Porini, Inc., and Network Systems International, Inc. BLUE FOX Porini and Network Systems were visited at the Megatex conference and during the interview they answered the preliminary questions which qualified them to be in the directory. Apriso's website was evaluated to learn if they offered lean planning and scheduling to textile and textile-related companies. Each survey was then used to create a directory page, such as the one shown in Figure 4.14. If a survey was not available, information from vendor websites and promotional materials was used to create the directory page. In the instances that information was either not provided or unavailable for sections of the directory pages, “NA” was added. The Directory of Lean Planning and Scheduling Systems Software for the Textile and Textile-Related Industries is included in Appendix D.

DATATEX TIS (Textile Integrated Solutions) - USA, Inc.
MQM (Machine Queue Management) (APS)
NOW (Network Oriented World) (ERP with MRP, MRPII, MES, P&S, etc.)

11810 Northfall Lane, Building 1203
Alpharetta (Atlanta)
GA 30004-1843 USA
www.datatex.com

Jim Noble, Dir. Sales & Marketing
(770) 667-8656, ext 111
Fax: (770) 667-8377
jnoble@datatex-usa.com

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X
BOARD Business Analytics/ Intelligence Applications	X

Operating Systems	Hardware	Databases
Windows 2000/NT/XP/Vista, IBM-AIX, OS/400, UNIX, LINUX	Pentium PC, IBM AS/400, IBM RS/600, UNIX Workstation, Java Virtual Machine	IBM DB2, Microsoft SQL, Oracle

-- Datatex software solutions are specifically suited to partner with Lean Concepts in many areas:
• Forecasting capabilities (BOARD Business Analytics) can identify ‘lumps’ or ‘voids in the demand.
• Planning module (TRP & MQM) allow demand leveling
• TRP explodes & plans materials & work center capacity
• Flexible costing structures with multiple user – defined levels
• Routings model the timing of materials & capacity to the actual need
• Order tracking facilitates the backflushing of materials & labor at needed milestones
• Single point / multiple points of reporting eliminates paper & non value – adding activities
• Contra traditional Lean, our textile customers often have regulatory reporting requirements which force them to maintain Lot Traceability. Datatex allows the system to manage these connections from the finished product back to the raw materials – all without the need of paper. Reporting would only be done as required.
• Logical warehouses minimize reporting & handling; no need to ‘put away;’ & shipping directly from production
• Allocate goods by location, lot number, element (roll / piece, etc.), or SKU
• Utilizes EDI – both in – bound & out – bound

Figure 4.14 Vendor Evaluation Example Page for Directory

4.3.2 Software Requirements Checklist

An original software requirements evaluation guide, *Software Requirements Evaluation Guide for Manufacturing Planning and Control Systems*, was created by APICS (American Production and Inventory Control Society) and TA SIG (Textile and Apparel

Specific Industry Group) (1998). The guide was to be used by members of the textile and apparel industries as an aid in choosing an applicable packaged software system for their company. The evaluation guide contains a checklist of the functions and features for a company to review when choosing the packaged system. This checklist was modified to include additional requirements needed for planning and scheduling systems in lean manufacturing. The requirements for lean planning and scheduling systems were adapted from the secondary sources of Langenwalter (2000) and Ake, Clemons and Cubine (2004). For more information on the original Software Requirements Evaluation Guide, contact a member of APICS at www.APICS.org. The original checklist contained the following functions and features to review:

1. General Requirements;
2. Item Definition;
3. Bill of Materials;
4. Routing and Process Definition;
5. Work Center Definition;
6. Product Costing;
7. Manufacturing Planning;
8. Production Activity Control;
9. Inventory Management;
10. Customer Service; and
11. Forecasting.

Each company is different and may place different priorities on software features. For this reason, it may be sufficient to use the checklist qualitatively, or a more quantitative review may be necessary for a more specific, in-depth evaluation. A qualitative scale may include priorities as critical, desired or not applicable. For a more quantitative scale, numbers can be assigned accordingly for a weighted score. An additional example quantitative rating scale from the APICS Software Requirements Evaluation Guide is as follows:

0 – Does not have and cannot support
1 – Does not have but could support through major modification
2 – Meets few requirements; additional functions added through major modification
3 – Meets some requirements; additional functions added through medium modification
4 – Meets some requirements; additional functions added easily
5 – Fully meets all requirements

For example, a critical item may receive a rating of 5, desired items receive ratings of 3 and not applicable items receive ratings of 1. The rating style will have to be modified to suit each particular company; however, when evaluating several software vendors, it is important to be consistent with the rating scales. A raw score can then be added based on how well the software package meets a certain requirement by using the rating scale above. For any requirement on the checklist a weighted score can be achieved by multiplying the requirement score in the "Importance" column by the raw score in the raw rating column. Sum the ratings to get a weighted score that can be used to compare different software packages. Figure 4.15 shows an example of the weighted rating. This weighted rating method, as suggested by APICS and TA SIG was used for the final requirements checklist.

	Importance			**Rating**	
MES Functions	Critical	Desirable	N/A	Raw	WTD
Production management	5			5	25
Performance metrics		3		4	12
Workflow control			1	4	4
Material tracking and genealogy		3		1	3
Section Total				14	44

Figure 4.15 Example of Weighted Rating
Source: (Hodge, 1998)

The objective of the modified checklist is to provide textile companies a guideline when reviewing or selecting an automated planning and scheduling system to accommodate their lean implementation. Section 7, Manufacturing Planning, of the original checklist was modified to include critical items necessary for lean manufacturing.

The sections under Manufacturing Planning were Demand Management, Production Planning and Master Production Scheduling (MPS), Materials Requirements Planning (MRP), and Capacity Requirements Planning (CRP). Additional categories were added to include Manufacturing Execution Systems (MES) and Advanced Planning and Scheduling Systems (APS) and Enterprise Execution Systems (ERP). For more information on choosing information technology for manufacturing environments, refer to Ake, Clemons and Cubine (2004) in *Information Technology for Manufacturing: Reducing Costs and Expanding Capabilities*. Modifications to the original checklist are shown in Table 4.16.

Table 4.16 Modifications to Original Requirements Checklist

	Importance			**Rating**	
	Critical	Desirable	N/A	Raw	WTD
MES Additional Functions					
Production management					
Performance metrics					
Workflow control					
Material tracking and genealogy					
Measurement and reporting					
Quality management					
Regulatory compliance					
Work instructions					
Model-centric design for routing capability					
Runs in real-time					
Constraint and capability based					
Integrates with other IT systems					
Section Total					

Table 4.16 Continued

	Importance			Rating	
	Critical	Desirable	N/A	Raw	WTD
APS Additional Functions					
Ability to group and split orders					
Rate or assign priorities to orders					
Routing and sequencing capabilities to ensure the best utilization of capacity					
Simple/graphical/user-friendly interfaces					
Kanban for pull based replenishing					
Ability to work in build-to-demand environments					
Real-time inventory alerts					
Integrate with other planning and scheduling systems					
Production schedule sharing from supplier to customer					
Demand scheduling					
Handles varying process/manufacturing/lead/change-over times					
Section Total					
ERP Additional Functions					
Flexible scheduling should include shift, daily and weekly production					
Forward and backward scheduling from critical resource					
Constraint-based scheduling, with user's choice of constraint orientations (capacity, materials, both);					
Ability to manage and prioritize materials in bulk and packs					
Identify production lines with products and rates per period					
Ability to schedule a product on more than one production line					
Sequencing of products and batches					
Lot traceability across entire supply/distribution chain; ability to mix lots					
"Soft allocation" of lots in various stages of production or storage to specific customer orders or forecasts, by quality specifications and delivery dates;					
Mixed model scheduling for each product line					
Transfer units between repetitive lines					

Table 4.16 Continued

	Importance			Rating	
	Critical	Desirable	N/A	Raw	WTD
All costs are automatically transferred with units					
Ability to modify for a specific schedule					
Set independent shop calendars for each production line					
Workbench or simulation capability to level load production lines					
Graphical line/load representation for simulation workbench					
Recycling scrap back into the process					
Intermediate storage requirements					
Ability to manipulate the load directly from graphical screen					
Sequencing algorithms to minimize steps					
Ability to link to customers and suppliers					
Ability to integrate with older systems					
Section Total					

As mentioned in the literature review, some of the features for the planning and scheduling system overlap. For this reason, items in the MES and APS categories may apply to the ERP category as well.

5 Summary, Conclusions and Recommendations

This research was conducted to determine the use of lean planning and scheduling systems in the textile industry. The objectives of this research were to determine what planning and scheduling systems, both manual and automated, are applicable in lean environments in the US textile industry and to identify the barriers that members of the textile and textile-related companies are facing when implementing lean.

5.1 Summary of Results

The research was qualitative in nature and conducted in three phases. Phase I analyzed information from secondary sources, Phase II analyzed information from primary sources, and the purpose of Phase III was to develop a Directory of Lean Planning and Scheduling Systems Software for the Textile and Textile-Related Industries and to modify the existing Software Requirements Checklist to account for lean planning and scheduling systems. Information was collected during each of the three phases to satisfy the six research objectives.

RO1 Identify the degree to which US textile companies are using lean techniques in their manufacturing operations;

- From both Phase I and Phase II sources, textile and textile-related companies are working towards implementing lean manufacturing and are at the beginning stages of implementation, and therefore companies have not yet adapted the lean culture.
- Improvements were seen from the companies interviewed that include decreased inventory, decreased raw materials and an increase in floor space that was used for a variety of reasons.

- Eleven different lean tools were being used in the companies interviewed. Value stream mapping and 5s are the most popular lean tools being used by these companies.
- Value stream mapping is an important tool, not only for implementing lean, but also for learning how a company's manufacturing process truly operates. Generated from VSM sessions are lists of Kaizen events or continuous improvement projects, that will enable the company to become more lean. Still, some companies feel it is not the best tool for their organization.
- Few lean concepts are currently used in the planning and scheduling operations.

RO2 *Identify what planning and scheduling systems US textile manufacturers are using;*

- The use of lean automated planning and scheduling systems is also low. Results show that only 20% of the companies interviewed were using automated lean planning and scheduling systems. Companies feel their operations and products are too complex and that the automated systems may not be able to handle that complexity. Automated systems have been developed that utilize lean concepts to assist textile manufacturing facilities in planning and scheduling.
- Results show that 30% of the companies interviewed were using kanban/supermarket/pull systems for the production control and 20% were using visual scheduling boards.
- Half of the companies interviewed were using combinations of manual and automated planning and scheduling systems.
- The majority of the planning and scheduling for the plant floor is still manual for the textile and textile related industries. Seventeen total planning and

scheduling instances were reported during the interviews and almost 65% of those were manual.

- Aberdeen Group showed through their research in other industries that around one third of companies involved in lean are still using MS Excel™ and 10-15% were using pencil and paper methods for planning and scheduling (Aberdeen Group, 2006b). Based on the results of the interviews with textile companies, 30% were still using MS Excel™, similar to the results from Aberdeen, and 30% were still using the pencil and paper method, twice that of other industries.
- Only 41% of the instances of planning and scheduling systems reported during the interviews were lean. Eleven percent of those instances were automated lean systems, 11% percent of the instances were visual scheduling boards, and nearly 18% were kanban systems.
- There exists a mismatch between traditional automated planning and scheduling systems and lean concepts; however, software vendors are recognizing this fact and have begun to offer lean modules and complete lean packages for use in planning and scheduling.

RO3 Determine the barriers to using lean planning and scheduling systems in US textile companies;

Chapter 4 included a list of barriers to both implementing general lean concepts and implementing lean planning and scheduling software. Regarding automated systems, software vendors are trying to make more user friendly programs that are compatible with a variety of systems to combat some of these barriers. The issue of complexity relates to the planning and scheduling system itself, as well as the complexity of the company's products and/or product mix. In regards to handling the complexity barriers of the system, many companies have created scheduling programs with simplified interfaces, visuals, and graphics that easily allow users to manipulate the schedule. The issue of product complexity was also a major barrier to adding planning and scheduling systems for lean environments to the textile industry. Lean planning and scheduling systems are becoming more intelligent every day. Many of the available systems can handle the complexity. One of the interviewed companies said that their lean planning and scheduling system handles their complexity fairly well. Other common barriers were getting top management to commit to the lean transformation, employees' resistance to change, getting past traditional ways of thinking and adapting to the culture change.

- Many barriers exist regarding planning and scheduling for the textile industry. Through the research, solutions were gathered from secondary sources as well as in the company interviews and case studies that may combat some of these typical barriers. Table 5.1 shows the common barriers and challenges companies are faced with when implementing lean manufacturing and the solutions found through both the Phase I and Phase II research.

Table 5.1 Complete List of Barriers and Solutions

General Lean Barriers and Challenges	Solutions
• Language barriers	• Pictures in addition to words • Common, easily understood language • Bi-lingual trainers/consultants
• Unmotivated/unenthusiastic employees • Employees resistance to change	• Encourage them to volunteer ideas and own the process so they feel empowered • Hold competitions • Reward employees • Employees receive lean training/handbook when hired • Attend seminars • "Learn by doing"
• Top management not committed	• Educate top management to get endorsement • Attend seminars • Visit mature lean manufacturing facilities
• Companies uncertain where to start	• Benchmark other industries
• Getting past traditional ways of thinking	• Attend seminars • "Learn by doing"
• Culture change	• Positive attitudes in management • Lean teams meet each week to stay on track
• Poor communication between multiple plants	• Integrate the IT systems • Work towards implementing lean throughout supply chain
• Difficulty sustaining	• Hold weekly/daily meetings to update and hold employees accountable • Lean division/manager/owner/champion
• Complexity of lean concepts	• Use common, easily understood language • Utilize outside "consultant" type services, for which grants are often available
• Expense of lean training and implementation	• Apply for government grants or grants through community colleges

Table 5.1 Continued

Planning and Scheduling-Specific Barriers	Solutions
• Differing IT systems • Multiple applications to support • No unifying architecture	• Transitioning to only one system or use IT solutions that are able to integrate with other systems
• Product complexity/numerous SKUs	• Reduce number SKUs by eliminating old/obsolete SKUs and reducing the complexity of the product
• Current scheduling system to complex/manual	• Kanban/pull systems • Visual scheduling cues for inventory levels • Automated lean planning and scheduling system
• Plant is disconnected from ERP system	• Integrate with common IT systems • Real time manufacturing performance measurements
• Integration with customers and suppliers	• Allow customers and suppliers access to IT • Work towards implementing lean throughout supply chain
• Aging/proprietary systems do not support lean	• Upgrade/modify or purchase new systems because systems that do not support lean will slow down the lean transformation
• Fear that technology may slow down workers	• Simplified and graphical user interfaces are available with most software companies
• Information for decisions unavailable	• Real-time management will help with decision making
• Differing machine process speeds • Excessive manufacturing lead times and setup/change-over times	• Software vendors familiar with the textile industry will be able to take these barriers into account, many already have
• Mismatch between traditional planning and scheduling systems and lean concepts	• Software vendors are updating/modifying and offering new software solutions that can better handle lean concepts
• Planning and scheduling system compatibility with differing product measurements	• Improve automated systems • Software developers should have experience or be familiar with textile industry

RO4 Determine where the implementation of lean planning and scheduling systems would be best applied;

- Lean planning and scheduling systems such as kanban/supermarket/pull do not have to be implemented throughout the entire process. Two of the three companies interviewed that have implemented kanban systems are using hybrid or combination systems where parts of the process are controlled by a kanban/supermarket/pull system and the special cases are manually scheduled using more traditional push systems. One company uses a kanban system at their bottleneck warping process, and another company uses a kanban system at the finished goods inventory. Only one company uses a kanban system for an entire pull process.
- Two textile companies from the interviews, as well as four textile companies from the literature, were using automated lean planning and scheduling systems.
- The two interviewed companies that used automated systems were large.
- One small, one medium, and one large company each used kanban systems, and therefore, using kanban systems may be applicable in any sized company. The two companies which used visual scheduling boards were small.
- For smaller companies, or at the plant level of larger companies, it is feasible to implement manual lean planning and scheduling systems such as kanban/ supermarkets/pull systems and scheduling boards.
- For larger companies and at the corporate level, it may be feasible to implement automated lean planning systems.

RO5 Determine the lean planning and scheduling software available to the textile industry and develop a systems directory; and

- While there seems to be a large number of lean planning and scheduling systems available, fewer systems are targeted to the textile and textile-related industries.
- Planning and scheduling systems are offered both as stand-alone packages and as modules that are functional in a larger package.
- The Directory of Lean Planning and Scheduling Systems Software for Textile and Textile-Related Industries contains fourteen software vendors who offer lean planning and scheduling systems for textile environments.

RO6 Determine the requirements of lean planning and scheduling systems to modify the existing Software Requirements Checklist.

- Planning and scheduling software must contain specific features and have the ability to handle certain concepts when used in lean environments. An original requirements checklist of features and functions for traditional automated planning systems was created in 1998 by APICS in conjunction with Textile and Apparel Specific Industry Group (TA SIG). This checklist was modified to include features and functions specific to lean environments and is found in Section 4.3.2. Examples include the ability to run in real-time, handles kanban concepts, is linked to the customer and supplier, and the ability to group and split orders to achieve optimal utilization of capacity and materials.
- There is no right or wrong answer to lean planning and scheduling systems. Some companies may be better suited to using manual systems. For other companies, it may be beneficial to invest in automated systems.

- Because every organization is different, each individual company's software requirements, features and functions desired will vary. The checklist is simply a means of organizing a list of requirements that are the common for lean manufacturing in order to make the decision to purchase software somewhat easier.
- Just as there is no right or wrong answer, there is not a one-size-fits-all software system. Not every system will be created to fit the specific needs of a textile manufacturing company; therefore, it would benefit textile companies to look for those vendors that market specifically to the textile industry and have associates with backgrounds in textiles.

5.2 Conclusions

- Results show that while all companies interviewed were implementing lean manufacturing, the majority of companies had recently started their implementation and 5s and VSM were the most popular lean tools being used.
- Results from the interviews and case studies show that there is a lack of lean planning and scheduling systems being used in the textile industry. Thirty percent of the companies interviewed were still using some method of pencil and paper for plant floor scheduling, twice that of other industries. Thirty percent of the companies were also using MS Excel™, which is similar to the results from other industries.
- While few of the companies interviewed are actually using lean planning and scheduling systems, the majority of them are looking for improved ways to plan

and schedule the plant floor.

- Although few published cases exist, textile companies are beginning to implement kanban/supermarket/pull systems and visual scheduling boards.
- Combination or hybrid kanban systems where parts of the process are controlled by a kanban/supermarket/pull system and the special cases are manually scheduled using push systems are the most popular methods.
- Top barriers textile companies face when implementing lean manufacturing are: getting top management's commitment, resistance to the culture change, and the complexity of the company's products or product mixes.
- Companies who utilize an outside consultant or lean expert to train the company on VSM and conduct follow-ups may have better success at lean implementation.
- A position for a lean manager/champion/team whose job will be to implement lean, sustain the process and train employees, in addition to implementing lean throughout the supply chain, will help improve the rates of lean implementation success.

5.3 Recommendations for Future Research

1. Additional software surveys should be conducted because new developments and new systems are created often.
2. Conduct case studies of implementing a kanban/supermarket/pull system at a textile facility to better understand how the process works.
3. Create a roadmap for implementing kanban/supermarket/pull systems in a textile facility.

4. Re-evaluate the companies interviewed in this survey in the future to see if additional lean tools were implemented and what tools have sustained success.
5. Expand sample to include a broader cross-section of other textile industry sectors.
6. Conduct study of an entire textile supply chain to learn how information flows between enterprises and how scheduling is carried out.

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APPENDICES

Appendix A: Hodge's Original Software Survey

2002 Software Survey for the Textile and Apparel Industries

The North Carolina State University, Department of Textiles & Apparel, Technology & Management, in conjunction with APICS, is conducting a survey to compile a listing/directory of enterprise/manufacturing software vendors. This directory is being compiled for textile executives looking for enterprise/manufacturing planning control solutions. If you do not market to the textile and apparel industry, please take a moment to return the survey so we can update our records. Please contact Dr. George Hodge, APICS TA-SIG Academic Advisor & Associate Professor, College of Textiles if you have any questions or concerns. Thank you for participating in this year's survey.

Contact Information for Software Directory -

1. Company Name: ______________________________
2. Address: ______________________________
____
____
3. Contact person: ______________________________
4. Phone: ______________________________
5. Fax: ______________________________
6. E-mail address: ______________________________
7. Web Site URL: ______________________________

Detailed Information for Software Directory -

8. Software Package Name: ______________________________

9. Total Number of Installations- (a) All Industries: ____ (b) Textiles: ____
(c) Apparel: ___ (d) Others (non-woven, knitting, furnishings, etc.): ____

10. Training Available:

	On-site	Off-site	Web-site
Yes			
No			

11. Which type of application best characterizes your software (check all that apply)
______MRPII (Manufacturing Resources Planning)
______ERP (Enterprise Resource Planning)
______SCM (Supply Chain Management)
______APS (Advanced Planning Systems)
______P&S (Planning & Scheduling)
_____ Other ______________________________(Please specify)

2002 Textile & Apparel Industry Software Survey   1

Figure A. 1 Original Software Survey

12. On which hardware platforms does your software operate (check all that apply)

__486 PC __Pentium PC __IBM AS/400
__Macintosh __HP 9000 __Unix workstation
__Other ______________________________ (please specify)

13. On which operating systems does your software operate (check all that apply)

__Windows 95 __Windows 98 __Windows 2000
__Windows NT __Windows NT __OS/2
__OS/400 __IBM-AIX __Unix
__LINUX __MAC OS __Other (specify)____________

14. Computer language/database (check all that apply)

__IBM DB2 __Microsoft Access __Microsoft SQL
__Oracle __Sybase Other (specify) ________

15. Electronic Commerce/EDI Support

Please indicate the national/international EDI standards that your software supports
____ANSI ASC X12 ____UN/EDIFACT
Please indicate any textile/apparel industry-specific EDI standards you support
___TALC/SAFLINC ___FASLINC

Please indicate the transaction sets that you support for each of the following EDI standards:

Transaction Set	**ASC X12**	**FASLINC**	**TALC/SAFLINC**
810 Invoice	☐	☐	☐
820 Remittance Advice	☐	☐	☐
830 Planning Schedule	☐	☐	☐
832 Price/Sales Catalog	☐	☐	☐
846 Inventory Inquiry/Advice	☐	☐	☐
850 Purchase Order	☐	☐	☐
852 Product Activity Data	☐	☐	☐
855 Purchase Order Ack.	☐	☐	☐
856 Ship Notice/Manifest	☐	☐	☐
861 Receiving Advice	☐	☐	☐
863 Report of Test Results	☐	☐	☐
866 Production Sequence	☐	☐	☐
870 Order Status Report	☐	☐	☐
940 Warehouse Shipping Order	☐	☐	☐

Is your company involved in electronic commerce (B-2-B/B-2-C)?
____ Yes ____ No

16. Please attach a brief description of your company and software product (approx. 200 words). The description you provide will be placed in the directory along with contact information.

Please return this form to: Dr. George Hodge, either by
e-mail: george_hodge@ncsu.edu or
fax: 919 515 3733 or **mail:** College of Textiles North Carolina State University
2401 Research Drive Raleigh NC 27695-8301

2002 Textile & Apparel Industry Software Survey 2

Figure A.1 Continued

Appendix B: Survey for the Directory of Lean Planning and Scheduling Systems Software for the Textile and Textile-Related Industries

2007 Lean Planning and Scheduling Software Survey
for the Textile and Textile-Related Industries

Hello, my name is April Wagoner. I am a graduate student with the Institute of Textile Technology at North Carolina State University, Department of Textiles & Apparel, Technology and Management. My thesis research is on Lean Planning and Scheduling Systems available for use in the Textile Industry. I am conducting a survey in order to compile a directory of Planning and Scheduling systems that can be used in the Textile and Textile-Related Industries and that support Lean Manufacturing. The directory will be a tool that industry executives can use when looking for lean planning and scheduling software.

Please take a moment to fill out the survey. If you do not market to the Textile and Textile-Related Industries, do not offer Planning and Scheduling software, or do not support Lean Manufacturing, please let me know so I can update the Directory.

If you have any questions or concerns, please contact April at Apigail@yahoo.com. Thank you for participating in this survey.

Qualifying questions:

1. Can your software be used to schedule the plant floor?
   Y __________ N__________

2. Can the planning and scheduling modules handle lean concepts?
   Y __________ N__________
   If Y, please write a few words as to what makes them lean.

____

3. Can your products be used in the Textile or Textile-Related industries?
   Y __________ N__________

Detailed information for software directory:

4. Total Number of Installations:
(a) All Industries: _____ (b) Textiles: _____
(c) Apparel: _____ (d) Others (Non-woven, furnishings, etc.): _____

5. Training: Please mark applicable boxes for training your company provides.

	On-Site Training	**Off-Site Training**	**Web-Site Training**
YES			
NO			

6. What type of application best characterizes your lean software? More than one may apply.

MRP (Materials Requirements Planning) __________
MRPII (Manufacturing Resources Planning) __________
MES (Manufacturing Execution System) __________
ERP (Enterprise Resource Planning) __________
SCM (Supply Chain Management) __________
APS (Advanced Planning and Scheduling Systems) __________
PS (Planning and Scheduling System) __________
Other (Please specify) ____________________

7. Can the product interoperate or integrate with other ERP/SCM/MRP/MES/Other systems? Y __________ N__________

If Yes, please indicate the systems. If Other, please specify ________

8. Do you import and export information to Excel/Access?

Y __________ N__________

9. **Lean Features**: Please mark which Lean features the planning and scheduling software can handle. Please add any additional Lean features in the "Other" boxes.

Kanban management/replenishment		Real-time inventory management	
Demand smoothing		Linked to customer	
Line design		Linked to supplier	
Line balancing		Visual scheduling (eg: Gantt Charts)	
Mixed-model production		Ability to create original rules/priorities	
Other:		Other:	

10. On which hardware platforms does your lean software operate? More than one may apply.

386 PC __________ 486 PC __________
Pentium PC __________ IBM AS/400 __________
IBM RS/600 __________ Macintosh __________
HP 9000 __________ UNIX Workstation __________
Other (Please specify)____

11. On which operating systems does your lean software operate? More than one may apply.

Windows 95 __________ Windows 98 __________
Windows 2000 __________ Windows XP __________
Windows NT __________ Vista __________
OS/2 __________ OS/400 __________
IBM-AIX __________ UNIX __________
Macintosh OS __________ LINUX __________
Other (please specify) ____

12. What is the computer language/database? More than one may apply.

IBM DB2	__________	Microsoft Access	__________
Microsoft SQL	__________	Oracle	__________
Sybase	__________		

Other (please specify) ____

13. Is the planning and scheduling module stand-alone or must it be installed as part of another program?

Stand-Alone _____ Functional as part of another program _____

Contact Information for Software Directory:

14. Please provide the contact information for the software directory.

Company Name:
Lean Planning and Scheduling Software Package Name:
Address:

Contact Person:
Phone:
Fax:
Email Address:
Web Site URL:

15. Please attach a brief description (approximately 200 words) of the product that will be included in the directory along with the contact information.

Please return this form to April Wagoner by e-mail: Apigail@yahoo.com

Appendix C: Software Vendors Survey List

Table C. 1 Complete List of Software Vendors

Vendors	Specific Program	Source
3M	High Jump Manufacturing Advantage	(Managing Automation, 2006)
Adexa	Plant Planner and Shop Floor Sequencer	(Bartels, 2004)
Advanced Systems Integration		(Apparel's Guide to Software and IT Solutions, 2006)
Apparel Business Systems		(Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)
ApparelMagic		(Apparel's Guide to Software and IT Solutions, 2006)
Application Consultants, Inc		(Hodge, 2000)
Apriso Corporation	FlexNet Production	(Managing Automation, 2006)
AS/AP Apparel Software	Visual ASAP	(Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)
Axapta Lean Enterprise		(Aberdeen Group, 2005)
BLUE FOX Porini, Inc.	Porini Planner Suite	Megatex, (Apparel's Guide to Software and IT Solutions, 2006)
Bristlecone		(Aberdeen Group, 2005)
Brooks Automation		(Aberdeen Group, 2005; Hodge, 2000; Managing Automation, 2006)
Centric Software		(Apparel's Guide to Software and IT Solutions, 2006)
CIMNET Inc		(Managing Automation, 2006)
Cognizant Technology Solutions		(Apparel's Guide to Software and IT Solutions, 2006)
Computer Care		(Apparel's Guide to Software and IT Solutions, 2006)
Computer Generated Solutions		(Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)
DataCraft Solutions		(Managing Automation, 2006)
DATATEX TIS – USA, Inc.	MQM, NOW	Megatex, (Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)

Table C.1 Continued

Vendors	Specific Program	Source
Demand Management Inc	Demand Solutions	(Apparel’s Guide to Software and IT Solutions, 2006; Hodge, 2000)
eBECS	Lean Dynamix’s AX	(Aberdeen Group, 2005)
Ensemble Business Software		(Apparel’s Guide to Software and IT Solutions, 2006)
Enterprise Logix	Logix	(Managing Automation, 2006)
Epicor Software Corp	Vista, Epicor Avante Lean {29}	(Apparel’s Guide to Software and IT Solutions, 2006; Aberdeen Group, 2005; Managing Automation, 2006)
Exact Software Company	Frogfish Solutions	(Apparel’s Guide to Software and IT Solutions, 2006; Hodge, 2000)
Factory Logic		(Aberdeen Group, 2005; Bartholomew, 2003)
FactoryDNA Inc.	On-Demand Enterprise	(Managing Automation, 2006)
FDM4 America Inc		(Apparel’s Guide to Software and IT Solutions, 2006)
GCS Software		(Apparel’s Guide to Software and IT Solutions, 2006)
GE Fanuc Automation	Proficy Tracker/ Proficy Historian	(Managing Automation, 2006)
Giraffe Production Systems (AUST.)	Production Scheduling and Production Planning Software	(Managing Automation, 2006)
Global Shop Solutions Inc	Global Shop (can schedule)	(Managing Automation, 2006)
Glovia		(Bacheldor, 2004b)
Greycon	S-Plan	(Hodge, 2000)
Hanford Bay Associates, Ltd.		(Hodge, 2000)
Horizon Software Inc	MRP Plus	(Managing Automation, 2006)
i2 Technologies		(Apparel’s Guide to Software and IT Solutions, 2006; McCurry, 2000)
IDEA LLC		(Apparel’s Guide to Software and IT Solutions, 2006)
Indigo8 Solutions Limited		(Apparel’s Guide to Software and IT Solutions, 2006)

Table C.1 Continued

Vendors	Specific Program	Source
Infor Visual Easy Lean	Infor ERP Visual	IIE Conference, (Apparel’s Guide to Software and IT Solutions, 2006; Aberdeen Group, 2005; Managing Automation, 2006)
International Systems, Inc.		(Hodge, 2000)
JDA Software (acquired Manugistics, Inc)		(Apparel’s Guide to Software and IT Solutions, 2006; Hodge, 2000)
Jesta I.S.		(Apparel’s Guide to Software and IT Solutions, 2006)
JOMAR SOFTCORP INTERNATIONAL, Inc.	JOMAR E+e	Megatex, (Apparel’s Guide to Software and IT Solutions, 2006)
Jonar Systems, Inc		(Apparel’s Guide to Software and IT Solutions, 2006; Hodge, 2000)
JRG		(Aberdeen Group, 2005)
LAMAR Software, Inc.	Info.Net	(Managing Automation, 2006)
Lawson Software		(Apparel’s Guide to Software and IT Solutions, 2006)
Lean Manufacturing Systems Inc	Flow Manufacturing	(Managing Automation, 2006)
Matrikon Inc	MxAPS	(Managing Automation, 2006)
MCBA, Inc		(Hodge, 2000)
Metamor Enterprise Solutions		(Apparel’s Guide to Software and IT Solutions, 2006)
Micro Analysis and Design		(Hodge, 2000)
Momentis Systems Inc.		(Apparel’s Guide to Software and IT Solutions, 2006)
Network Systems International, Inc.	*net* ProPlan & *net* Scheduler	Megatex, (Apparel’s Guide to Software and IT Solutions, 2006)
New Generation Computing Inc		(Apparel’s Guide to Software and IT Solutions, 2006; Hodge, 2000)
nMetric	4C@SITE Lean Production Scheduling and MES	IIE Conference, (Managing Automation, 2006)
OpenPro Inc	OpenPro web based ERP Solution	(Managing Automation, 2006)

Table C.1 Continued

Vendors	Specific Program	Source
Oracle 11i	Oracle Applications	(Aberdeen Group, 2006d; Bacheldor, 2004b; Managing Automation, 2006)
Pelion Systems	Demand Manager	IIE Conference, (Aberdeen Group, 2005; Managing Automation, 2006)
Plexus Online by Plexus Systems	Plexus Online	(Managing Automation, 2006)
Polygon Software		(Apparel's Guide to Software and IT Solutions, 2006)
Preactor International	Preactor 400 APS	(Managing Automation, 2006)
Prescient Systems		(Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)
Principles and Applications, Inc		(Hodge, 2000)
QAD	Lean Manufacturing Resource Guide 90	(Bacheldor, 2004b; Bartholomew, 2003; Managing Automation, 2006)
Ramco Systems Corporation		(Hodge, 2000)
REACH Technologies		(Apparel's Guide to Software and IT Solutions, 2006)
Rockwell Automation		(Aberdeen Group, 2005)
SAP	SAP Manufacturing, SAP for Mills Products	(Apparel's Guide to Software and IT Solutions, 2006; Aberdeen Group, 2005; Bacheldor, 2004a; Bacheldor, 2004b)
SAS	SAS Systems	(Apparel's Guide to Software and IT Solutions, 2006; Managing Automation, 2006)
Smart Software, Inc		(Hodge, 2000)
Softbrands	Evolution, Fourth Shift Edition for SAP Business One	(Managing Automation, 2006)
Synchrono	Synchrono:Adaptive Supply Chain	(Managing Automation, 2006)

Table C.1 Continued

Vendors	Specific Program	Source
Taylor Scheduling Software, Inc.	Taylor Scheduler	IR (Taylor Scheduling Software Inc., 2004)
Technology Group International	Enterprise 21 ERP Solution	(Managing Automation, 2006)
TSI Systemgroup Inc		(Apparel's Guide to Software and IT Solutions, 2006)
TWW	Winman	(Hodge, 2000; Managing Automation, 2006)
TXT e-solutions		(Apparel's Guide to Software and IT Solutions, 2006)
User Solutions, Inc.	Resource Manager DB	(Hodge, 2000)
Visiprise Inc	Visiprise Manufacturing Operations / Process Planning	(Managing Automation, 2006)
Waterloo Manufacturing Software	TACTIC	(Hodge, 2000)
Workbrain		IR (Workforce optimization apps extend lean endeavors.2006)
Xdata Solutions Inc	GXD Graphical ERP	(Managing Automation, 2006)
Xperia Solutions (formerly Online Data Systems, Inc)		(Apparel's Guide to Software and IT Solutions, 2006; Hodge, 2000)

Appendix D: Directory of Lean Planning and Scheduling Systems Software for the Textile and Textile-Related Industries

The following fourteen companies are listed in the directory.

1. Apriso Corporation**
2. AS/AP Apparel Software
3. BLUE FOX Porini, Inc.**
4. DATATEX TIS - USA, Inc.
5. eBECS
6. Giraffe Production Systems
7. JOMAR SOFTCORP INTERNATIONAL
8. LAMAR Software, Inc.
9. Network Systems International, Inc.**
10. Pelion Systems
11. Preactor International
12. SAP**
13. Taylor Scheduling Software, Inc.
14. User Solutions, Inc.

**Directory information based on company website

Apriso
FlexNet Production (MES)

One World Trade Center, Suite 1000 (562) 951-8000
Long Beach, CA 90831-1000 (888) 400-7587
www.aprisio.com

Lean Features

Kanban management/replenishment	
Demand Smoothing	
Line design	
Line balancing	
Mixed-model production	
Real-time inventory management	
Linked to customer	X
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	

Integrates with

MRP	
MRPII	
ERP	X
MES	
SCM	
CRM	X

Import/Export with

Excel	
MS Access	

Operating Systems	Hardware	Databases
NA	NA	NA

Apriso offers the FlexNet Adaptive Operations Execution Platform and Model Suite. Solutions can be implemented individually or as an entire suite. FlexNet integrates seamlessly with ERP systems enabling the agility required to support new extended business models and continuous improvement initiatives. With FlexNet, performance is optimized across all aspects of your extended value chain including your people, materials, machines and processes. FlexNet provides for the transfer of real-time data, signals, alerts, key performance indicators (KPIs), or business intelligence from any network location to any other location around the world. FlexNet empowers manufacturers to respond quickly to strategy shifts, changing market conditions and unexpected events. FlexNet delivers cost-effective WIP tracking, traceability, genealogy and compliance, driving continuous improvement, Lean Manufacturing and SixSigma initiatives.

AS/AP Apparel Software
Visual ASAP (MRP, ERP, SCM)

1000 Abernathy Rd. NE
Ste. 184
Atlanta, GA 30328
www.visualasap.com

Carrie Sagel Burns
(770) 993-4141 Fax: (770) 993-2868
csagel@visualasap.com

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	
Real-time inventory management	
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	**Hardware**	**Databases**
Windows 95/98/2000/XP/NT/ Vista, Macintosh OS	386 PC, 486 PC, Pentium PC, Macintosh	Visual FoxPro

AS/AP™ RANKED #1 OVERALL in Apparel Magazine's Scorecard Survey is THE ONLY totally integrated, Accounting, Manufacturing, and Distribution System designed and developed by the same industry experts since 1983. AS/AP™ provides the FLEXIBILITY required by the Apparel Industry with complete ERP/PDM (Product Data Management)/MRP/PLM (Product Lifecycle Management) solutions, Supply Chain Management, Comprehensive Shop Floor Controls, Event Management, Dynamic BOM (Order Configurator), Critical Path, Query Maker for ad hoc reporting, EDI and total eCommerce solutions. To satisfy vertical market requirements, in addition to Custom Programming, AS/AP™ also blends combinations of features into industry-specific packages for Uniform Companies, Advertising Specialties, and Embellishers.

BLUE FOX Porini, Inc.
Porini Processing Planner, Porini Spinning Planner, & Porini Loom Planner (P&S)

31416 Agoura Road, Suite 150
Westlake Village (LA), CA 91361
(818) 887-0840 Fax: (818) 313-7900
www.bluefoxta.com
America@BlueFoxTA.com

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	
Real-time inventory management	X
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
NA	NA	NA

BlueFox offers a Processing Planner module for dyeing, printing and finishing plants and a Loom Planner module for weaving plants. The Planners are used to facilitate monitoring, balancing, planning and fine scheduling in multi-phase finishing, weaving, and knitting processes. The Planners utilize Gantt charts and allow the opportunity to perform simulations. Planners can be interfaced with any ERP and not only receives data on customer orders, production orders, machine status and styles, but also processes information concerning production progress updates. This kind of data can be fed straight from production monitoring systems in real time.

Loom Planner for Weaving: this powerful tool schedules those warps, which weaving production orders are allocated to. This interactive planning and scheduling module can be the starting point from which the entire production process is launched.

Loom Planner for circular or warp-knitting: it takes care of scheduling production orders, requiring the allocation of several components (cones, small beams, texture or effect beams, etc).

DATATEX TIS (Textile Integrated Solutions) - USA, Inc.
MQM (Machine Queue Management) (APS)
NOW (Network Oriented World) (ERP with MRP, MRPII, MES, P&S, etc.)

11810 Northfall Lane, Building 1203
Alpharetta (Atlanta)
GA 30004-1843 USA
www.datatex.com

Jim Noble, Dir. Sales & Marketing
(770) 667-8656, ext 111
Fax: (770) 667-8377
jnoble@datatex-usa.com

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X
BOARD Business Analytics/ Intelligence Applications	X

Operating Systems	Hardware	Databases
Windows 2000/NT/XP/Vista, IBM-AIX, OS/400, UNIX, LINUX	Pentium PC, IBM AS/400, IBM RS/600, UNIX Workstation, Java Virtual Machine	IBM DB2, Microsoft SQL, Oracle

-- Datatex software solutions are specifically suited to partner with Lean Concepts in many areas:
• Forecasting capabilities (BOARD Business Analytics) can identify ‘lumps’ or ‘voids in the demand.
• Planning module (TRP & MQM) allow demand leveling
• TRP explodes & plans materials & work center capacity
• Flexible costing structures with multiple user – defined levels
• Routings model the timing of materials & capacity to the actual need
• Order tracking facilitates the backflushing of materials & labor at needed milestones
• Single point / multiple points of reporting eliminates paper & non value – adding activities
• Contra traditional Lean, our textile customers often have regulatory reporting requirements which force them to maintain Lot Traceability. Datatex allows the system to manage these connections from the finished product back to the raw materials – all without the need of paper. Reporting would only be done as required.
• Logical warehouses minimize reporting & handling; no need to ‘put away;’ & shipping directly from production
• Allocate goods by location, lot number, element (roll / piece, etc.), or SKU
• Utilizes EDI – both in – bound & out – bound

eBECS
LEAN Dynamix's AX (ERP)

NA

www.ebecs.com

Darren Hogg
(678) 357-4838
dhogg@ebecs.com

Lean Features

Kanban management/replenishment	X
Demand smoothing	X
Line design	
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Windows 95/98/2000/XP	386 PC, 486 PC, Pentium PC	Microsoft SQL

The particular planning and scheduling module must be part of Microsoft Dynamix's AX. LEAN Dynamix's AX was developed specifically to support Lean concepts. The software can work with Kanbans or Lean Order Scheduling and includes visual tools.

Giraffe Production Systems
Production Scheduling and Production Planning Software (MES, P&S, APS)

365 Queen St.
Melbourne VIC 3000 Australia

Vince Levenda
61 3 9383 7454   Fax: 61 3 9640 0125
giraffeinfo@giraffeproductionsystems.net

http://www.listensoftware.com/hrxp/cmWebsite.asp?process=display&contentid=827

Lean Features

Kanban management/replenishment	X
Demand smoothing	X
Line design	X
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X
Orienting production resources and tasks to customer demand and ensuring factory activities are driven by customer demand.	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Windows 95/98/2000/XP/NT/Vista & proprietary systems associated with PLCs	Pentium PC, Server computers, & Industrial computers such as PLCs	Microsoft Access/ SQL, & proprietary databases associated with PLC networks

Software to automate resource planning for textiles processing and clothing and footwear manufacturing. Optimised capacity planning, process planning, plant scheduling, machine scheduling and production control. Fully automated re-scheduling from real-time production data from machine sensors and controls. Giraffe Production Systems offers MRP, MRPII, MES, SCM, and ERP applications as well as the P&S, and APS.

JOMAR SOFTCORP INTERNATIONAL
JOMAR E+e (ERP, SCM, APS, P&S, MRP)

1760 Bishop street
Cambridge, Ontario, Canada
N1T 1J5
www.jomarsoftcorp.com

John A. Blasman
(519) 740-0510 Fax: (519) 740-9812
sales@jomarsoftcorp.com

Lean Features

Kanban management/replenishment	X
Demand smoothing	X
Line design	X
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X
Other: CRM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Windows 95/98/2000/XP/NT/ Vista, OS/2, OS/400, IBM-AIX, UNIX, LINUX	386 PC, 486 PC, Pentium PC, IBM AS/400, IBM RS/600, HP 9000, UNIX Workstation, All Intel based servers	IBM DB2, Microsoft SQL, Oracle

JOMAR develops and implements web-based multi-platform Software technology for global multi-plant vertically integrated Textile and Apparel manufacturers. The integrated JOMAR suite includes ERP, Supply Chain Planning with Internet tracking across subcontractors, fabric suppliers and distribution centers. JOMAR supports Textile processes from raw fiber to yarn, warping, weaving, knitting, finishing, cutting, sewing and printing. The Software functionality includes Mobile Computing, EDI, Schedule Board, Workflow, R.F. Barcoding and Data Collection, Touch Screen Technology, Document Management, Multi-Currency and Business Intelligence.

JOMAR clients are diversified and manufacture products for the marine, ballistic, fire repellent, automotive, military, industrial, upholstery, aerospace, polymers and composite industries. Our sewn products' clients manufacture and distribute for the home fashions, sportswear, workwear, women's fashion and casual wear.

LAMAR Software, Inc.
Info.Net (MRP, MRPII, MES, ERP, P&S)

897 Oak Park Blvd #262
Pismo Beach, CA 93449
www.lamarsoftware.com

Gary Halvorsen
(805) 929-1482 (805) 929-1495
info@lamarsoftware.com

Lean Features

Kanban management/replenishment	X
Demand smoothing	
Line design	X
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Client (Windows 95/98/2000 XP/NT/Vista, Macintosh OS) Server (IBM-AIX) Also UNIX, LINUX and Solaris	Client (386 PC, 486 PC, Pentium PC, Macintosh, UNIX Workstation) Server (Pentium PC, IBM RS/600, HP 9000, UNIX Workstation)	Programmed in C with a JAVA applet, Client databases supported are C-Scribe and MYSQL

Manage the entire business cycle of your growing company with Info.Net's applications. Info.Net supports your growth from a very simple business to a very sophisticated one. For example, our customers use Info.Net to prove to the FDA, FAA and DCA auditors that they; can accurately document all 'As-Shipped' configurations, are able to do customer specific recalls, and have actual cost project accounting.

You can also run your company with real-time information exchange to your supply chain partners.

Info.Net's applications integrate the data and demands from Financial Accounting, HR, Inventory Control, Quality, Planning, Purchasing, Project Control, Production and Field Service.

Business Intelligence 'BI' is built in to Info.Net, not added on.

We offer ASP hosted service pricing and enterprise pricing.

The following link is for the Info.Net Functionality Overview.
http://www.lamarsoftware.com/literature/InfoNet-features.pdf

The following link is for the Info.Net brochure that describes who we are and what we do.
http://www.lamarsoftware.com/literature/LAMAR%20Software%20Brochure200609.pdf

Network Systems International, Inc.
***net* ProPlan & *net* Scheduer** (ERP, MRP, P&S)

200 North Elm Street
Greensboro, NC 27401
www.nesi.net

Clark H. Lane
(336) 271-8400 Fax: (336) 273-3235
lanec@nesi.net

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	X
Mixed-model production	
Real-time inventory management	X
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	
Ability to create original rules	

Integrates with

MRP	X
MRPII	
ERP	X
MES	
SCM	

Import/Export with

Excel	X
MS Access	X

Operating Systems	**Hardware**	**Databases**
Windows PC & AS/400 environments, iSeries	NA	Microsoft SQL

net ProPlan: Time phased resource plans for materials and processes with capacity constraing smoothing capabilities
net Scheduler is the product within the *net collection* responsible for manufacturing order management. Finite machine scheduling. Manufacturing environment control with complete raw materials management, finite machine scheduling and percent return yields.

Pelion Systems

Demand Manager module within Pelion's Lean Manufacturing Operating System (MES, SCM, P&S)

2520 55th Street, Suite 210
Boulder, CO 8030
www.pelionsystems.com

John Howlett
(720) 890-2800, x160   Fax: (720) 890-1211
john.howlett@pelionsystems.com

Lean Features

Kanban management/replenishment	X
Demand smoothing	X
Line design	X
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X
Other: Value Stream Mapping	X
Other: Machine cell management	X
Other: Supplier collaboration portals	X
Other: Visual work instructions	X
Other: Lean OEE	

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
386 PC, 486 PC, Pentium PC, IBM AS/400, IBM RS/600, HP 9000, UNIX Workstation	Windows 95/98/2000/XP/NT/ Vista, IBM-AIX, UNIX	IBM DB2, Microsoft SQL, Oracle

Pelion's Lean Scheduling application compares actual demand volume and mix to factory resources and alerts planners to potential resource bottlenecks to ensure effective daily scheduling, production sequencing and load balancing.

Problems We Solve:
"We need a way to make it simple for people to know what to build, how much to build and when to build it."
"We've focused on Lean practices for years, but we still have pains in running production."
"We can't synchronize our production requirements across departments based on customer demand."
"Heijunka is a powerful concept, but it is too hard to do manually in our business."
"I wish I had the technology to drive my mix with Every Product Every Interval (EPEI) logic."
"We are forced to allocate overtime because we don't have the right products or quantities to support our build schedule."

Benefits We Provide: Improve On-Time Shipping, Reduce Lead Times, Build the Right Product Mix, Reduce Product Backlogs, Reduce Overtime Costs, Reduce Planning Effort and Fire-fighting, Increase Management's Confidence in Our Ability to Hit the Plan

Preactor International
Preactor 400 APS (P&S, APS)

Cornbrash Park, Bumpers Way
Chippenham, Wiltshire, SN 14 6RA, UK
www.preactor.com

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Lean Features

Kanban management/replenishment	
Demand smoothing	X
Line design	
Line balancing	X
Mixed-model production	X
Real-time inventory management	
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X
Other: Heijunka Scheduling	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X
Other: SFDC, SOP	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Windows 2000/XP/NT/Vista	486 PC, Pentium PC	SQL 2005 Server

Preactor International is the world leader in production scheduling software with more than 7,000 installations in more than 1,700 companies located in 58 countries. Preactor's unique combination of ease-of-use, flexibility and affordability provides planners with a decision support tool that helps companies reach maximum agility in a fast moving, demand driven, make to order, lean environment.

Preactor is designed for integration with other software such as ERP. These products typically export a list of operations that need to be completed to produce all new and existing demands. Using Preactor, the user then schedules which task to complete, by which production resource, and at what time automatically using rules and also using drag-drop on the interactive planning board. When released by the planner the schedule information updates ERP with the confirmed production schedule, revised route, sequence and timings from the Preactor plan. Preactor's sequencing engine provides additional functionality over and above competitive products. For example multiple constraints (e.g. machines, staff, tooling etc), attribute based sequencing (e.g. preferred sequencing and campaigning to minimise changeover times), complex, user definable scheduling rules and dependencies between orders.

Preactor has also been integrated with MES software. The schedule generated by Preactor is passed to MES for execution at shop floor level. Message driven feedback on progress then automatically updates the schedule so providing an up the minute view of any problems to trigger a re-schedule.

What companies need is visibility. They need the ability to see what's happening now and what the effect their decisions will have on the future. Preactor advanced planning and scheduling solutions deliver this and compliments the user visibility in ERP. Preactor helps planners see the current load, show the impact of new orders and unexpected events on capacity and delivery promises and provide a tool to test the options before decisions are made. It enables the planner to have the detail to manage the shop floor effectively.

SAP
SAP Manufacturing (ERP, SCM)
SAP for Mills Products (ERP)

3999 West Chester Pike
Newtown Square, PA 19312
www.sap.com

(866) 609-1063

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	
Mixed-model production	
Real-time inventory management	X
Linked to customer	X
Liked to supplier	X
Visual scheduling (eg: Gantt Charts)	
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	
MS Access	

Platforms	Hardware	Databases
Enterprise SOA, SAP NetWeaver, and SAP's Ecosystem	NA	NA

SAP Manufacturing is the only comprehensive solution for managing manufacturing operations with embedded Lean and Six Sigma -- empowering you to deliver superior responsiveness and performance. And since it's built on the SAP NetWeaver platform, SAP Manufacturing connects seamlessly with your entire enterprise, including your current plant floor infrastructure.
SAP Manufacturing gives discrete and process manufacturers functionality to:

- Coordinate operations with partners and suppliers
- Detect and resolve exceptions and performance deviation in real time and at low cost
- Institutionalize Lean and Six Sigma processes and monitor production to drive continuous improvement
- Comply with environmental, health, and safety standards
- Improve employee productivity and create a high-quality work environment

With SAP Manufacturing, your management and production departments gain real-time visibility into key data. Managers can document, track, and interpret quality and performance using rich analytics capabilities. Production teams can leverage role-based applications for plant managers, production supervisors, maintenance supervisors, and quality inspectors to detect and respond rapidly to exceptions and variances -- and deliver superior performance. SAP Manufacturing helps you to plan, schedule, sequence, execute, and monitor all your manufacturing processes optimally.

SAP for Mill Products solutions can easily share schedule information with shop-floor manufacturing-execution systems and support both make-to-order and make-to-stock manufacturing scheduling and execution. SAP offers SAP for Mill Products, a comprehensive portfolio of solutions tailored to the specific practices, processes, and challenges of the textiles industry.

Taylor Scheduling Software, Inc.
Taylor Scheduler (APS, P&S)

Taylor Scheduling Software, Inc.
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www.taylor.com

Jim Rota
(780) 414-6718 ext: 224
Fax: (780) 414-6716
marketing@taylor.com

Lean Features

Kanban management/replenishment	
Demand smoothing	
Line design	
Line balancing	X
Mixed-model production	X
Real-time inventory management	
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	Hardware	Databases
Windows 2000, Windows XP, Windows NT	Pentium PC	Microsoft SQL, Oracle

Taylor Scheduling Software has been developing and marketing advanced planning and manufacturing scheduling systems (production scheduling, finite capacity scheduling) since 1989. Taylor Scheduling Software Inc. provides Interfacing services at guaranteed pricing to connect the legacy ERP, MRP, MRPII (or other systems) to the Scheduler and Planner. Taylor Continuing Support (TCS) We provide our customers with a range of technical support levels: Premium TCS, Standard TCS, Updates Only TCS or Time and Materials TCS. You can choose the appropriate level for your operation and needs.

User Solutions, Inc.
Resource Manager DB (MRP, MRPII, APS, P&S)

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(248) 486-1934 Fax: (248) 486-6376
jc@usersolutions.com

Lean Features

Kanban management/replenishment	X
Demand smoothing	
Line design	
Line balancing	X
Mixed-model production	X
Real-time inventory management	X
Linked to customer	
Liked to supplier	
Visual scheduling (eg: Gantt Charts)	X
Ability to create original rules	X

Integrates with

MRP	X
MRPII	X
ERP	X
MES	X
SCM	X

Import/Export with

Excel	X
MS Access	X

Operating Systems	**Hardware**	**Databases**
Windows 95/98/2000/XP/NT Vista	386 PC, 486 PC, Pentium PC	Microsoft Access, Microsoft SQL

Resource Manager-DB for Lean Manufacturing
With a unique Microsoft Office-centric approach, Resource Manager-DB enables a "best-of-breed" approach by adding powerful and flexible manufacturing planning, scheduling, and tracking features to any system. The intuitive “no-rules” design easily adapts to how customers are working now, facilitating quick implementation and easy maintenance. Now, in addition to traditional MRP and Shop Management functions, the system supports Lean Manufacturing. This unique combination facilitates an easy and affordable approach for companies to adapt Lean Manufacturing methods at their own pace.

Lean Customer Drives Lean Features

User Solutions worked with the NIST-Manufacturing Extension Partnership (MEP) on a project to support Instruments for Industry (IFI), a Long Island-based electronics assembly company committed to Lean Manufacturing. As a result, Resource Manager-DB was adapted to support Lean Manufacturing principles. Orca Technical Services, a subsidiary of IFI, is now a Distributor for the product, utilizing an actual live environment as part of an East Coast Training Center for Resource Manager-DB. According to Robert Krause, MRP Specialist for IFI, “In my 20 years of working with MRP and Inventory Systems, it’s refreshing to work with a product that is so open and flexible to support our initiatives.” Robert continues, “While the whole purpose of Lean Manufacturing is to reduce systems – you still need a system for managing the Purchasing and parts of the business that are not appropriate for Lean Manufacturing Techniques. Resource Manager-DB does this and fully utilizes KanBan Control, automated KanBan signal replenishment, supports the Front/Back bin, Point of Use principles and is fully Bar Code enabled.”