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Reducing changeover times in a web offset packaging environment

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Reducing Changeover Times in a Web Offset Packaging Environment

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Abstract

The printing industry has been experiencing steadily rising costs and declining profits, at times leading to the closing down, consolidation, or restructuring of printing companies. Lean Manufacturing is an effective tool that has helped several printing companies to overcome these rising costs by reducing the cost of production and by improving productivity (Cooper, 2007). This research identified methods to reduce setup times, leading to savings of close to $60,000 annually on one press. The average setup time was reduced by 60%, from over two hours to less than one hour. The changes implemented on one press could be standardized on the other two similar presses in the offset department to provide annual savings of over $200,000.

The researcher worked with a packaging company for a period of six months, during which time he worked on improving the changeover time on one of the Stevens web offset presses. The method of study employed was called Action Research, which involved direct interaction with employees of the organization. The researcher used Process Cycle Efficiency (PCE) as a parameter of success, which is measure of the value added time.

This research demonstrates that a Single Minute Exchange of Die (SMED) event can be used successfully in reducing setup times on a Stevens web offset press.

Chapter 1

Introduction

Over the last two decades, there has been a global focus on the importance of Lean Manufacturing. *Lean Manufacturing* can be defined as a journey of continuous improvement by implementing innovative ideas to reduce waste and increase productivity (Womack et al., 1990). Toyota Motor Corporation chose to reduce wastes and increase productivity by continuous improvement methods rather than capital investments (Raman & Stewart, 2007). Since that time, many manufacturing industries have taken initiatives in implementing the practice of Lean Manufacturing in their production lines.

Lean Manufacturing has now spread to the printing industry. A survey conducted by the Printing Industries of America and Graphic Arts Technical Foundation (PIA/GATF) concluded that 77% of American printing company managers had heard of or have read about Lean Manufacturing. It further added that 66% were familiar with the concepts and tools, while 40% were actually using Lean Manufacturing to strengthen their business (PIA/GATF Conducts Lean Manufacturing Survey, 2008).

Problem Statement

A packaging printer in Connecticut faced problems with the time spent on changeovers and was hopeful the time could be reduced. The researcher worked with the company for six months to reduce the changeover time. The press studied was the Stevens web offset press (see Appendix A1). Stevens Technology is an American manufacturer of Web offset presses based in Fort Worth, TX. The Stevens press is a web offset press that produces roll-to-roll. The press is used primarily for printing food-packaging products.

The circumference of the plate, blanket, and impression cylinder determined the “repeat length” of the print order. The plate, blanket, and impression cylinder together formed a system referred to as an *insert* (see Appendix A2). The Stevens press came equipped with a feature that allowed for changing the repeat length by changing the inserts on the press at every unit. The different insert sizes used were 17.5”, 21”, 22.5”, 23.5”, 24”, and 26”. The reason for using different insert sizes was to accommodate as many copies of a product as possible within one repeat length. For instance, if a food pouch measured a width of 4 1/2”, then five such food pouches would fit on a 22.5” insert in the most economical manner with minimal waste.

The insert change was considered an overhead activity and the company did not charge the customer for the time spent performing it. The events following the insert change, such as changing inks, plates, and paper rolls on the press,

were charged to the customer, but the actual insert change was not. As a result, the company wanted to reduce the time taken to perform an insert change.

Personal Interest of Study

The researcher comes from a family who owns a business in a similar line to that of the company involved in this research. The aim was to learn as much as possible during the implementation of this research, and to take the lessons learned back to the family business.

Problems Currently Plaguing the Printing Industry

The Printing Industry worldwide has been facing problems pertaining to:

1. Increased cost of raw materials
2. Increased competition
3. Slowing economy
4. Environmental challenges

According to Kadlub (2008), the Printing Industry has been in the midst of a transformation over the last decade. The evolution of new media such as websites and search engines has driven print volumes down.

Increase in Raw Material Cost

The print market has been seeing a consistent increase in the price of paper (Steinmetz, 2006). Printing companies are also seeing a larger variation in the demand for print. The printing costs in China have increased as much as 40% since the beginning of 2008 (Page, 2008). Other factors to consider include the price of oil, the currency fluctuation in the US dollar, and the new labor laws in China.

In the US, paper mills are being accused of not doing enough to help printers cut costs. The rolls produced by certain mills are defective, and then the printers used these rolls. One of the recent problems included stone damage, in which the end of the paper reel was dented and water damaged (Hooker, 2009).

Increased Competition

At one time, printers faced competition from other companies within the same town or state. Competition has now become global. With countries such as India, China, and the Philippines providing cheap labor, the cost of printed goods has become very competitive (Delmontagne, 2008). The global recession has exposed printing companies with poor business models in the UK. In a survey conducted by Plimsoll Publishing, 310 of the leading 1000 printing companies in the UK were in financial danger. Of these, 236 experienced falling profits, with 192 losing money. Further, the UK printing industry as a whole has overcapacity, with 42% reporting falling sales (Pattison, 2009).

Cagle (2008) explains that, in spite of the rising cost of raw materials, raising prices to the customer is unlikely to be successful. Ultimately, the low cost producer prevails.

Slowing U.S. Economy

The middle of 2008 has seen a global recession that left no country unaffected. The U.S. is amongst the worst of the affected countries. In particular, the manufacturing and financial sectors are deeply affected. The fall of the automobile industry has compounded issues for the printing industry. US automakers comprise the single largest category within commercial printing, accounting for as much as 12% of all advertising. Their spending in 2008 was $15 billion, which was almost equal to 1999 figures; however, it was down from $24 billion in 2004 (Bullock, 2008).

German press-manufacturing giant, Heidelberg, expects an operating loss of close to EUR 40 million in 2008; down from a positive result of EUR 26 million in 2007. Despite the success of Drupa in June 2008, the company still expects to post losses due to the sluggishness of the world economy (Heidelberger, 2008).

In Germany, the printing industry grew by 2.5% in 2007, but by only 1.8% in 2008. This drop in growth has been linked to the slowing economy, as advertising accounts for a considerable portion of the printing industry. During tough economic times such as these, corporate companies are cutting back on advertising expenditure (Labitzke, 2008).

Environmental Challenges

Companies such as Walmart and Toyota, who have a global image of sustainability, expect their printers to be green as well (Rosenberg, 2008). This not only requires a printing company to maintain green standards, but also work with green suppliers.

A major benefit of digital printing is the reduced waste from setup and overproduction. This advantage, however, is overshadowed by the problems faced in *de-inking,* which is the process of removing inkjet toner printed on paper so that it may be recycled (DeWitt, 2009).

While the problems faced by the printing industry cannot be completely eliminated, following Lean Manufacturing practices can help reduce them.

Objectives of this Research

The main objective of this research is to prove that Single-Minute-Exchange of-Die (SMED) can be used to reduce changeover times on a Stevens Web Offset press. The researcher is also keen on using Process Cycle Efficiency (PCE) as a parameter of success to determine if the changeover process can be classified as lean. This parameter has not been used to measure the success of reducing changeover times within the printing industry.

Chapter 2

Literature Review

The literature review explains the history and basics of manufacturing and reviews some of the commonly used tools. This section also reviews the work culture at Toyota Motor Corporation and takes a look at some of the reasons behind the company's success.

Lean Manufacturing

"Everyone wants to be the Lance Armstrong of lean business these days" (Hassler, 2008). Unfortunately, while Lean Manufacturing is easy to understand, it is complex to implement (Domingo et al., 2007). The concept of Lean Manufacturing (often referred to as *Lean)* is understood from its basic definition, its history, and an examination of the ways in which it has been implemented.

<u>Definition of Lean</u>

Lean means "manufacturing without waste" (Taj, 2008). Rothenberg & Cost (2004) have defined Lean as "a way to reduce buffers." The term, *Lean Manufacturing,* or Lean*,* was first used by Womack et al. (1990), in their book *The Machine that Changed the World.* The term, Lean Manufacturing*,* describes the type of production employed by Toyota in the 1950s. Lean deals with the concept of reducing wastes in all its forms to increase productivity and to

maximize profits. Lean Manufacturing has helped Toyota Motor Corporation become a global giant (Alukal, 2007).

A Lean system focuses on providing a customer what he or she wants, at the price they are willing to pay for it, and at the time they want it (Brown et al., 2006). According to Taichi Ohno, one of the founders of the Lean culture at Toyota, wastes account for 95% of all costs in a company (Comm & Mathasiel, 2005). Lean focuses on eliminating wastes or *muda* (Japanese for “waste.”)

The seven types of wastes according to Lean are classified as:

1. Rework – due to customer dissatisfaction
2. Overproduction – producing without reason
3. Over processing – spending too much time on the product
4. Transportation – unnecessary movement of goods
5. Inventory – high levels of stocked raw materials
6. Waiting – delayed set-ups
7. Motion – physical strains, such as walking, lifting, and bending (Imai, 1986., Taj, 2008).

Lean is not restricted to just reducing waste. When compared to mass production, Lean uses “half the human effort, half the space, half the time, half the inventory” to produce a similar product (Lathin & Mitchell, 2001 p. 321). Any

activity performed that does not add value to the product as defined by the customer is termed *non-value added* or *waste* (Comm & Mathasiel, 2005). Mass producers can expect improvements to the extent of 90% reduction in inventories, 90% reduction in lead time, 90% reduction in cost of quality, and 50% increase in productivity (Lathin & Mitchell, 2001).

Table 1 gives a glossary of Lean terminology. For a more detailed glossary, refer Appendix D2.

Table 1. Glossary of Lean Terms

Term	Definition
Kaizen	Japanese term meaning continuous improvement."Kai" means change and "zen" means good.
Just in Time Manufacturing	A planning system for manufacturing processes, which optimizes needed material inventories at the manufacturing site to only what is needed. JIT is a pull system; the product is pulled along to its finish, rather than conventional mass production, which is a push system.
Kanban	Japanese term. It is one of the primary tools of a JIT system. It maintains an orderly and efficient flow of materials throughout the entire manufacturing process. It is usually a printed card containing specific information such as part name, description, quantity, etc
MO-CO-MOO	Acronym for “Make One – Check One – Move One On.” This system was used to facilitate single-piece production.
Poka-Yoke	Japanese for “mistake proofing.” Toyota engineered their products in such a way that mistakes would not be an inherent part of the design.
Lean Manufacturing	Philosophy developed by Toyota aimed at eliminating waste (non-value added steps, material, etc) in the system.

Toyota Production System (TPS)	The Toyota production system is a technology of comprehensive production management. The basic idea of this system is to maintain a continuous flow of products in factories to flexibly adapt to demand changes. The realization of such production flow is called Just-in-time production, which means producing only necessary units in a necessary quantity at a necessary time. As a result, the excess inventories and the excess work force are naturally diminished; thereby achieving the purposes of increased productivity and cost reduction.

History of Lean

The concept of Lean first appeared in the 1920s when Henry Ford wanted to adopt ways to make Ford car engines more fuel efficient in light of a global oil crisis (Womack et al., 1990). This practice of Lean was later mastered by the Toyota Motor Company when Taiichi Ohno, regarded widely as the Father of the Toyota Production System (TPS), sent his engineer Eiji Toyoda to the Ford Rouge Plant in the United States to study its system of manufacturing.

Toyoda returned to Japan and reported his observations of wastages at the Ford Plant to Ohno. Ohno then worked towards strategizing a waste-reduction module, which he started to implement at the Toyota Motor Company. Thus, the Toyota Production System was born (Womack et al., 1990; Lean Manufacturing History, 2007; Lathin & Mitchell, 2001).

Toyota Production System

The Toyota Production System (TPS) focuses on removing wastes from within a process and making it "lean" (Lander & Liker, 2007). The essence of TPS is to reduce batch-wise manufacturing and to produce in a "lean" manner, a direct contrast to Ford's method of mass production (Womack *et al.*, 1990).

The disadvantages associated with batch production are:

1. Rising inventories equate to a drop in cash flow.
2. Large inventories occupy more floor space, thereby limiting the company's scope of expansion.
3. A company holding large inventories cannot adapt to a quick shift in customer demand (Brown et al., 2006).

The importance of TPS came to the fore soon after the oil crisis in the early 1970s. People started to notice that Toyota had not been as badly hit as their competitors and that it took less time to recover (Lander & Liker, 2007). Toyota focused on redesigning the Mass Production System and converted them into U-shaped sub-assembly cells. The shop floor ultimately resembled smaller manufacturing cells (Black, 2007). Other companies who tried to copy the TPS did not meet with as much success. The main reason for this was that they were trying to implement the concepts in a formulaic way that was never intended. Toyota, on the other hand, believed in Continuous Improvement and constant innovation (Lander & Liker, 2007).

To quote one of the principles defined in *The Toyota Way*: “Create continuous flow to bring problems to the surface. Create flow to move materials and information fast, as well as to link processes and people together so that problems surface right away” (Liker, 2004).

This principle explains the importance of moving the material faster through the process, while linking the process with the people. This principle demonstrates that simply getting rid of excess inventory is not enough to make an organization Lean (Lander & Liker, 2007).

The formulation of the TPS followed certain design rules:

1. The first design rule calculated the *Takt Time* (TT) that was based on the daily demands from the customer.
2. The second design rule was based on the *MO-CO-MOO Principle*. This is an acronym for “Make One. Check One. Move One On”. In Lean terms, this is also referred to as *one-piece flow* (Shingo, 1989).
3. The third design rule was to design manufacturing cells in such a way that the processing time is less than the *Necessary Cycle Time* (NCT). The Necessary Cycle Time, in turn, is slightly less than the Takt Time to provide a margin of safety.
4. The fourth design rule applied to the Inventory Control System and encouraged the “pull” system of functioning. This system was known within Toyota circles as *Kanban* (Black, 2007).

Toyota House of Quality

Toyota developed their House of Quality as a derivative of the Quality Function Deployment (QFD) developed by Mitsubishi in 1972. The foundation of the house was that the product must reflect the customer's requirements. This meant the marketing, engineering, and manufacturing teams needed to work together from the conception of the product (Hauser, 1988; Womack et al., 1990). As an example, the house helped Toyota to improve the rust prevention in their cars and improved their position from being the worst in the industry to the best. They relied on customer feedback to overcome their problems (Hauser, 1988).

Tools of Lean

The tools of Lean that will be reviewed are 5S, Value Stream Mapping, and Single Minute Exchange of Dies.

5S

While 5S is commonly referred to as only a "housekeeping" tool, it goes beyond that. It is a workplace environmental hygiene that originated in Japan (Douglas, 2002). It has also been defined as "an idea that reshapes the workplace and provides a foundation for all improvement" (Patten, 2006, p. 57). The five points originate from the following five Japanese terms, each starting with the letter, "S" (Imai, 1986; Ho, 1999; Douglas, 2002):

1. Seiri (Sort) – This activity involves the segregating and discarding of items no longer useful. It is important to differentiate between what is essential and what is not (Patten, 2006). Ho (1999) stresses the importance of a principle called "one-is-best," which applies to manufacturing, as well as to administrative workplaces. This includes one set of tools, one set of stationery, one location for storage of files, and so on.

2. Seiton (Set) – This activity involves the arranging and identification of all useful items. A well-known expression of seiton is "A place for everything and everything in its place" (Chapman, 2005). Just as it

is important to keep the workplace neat, it is also important to arrange things in a manner that best serves the purpose functionally (Patten, 2006).

3. Seiso (Shine) – This thought reflects the importance of keeping the workplace clean and neat. For best results, seiso adherents recommend implementing this culture of cleanliness into the daily routine (Imai, 1986). According to Ho (1999), “Everybody is a Janitor.” The culture in Japan, where the 5S originated, encourages people to clean up after themselves. A challenge in Seiso is to identify and to eliminate the root cause for the dirt, rather than to repeatedly clean (Patten, 2006).

4. Seiketsu (Standardize) – This activity involves introducing standards in every workstation. This includes supplies (such as brooms, buckets, mops, rags, etc) for cleaning at every station. Management must also allocate time at the end of every shift to complete the cleaning tasks (Chapman, 2005). A popular way to develop standards is by using the 5Ms, which is an idea borrowed from Kaoru Ishikawa’s fishbone diagram (Refer Appendix A6 also)(Patten, 2006). The five Ms are:

    I. Manpower
    II. Methods

III. Materials

IV. Machines

V. Measurements

7. Shitsuke (Sustain) – This activity involves disciplining the employees involved to maintain the achievements of the first 4Ss. There is a need for constant motivation and a focus on continuous improvement (Imai, 1986). The word, *Shitsuke*, originally comes from the textile industry and refers to the tacking (guiding stitches) used for the proper sewing of garments (Ho, 1999). The challenge in implementing 5S is to do something even though it is known to be difficult, rather than conduct periodic audits (Patten, 2006).

A sample 5S Audit Form is in found in Appendix C1. Table 2 gives the English translation of the 5S terms and shows some examples of their application.

Table 2. Translation of 5S terms

Japanese	English	Meaning	Example
Seiri	Sort	Organize	Clear out rubbish
Seiton	Set	Neatness	Easy to retrieve files
Seiso	Shine	Cleanliness	Everyone cleans
Seiketsu	Standardize	Clean up	Transparent storage
Shitsuke	Sustain	Discipline	Daily 5S

Value Stream Map (VSM)

A *value stream* is a series of activities, both value-added and non-value-added, designed to bring a product from raw material to the finished product (Renfroe, 2007; Womack, 2006). The term, *Value Stream Mapping (VSM)* was introduced in the Lean Enterprise Institute (LEI) workbook, *Learning to See in 1998.* Lian & Landaghem (2007, p. 3038) have defined *VSM* as “a mapping paradigm used to describe the configuration of value streams.” The VSM technique charts out a map showing how the product flows from start to finish. Such a chart serves these two purposes:

1. It illustrates the product’s manufacturing life cycle by identifying each step through the production process.

2. It is a tool that can help enlighten managers who refuse to believe their manufacturing techniques are "obese" and to show them the light of Lean Manufacturing (Lovelle, 2001).

Product Family

A company may have hundreds of different products manufactured. In cases like this, it is impractical to draw a VSM for each product. In these cases, the products are grouped into product families. A *product family* is a group of products passing through similar steps of manufacturing using similar equipment within the organization (Womack, 2006).

Once the product family has been identified, the VSM activity can start. It is important to conduct the VSM in a cross-functional team environment (Lovelle, 2001). A good team size consists of seven to ten people. A team of this size ensures that there are enough members to walk the shop floor and conduct interviews. It is not advisable to conduct a VSM with just one person, as there is not enough cross-functional dialogue, and results may be biased (Manos, 2006). Once the team has been created, a *Kaizen* (Japanese for "change for better") event begins, ideally for three days.

Kaizen Event

The course map for the three-day Kaizen event includes creating a current state map, a future state map, and a draft plan for the implementation (See Table 3).

Table 3. Three-Day Kaizen Event Agenda

Day 1	Day 2	Day 3
• Introduce concepts of VSM	• Draw the current state map	• Create the future state map
• Determine product families	• Perform Lean concepts training	• Develop a draft plan
• Walk the shop floor and gather information		

As illustrated in the industry magazine *Quality Progress* (Manos, 2006), simple symbols can be used to denote processes such as inventory and flow. A finished VSM map illustrates where obvious wastes exist. These wastes include movement of goods, overproduction, rework, or inventory. By studying the map, it is easy to locate and to address the problem of waste. A list of commonly used icons are shown in Appendix A3.

Current State Map

The current state depicts how the organization is functioning at present (Manos, 2006). The team creates the current state map by walking through the shop floor and collecting data from the operators. It is not advisable to create the map from the confines of the office. The main objective to drawing the current state is to determine if each process step satisfies these parameters:

- *Valuable*: The best way to determine the value of a step is to ask if the customer would feel less satisfied if the step was omitted

- *Capable*: This parameter analyzes the degree to which the process produces good quality every time.
- *Available*: The process must be capable of operating when the need arises and not suffering from downtime.
- *Adequate*: Does the process have enough capacity to handle the peak customer requirements?
- *Flexible*: The process must be capable of switching from one product line to the next at a low cost (Womack, 2006).

The overall goal of VSM is to move from a batch-wise production to a pull-based system where every process downstream has a requirement for the products manufactured upstream (Lovelle, 2001). A sample current state map is found in Appendix A4.

An important parameter in the creation of the current state is the takt time of a process. *Takt time* is defined as the number of units required by the customer in units of time (Womack, 2006). *Takt* is the German word for the baton used by the conductor of an orchestra to control the speed and timing. Takt time refers to how frequently a product needs to be manufactured in order to satisfy customer demand (Manos, 2006).

The formula for Takt Time is shown in Equation (1).

$$\text{Takt time} = \frac{\text{Time available (per shift)}}{\text{Customer demand (per shift)}} \quad \ldots(1)$$

Future State Map

Lovelle (2001) says that it is critical for a company to develop a future state map to provide a blueprint for the company to approach its ideal lean state. The future state indicates the changes required within a department to ensure a continuous flow and takt time. Establishing a continuous flow and a pull system ensures a dramatic reduction in throughput time and cost, and a significant improvement in quality (Womack, 2006). A sample future state map is found in Appendix A5.

Single-Minute Exchange of Dies (SMED)

Shigeo Shingo is considered the founder of Single-Minute Exchange of Dies (SMED). He has helped numerous companies understand the importance of SMED and is the reason behind Toyota's success with Lean Manufacturing practices (Shingo, 1983). In 1988, the Utah State University College of Business established the Shingo Prize to promote Lean Manufacturing awareness and to recognize companies who achieved world-class manufacturing practices (Richey, 1996). Some of the past recipients of the Shingo Award for Excellence in Manufacturing (shingoprize.org) include:

- Boeing - Integrated Defense Systems (Defense)
- Autoliv (Airbags)
- The HON Company (Office Furniture)
- Boston Scientific Corporation (Medical Devices)

- BAE Systems (Aerospace & Defense)
- Delphi Corporation (Mobile Electronics)
- Lockheed Corporation (Aerospace & Defense)
- Raytheon Missile Systems (Defense)
- Freudenberg - NOK (Elastomeric Seals & Molded Products)
- Johnson Controls (Automotive Supplier & Building Controls)
- O.C. Tanner Company (Employee Recognition Products)

Manufacturing companies, as well as researchers, often use Shingo's methodology for conducting SMED. One of the main reasons that companies are interested in implementing SMED is the growing trend of producing smaller batches with a larger variety of products (McIntosh et al., 2007). Shingo is an expert at identifying the difference between value added and non-value added processes. He describes as value added only as those processes converting or transforming a product towards the customer's needs and wants (The SMED System For Reducing Changeover Times, 1988).

While printers often argue that their industry does not deal with dies (Cooper et al., 2007), they would do well to consider a similar approach. Especially with today's hectic schedules and competitive environment, SMED has assumed a larger importance. According to Peter Witzig, the Product Manager for the Folding Carton Division of Bobst Group USA Inc., it is just as important to use the right kind of tooling as it is to distinguish internal from external activities (Witzig, 2006). SMED in the printing industry can include quick changeover of plates, inks, and rollers, and washing of cylinders.

The idea behind SMED is to reduce the two kinds of make-ready times required to set up the press between jobs:

1. *Internal Setup*, which can be performed when the machine is not running. This includes plate changing, blanket washing, and anilox roller cleaning.

2. *External Setup,* which refers to stations that can be setup while the machine is running. These include plate making, ink mixing, and offline cleaning (Shingo, 1985; Leschke, 1997).

SMED has been known to work very well, with most printing companies trying it reporting significant reductions in make-ready times. SMED can also be applied to the binding areas (Renfroe, 2007).

Stages of SMED

There are three important stages in the implementation of SMED in any industry:

1. Separating internal and external activities. This is the most important step in the implementation of SMED because it helps filter out the internal activities that actually need to be addressed. This step also helps the workers understand that time is wasted doing activities that can be done when the machine is running.

2. Converting internal to external setup. This involves a two-step process in which:

    a. The existing processes are analyzed to identify if any external processes are wrongly being considered as internal, and

    b. Internal processes are studied in an attempt to convert them to external processes.

3. Streamlining all aspects of the changeover. Finally, after the internal activities have been identified, it is important to streamline them to reduce the time the machine is not producing. For example, Toyota managed to reduce the time taken for setting up their bolt-maker from eight hours to fifty-eight seconds (Shingo, 1983),

Difficulty in Implementing Lean Manufacturing

In the J. Kenny article (2007), Tom Southworth of Southworth Consulting pointed out that label printers have embraced Lean Manufacturing easier than have other types of printers because of their large order sizes, quick turnarounds, and frequent die changes. He says that most companies only “dabble with” the concept of Lean management. Southworth refers to these people as Citizens Against Virtually Everything (CAVEs).

Some of the reasons attributed to failure of Lean techniques include:

1. Lean can only be successful after a company has addressed both the organizational, as well as the technical, aspects of quality management.
2. Individuals fail to see the increased opportunities for participation and autonomy, and end up feeling insecure.
3. The management often feels the employees should be disclosed information only on a “need to know basis” (Lathin & Mitchell, 2001).
4. Companies are inclined to implement only selective aspects of the TPS. To be successful, a company needs to put the entire system in place.
5. A company must be willing to stop what they are doing, analyze what is not working, and accept that it is not working.
6. Employees need to feel encouraged and motivated when they contribute.
7. Managers have to be completely involved in the process of implementation, training, motivation, and engaging the employees (Hassler, 2008).

Implementing Lean within Printing Companies

The following are some companies who have undertaken Lean programs in their company with success.

Luminer Converting, Lakewood, NJ

Luminer Converting is a part of the Luminer group and is an ISO-9001 certified printing and converting company specializing in high-quality labels and promotional materials.

According to President Tom Spina (2007) this business had too much inventory and too much cash outlay, and not enough money was being spent on other things. The company attacked the inventory problem aggressively and within four weeks, they removed four 30-foot dumpsters of waste materials. This exercise opened up 2,000 square feet of floor space that eventually ended up housing the packaging area. A bar code system was introduced to track the inventory, so now every item can be traced on a computer.

The result of these exercises was large cash savings to the company. It now pays its suppliers within 10 days; hence, they are eligible for discounts. In a matter of 18 months, the inventory was reduced from $400,000 to less than $200,000, which has allowed the company to grow 20%.

The company then focused on the press shop floor and removed everybody's toolboxes. All tools were mounted on a wooden board and labeled. (Kenny, 2007). Table 4 shows the company's activities and benefits.

Table 4. Summary of Luminer Converting

• Company identified the problem of excess inventory causing excess cash to be locked up
• Company performed Kaizen events and within four weeks opened up 2000 square feet of space that now houses the packaging area
• Bar code system introduced to track inventory
• Within 18 months, inventory reduced from $400,000 to $200,000
• Company has grown at 20%
• Removed individual toolboxes and created shadow boards for tools

Associates Graphics Services (AGS) Wilmington, DE

The 50,000 square foot plant of this commercial printer has been designed to provide maximum flow and to streamline the flow of materials through the plant. According to the Production Manager Bryan Taylor (2006), the facility was designed to streamline the flow of jobs through it. Each press has a cutter and a folder within a few steps, providing a direct flow of the work.

AGS designed a dual workflow system that helps monitor the work-in-process materials. This system has increased productivity by more than 30%. The company also gathers data regarding three important factors, including press uptime, on-time percentages for jobs and estimates, and on-time percentages for proofs.

As shown in Table 5, by practicing Lean, AGS has not only eliminated wastes, but also improved the company's quality, productivity, and sales (O'Brien, 2006).

Table 5. Summary of Associates Graphics Services

• Factory designed to streamline flow and remove bottlenecks • Company has created smaller manufacturing cells • Dual workflow system that helps monitor work in process has increased productivity by 30%

Tailored Label Products, Menomonee Falls, WI

Tailored Label Products started out their Lean program by creating a VSM to accelerate order entry and to streamline the front-end processes. The company spent five months analyzing wastes and identifying potential bottlenecks. They measured the distance that a person needed to walk from one workstation to another, the position of equipment, and the inventory. They also computerized many manual processes. They also categorized their job orders into groups so they would have a clearly defined method for each product.

The company grew 20% in the first year of practicing the Lean system. An order typically taking close to 40 hours to process -- from the time the order was placed to the time it was loaded onto the press -- now took only 3 to 4 hours. According to the President of Tailored Label Products, Mike Erwin, VSM helped

the company tremendously. Table 6 illustrates the company's activities and benefits.

The company had an old press that required extensive time for make-ready and cleaning. Using VSM, they charted out the different wastes, such as color-to-color wastes, idle time, and lost time between shifts. This helped them reduce setup times by half (Kenny, 2007).

Table 6. Summary of Tailored Label Products

- Company started lean journey with VSM
- Company spent five months analyzing wastes
- Time for job to go from order entry to press reduced from 40 hours to 3 hours
- Reduced setup times on old press by 50%
- Company has grown 20% in the first year of practicing lean

A1 Paper Stationery

The group Managing Director, Tom Jones, kick started the Lean Manufacturing program in 2005 with a two-day program. In the following year, the company conducted two five-day programs. The main goals of these workshops were to increase solid hours and to improve machine efficiencies.

The programs had the complete involvement of the production staff. Six people participated in every program, and the remaining people were briefed on

the events with presentations. One project was to reduce the make-ready of a press using video. A Gantt chart containing about 150 operations was drawn, and the manufacturing staff analyzed the diagrams. As a result of this exercise, the make-ready time was reduced by 40%.

Jones feels that, as a result of these workshops, better engineering and maintenance programs have been initiated, and the company has “learned a lot of things that were not directly related to the program” (Ross, 2006). Table 7 illustrates the company’s activities and benefits.

Table 7. Summary of A1 Stationery Products

- Company started on lean to improve machine efficiencies
- Team of six people involved; all others constantly briefed on progress
- Video of press changeover was captured
- Gantt chart created analyzing 150 different activities performed
- Make-ready time reduced by 40%

Summary of Setup Reduction Performed in Printing Companies

Various printing companies have tried to adopt Lean Manufacturing, but a select few have been more successful than others in implementing quick changeovers.

Graphic Arts Division, Fountain Inn, SC

Graphic Arts Division is the label manufacturing division of Sherwin-Williams, the largest paint manufacturer in the United States, based in of Cleveland, OH. The paint company was having considerable inventories of Work-in-Process jobs because the label division was facing delays in production. The problem did not lie with a lack of capacity at the printing division; rather it was a combination of press-idle time between runs and sub-optimal scheduling. Management decided to implement a three-pronged "get well" program that involved quicker changeovers, a PC-based system for production planning, and an inventory planning improvement project.

The quick changeover project realized that the most immediate improvements. When the problem was analyzed, the team realized that 68% of production time was spent performing setups. The team videotaped changeovers and separated internal activities from the external ones. They realized that the largest delays occurred in performing the small adjustments required to run the job, such as ink and paper adjustments. The company solved this with the help of "mag cards" that recorded pre-press data for feeding into the press. This way, the

press would be up to 90% close to ready, with only minor adjustments needed. The company managed to reduce the average daily setup times from 3.5 hours to 45 minutes -- a 55% reduction. This reduction also resulted in a 250% increase in effective capacity. Table 8 illustrates the company's activities and benefits.

Table 8. Summary of Graphic Arts Division

- Largest paint manufacturer in the United States
- Paint division facing work-in-process issues because of production problems in the label manufacturing division
- Problems identified as press idle time between runs and sub-optimal scheduling
- Solutions identified as quicker changeovers, a PC based system for production planning, and an inventory planning improvement project.
- 68% of production time spent performing setup
- Majority of time spent making "small adjustments"
- Company used "mag cards" to load preset data into the press. Press could be up to 90% ready with this data.
- Setup time reduced from 3.5 hours to 45 minutes: 55% reduction
- 250% increase in capacity

Kappa Kraftliner AB, Sweden

The employees at this Swedish paper mill used to take between 6 to 8 hours to change a paper roll on the paper machine. A SMED event was conducted. Results of the event showed that waiting, which was viewed as a part of the process, caused many of the delays. Measures taken as a result of the analysis included checklists (which provided clear instructions to the operators) better arrangement of work tools, and minor modifications to the paper machine. As a result, the time taken to change the roll was reduced to 3 to 3.5 hours. The aim is to reduce it to less than 2 hours (Lundberg, 2002). Table 9 illustrates the company's activities and benefits.

Table 9. Summary of Kappa Kraftliner

- Average time to change paper roll was 6 to 8 hours
- SMED event conducted and checklists were implemented with clear instructions
- Better arrangement of tools
- Minor modifications to the paper machine
- Time reduced to 3 to 3.5 hours
- Company aims to further reduce it to less than 2 hours.

Summary of Setup Reduction Performed by Print Equipment Manufacturers

Print equipment manufacturers have found the need to perform SMED in the manufacturing of their products, as well as in the engineering of their products. The purpose of performing SMED is to be quick changeover-friendly so that customers can reap the maximum benefits from purchasing their equipment.

Paper Converting Machine Corporation, USA

Paper Converting Machine Corporation (PCMC) introduced software known as, PrintReady, in their 1m wide, eight- color VisionG Flexographic printing press. This software helps the press achieve a safe, tool-free changeover in less than 60 minutes. The press is designed to eliminate waste and to provide energy efficiency. It is a gearless, low- maintenance design, offering a compact footprint, and is CE certified. The press is able to remember impression cylinder settings and sets them automatically, thereby saving up to EUR100,000 annually (Less Than One Hour, 2008). Table 10 illustrates the company's activities and benefits.

Table 10. Summary of PCMC

• New software called PrintReady that can help achieve quick changeover in less than 60 minutes • Press designed to eliminate waste and increase energy efficiency • Press remembers impression cylinder settings and sets automatically • Annual savings: EUR 100,000

MAN Roland, USA

The Roland 700 press from MAN Roland comes equipped with QuickChange options, which help reduce changeover time, thereby resulting in a 30% increase in capacity. The QuickChange feature enables job changeovers to be pre-selected at the central console and to be performed automatically. As shown in Table 11, its features include:

1. Ink pre-settings that ensure faster settings for subsequent jobs
2. Automatic transfer gripper and infeed drum adjustments for substrates of different thicknesses
3. A setting for printers that need to often change from flood coating to spot coating (More Capacity with Quick Change, 2006)

Table 11. Summary of MAN Roland

• Roland 700 comes equipped with QuickChange option
• Preselect job changeovers to be performed automatically
• Ink presetting for faster settings
• Automatic gripper and drum adjustments
• Quick change from flood coating to spot coating
• 30% increase in capacity

Valmet Rotomec, Italy

With the CI 401 ES, Valmet Rotomec introduced a central impression flexo press, offering an eight-color full-color changeover in just 15 minutes. It is a driveless press that also features electronic shaft, online sleeve changing, and automatic wash down systems, in addition to an automatic register control. The press has also been fitted with a heavy duty dryer to improve drying performance by 50% over other flexo presses (Valmet Introduces Rapid Change Over Flexo Press, 2001). Table 12 illustrates the company's activities and benefits.

Table 12. Summary of Valmet Rotomec

• New Central Impression (CI) eight color flexo press • Changeover possible in 15 minutes • Driveless press with electronic shaft, online sleeve changing, and automatic washdown system • Heavy duty dryer to improve drying performance by 50%

Summary of Setup Reduction Performed by Non-Printing Equipment Manufacturers

Lean Manufacturing concepts, including quick changeovers and SMED have been gaining popularity in the manufacturing industries. A few non-printing manufacturing companies where SMED principles have been successfully implemented are reviewed here.

<u>Manufacturer of Precision Engineered Tubing; North Branch, NJ</u>

The facility features high-precision forming/welding that transforms flat-coiled material into tubes. The company identified the need to reduce length mill changeover times. All changeovers require modifying at least something on the mill, while some changeovers require changing everything. A SMED team was formed, consisting of machine operators and assistants, mechanics, engineers,

and managers concerned with the mill. Care was taken to include representatives from every shift.

The first initiative was to isolate the “external” activities -- those that could be performed prior to the machine stopping for the changeover. The team agreed on preparing a SMED cart that would house all the tools required for the changeover, so that the operators would not have to waste time on motion and looking for tools. An order was created in which the activities must be performed. The team discovered many of the activities could be performed in “parallel” (i.e., independent of another activity).

The changeover, which had previously taken 30 hours, was completed in 3.5 hours. Although additional people were used for the changeover, they were not required for the entire changeover. In all, the four people completed the task in 1.5 hours. The savings was 18.5 hours (Chaneski, 2008). Table 13 illustrates the company’s activities and benefits.

Table 13. Summary of Precision Tubing Manufacturer

- Need to reduce length mill changeover times
- Cross functional SMED team formed; included representation from all three shifts
- External activities identified and isolated
- SMED cart created housing all the tools used for changeover
- Parallel activities identified
- Additional people employed for new changeover
- Changeover time reduced from 30 hours to 3.5 hours
- Close to 90% reduction in changeover time

Ingersoll Cutting Tool Co. (ICTC); Rockford, IL

The company makes a wide range of indexable cutting tools and inserts. With over 5000 different inserts manufactured on 15 different machines, there were potentially over 75,000 different changeovers possible. Analyzing each of these changeovers was virtually impossible. Instead, the products were grouped into 60 product families.

The external consultants who were working with the company realized that, in addition to reducing setup time, the company also needed to produce in smaller lot sizes in order to receive the full impact of quick changeovers. Their recommendation was to reduce the lot sizes from 10,000 to 500. Management was given a proposal that asked for an investment of $20,000 to reduce setup

times by 50%. The reduction in setup times also meant a reduction in overtime costs to the tune of $280,000 annually. The reduction in lot sizes also meant a 75% reduction in lead times and work-in-process. This improved the company's responsiveness to their customers, as well as their market share (Rehman & Diehl, 1993). Table 14 illustrates the company's activities and benefits.

Table 14. Summary of Ingersoll Cutting Inc.

- Products grouped into 60 families
- Needed to reduce lot size to feel full impact of reduced changeovers
- Reduced lot size from 10,000 to 500
- Investment of $20,000 to reduce setup time by 50%
- Annual savings of $280,000
- 75% reduction in lead times and work-in-process
- Improved response to customer demands

Chapter 3

Hypothesis Statements

The hypothesis statements were framed with the intention of verifying if SMED does in fact help improve the PCE of a process.

Null Hypothesis H_o: Using SMED as a tool of lean does not help improve the Process Cycle Efficiency (PCE) of changeovers on a web offset press above 15%

$$PCE \leq 15$$

Alternate Hypothesis H_A: Using SMED as a tool of lean helps improve the Process Cycle Efficiency (PCE) of changeovers on a web offset press above 15%

$$PCE > 15$$

The statistical testing of the null hypothesis will be done using the t-test at a 5% significance level.

Chapter 4

Methodology

The method of study employed was called Action Research. This involved direct interaction with employees of the organization and required the researcher to be actively involved in the implementation of projects.

Video Recording the Insert Changes

The filming of the insert changes was done using a Sony Handycam Video Recorder. The researcher chose a position by the press that provided the best coverage and the least amount of interference of all the activities that were performed. The researcher's intention was to be as inconspicuous as possible, so as to prevent any interruption in the operator's functions and to avoid the operators feeling conscious of being filmed. A total of seven insert changes were filmed:

- three on the first shift,
- two on the second shift, and
- two on the third shift.

Care was taken in labeling the discs to avoid any confusion. The activities filmed on Side A were mentioned on the front label, and the same was done for side B. Notes, including the exact time that the insert change started and the time that it finished, the job number, the number of helpers, and any activity that was not caught on camera, were recorded in a separate book.

The recording began as soon as the press was stopped for a job and continued until a sellable item to the customer was produced on the next job. With the researcher’s intention of bringing the breaks to the attention of the crew, the camera continued to record when an operator went on break during the insert change process.

Creating an Excel Spreadsheet

After each insert change was filmed, the researcher reviewed the video recording and charted the times for each activity. A time study chart was created in Microsoft Excel XP, listing the time taken for each action and classifying activities into value-added, non-value added, and non-value added but necessary.

Value-added activities were defined as those activities the customer would agree to be charged for. For example, the customer would agree to be charged for the time taken to remove the old plate and insert the new plate, but not the time taken to undo and reattach bolts, to look for tools and so on.

The non-value added activities were defined as those not necessary to the insert change process (e.g. searching for tools, walking distances to acquire tools or materials, etc).

The non-value added but necessary activities involve those activities that the customer would not be willing to pay for, but are needed in order to perform the insert change. In the example cited above, the act of undoing and re-attaching the bolts during a plate change is non-value added but necessary in order to complete the plate change.

A SMED analysis would help to identify ways to eliminate the non-value added activities, and to identify ways to reduce the time spent on non-value added but necessary activities. In turn, these changes would increase the value-added portion of the entire insert change time and increase the Process Cycle Efficiency (PCE) that was the parameter of success.

Calculating the Process Cycle Efficiency

The parameter used to calculate the success of the SMED program was Process Cycle Efficiency (PCE). The PCE is a ratio that indicates the percentage of time spent performing value-added activities. Equation (2) shows the formula for calculating the PCE.

$$\text{PCE\%} = \frac{\text{Value added time}}{\text{Total lead time}} \times 100 \quad \ldots(2)$$

The objective was to calculate the PCE of the insert changes before the SMED event and compare them with the PCE values from after the SMED event to gauge the success of the event.

Calculating the Possible Annual Savings

By identifying the potential areas for time reduction, the researcher was able to calculate the possible savings to the company as a result of implementing SMED. The company uses a Management Information System called Globetek in which the operators are required to record their respective activities on a keypad and track the time spent on that activity. Based on the reports from the previous two years (2006-07 and 2007-08) the researcher was able to calculate the total number of hours spent on insert changes during the entire year. Based on the machine hourly rate and the estimated reduction in insert change time, the savings were calculated.

The insert changes prior to conducting SMED were termed as “baseline” insert changes since they were used as the basis for conducting SMED.

Creating a 5S Team

A 5S event was planned as the first step to improving employee involvement. The purpose of the 5S event was to encourage team building and to make the workplace more visual and more efficient. A non-offset person was

included in the team to provide a fresh perspective. This person also served as the note-taker and facilitator of the group. The final team was composed of these seven members:

- Operators from the first and second shifts – 2
- Assistant operator from the third shift – 1
- Manager from the shipping department – 1
- Leads from the second and third shifts – 2
- Process engineer intern (the researcher) – 1

Conducting a 5S Event

By conducting a 5S event, the researcher attempted to ensure proper accessibility of tools and to improve employee morale. Although the event was called a 5S event, in reality, the activities were only done targeting these first 3Ss (i.e., Simplify, Standardize, and Shine). The fourth and fifth Ss (i.e., Standardize and Sustain) could be possible only after the first 3Ss had been maintained for three to four weeks at least.

The event was conducted over two working days during the first shift; it required the press to be inoperable for the entire eight-hour shift.

Day 1 Sequence of Events

2. A two-hour orientation and training on 5S and workplace visual management took place.

3. A one-hour "Gemba" (Japanese for shop floor/workplace) walk involved the team walking together through the workplace and taking pictures of areas that required improvement.

4. The team returned to the meeting room and analyzed the pictures. The team brainstormed to find solutions to the problems that were caught on camera.

5. Sub-teams of two were created within the group, and different tasks were assigned to different groups. The sub-teams identified the time it would take to complete each of the sub-tasks within the eight hours that the press was scheduled to be down.

6. Once the pictures were analyzed and tasks assigned, the team filled out a "Pre-5S event audit sheet." This audit sheet was the form that had been used by the company in previous years; it had been compiled from a variety of lean manufacturing books and websites. As mentioned earlier, the activities targeted were only the first 3Ss; therefore, the pre-audit sheet only covered the first 3Ss.

7. The 5S team discussed each of the items on the audit sheet and decided on scores as a team. A score of 5 for an item meant the item had no violations, and a score of 0 meant the most violations. The maximum score possible was 90.

8. The goal was set to double the initial audit score.

9. A wooden pallet was placed on the floor; any item that was not nailed down onto the press was removed from its place and placed on the pallet.

10. The team took back only items that they had identified a permanent place for. This exercise eliminated multiples of an item; in addition, it cleared space.

11. Team 1 was assigned with the physical cleaning of the press and the walls. Team 2 was assigned with labeling all the items that were on and off the press. Team 3 was assigned the task of finding a permanent spot for everything and to clearly demarcate the spot with marking tape/paint; this included creating a shadow board of the tools used during the insert change and the clear labeling of tools (see Appendix C4).

<u>Day 2 Sequence of Events</u>

1. Teams continued with their tasks from the previous day.
2. Four hours into the second day, the 5S event was concluded.

3. The teams did another walk of the Gemba and took pictures of the improved workspace.
4. The teams gathered again in the meeting room and analyzed the new pictures and discussed the improvements.
5. Tasks that could not be completed were re-visited and a 30-60-90 day plan was created depending on the time needed to complete the unfinished tasks
6. The teams discussed for an hour and drew out a housekeeping checklist that would be used to maintain the workspace. Weekly audits would evaluate the condition of the workspace
7. A team picture was taken with all the individuals who participated, and a poster was created. This poster (refer Appendix B1) had a picture of the team, the before- and after-pictures from the 5S event, notes highlighting the achievement of the teams, and the two audit forms. This poster was placed at the side of the press.

Once the 5S event was concluded, a different team was put together to form a SMED team. The reasoning behind choosing a different team was to get as many people involved as possible.

Creating a SMED Team

The researcher created a SMED team with help from the Manager for Continuous Improvement and the Manager of the Offset Department. The individuals were selected based on their level of enthusiasm and dedication, as well as their ability to influence the decision-making of others around them. A non-offset person was included in the team, as well, to provide a fresh perspective. This person also served as the note-taker and facilitator of the group. The SMED final team was composed of eight members:

- One operator from the first, second, and third shifts - 3
- Leads from the first shift - 1
- Operator from the Pre-press Department – 1
- Offset Department Manager – 1
- In-house Senior Process Engineer - 1
- Process engineer intern (the researcher) –1

In addition, the team was assigned a mentor who was the "lean champion" of the organization. Although the mentor was not involved in each individual project, he would provide the basic training and would be consulted and updated on the progress of the individual projects.

A five-week schedule was created; it included weekly two-hour meetings to discuss the changes and to chart the course for the following week.

Week 1: Initial Training and Orientation

At the SMED meeting on Week 1, the team was trained on the basics of lean manufacturing, 5S, and SMED by the team mentor. The training lasted two hours and included a Power Point presentation that included visuals from other organizations that had successfully implemented 5S and SMED programs. The in-house Senior Process Engineer conducted the training. The team was encouraged to voice their opinions and suggestions, as well as to relate the problems they faced during insert changes. The session's goal was to be as interactive as possible and to encourage participation of all team members.

Week 2: Analyze Insert Change and Separate Results into Internal, External, and Parallel

The team gathered to review the videos of the insert changes that had been filmed. The activities were classified as:

- Internal - activities that could be performed only when the press was not running;
- External - activities that could be performed while the press was running; and,
- Parallel - activities that could be performed in tandem by two operators when the press is down, thereby reducing the time for internal activities.

In the meeting room, there was a white board that was divided into three sections: Internal, External, and Parallel. As the team watched the video, each

activity was classified into one of the three categories and written in its respective column. The times associated with each activity were also noted.

The team then performed the same exercise for each of the different insert changes filmed. There were four charts created in all, showing all of the different activities. This was done to see if there was a pattern in the way the insert changes were performed.

<u>Week 3: Streamlining Activities</u>

The following week, the team re-grouped to analyze the information from the previous week. The target was to reduce the insert change time by as much as possible. This involved these three steps:

1. Separating internal from external activities;
2. Converting internal to external setup; and,
3. Streamlining internal setup activities.

Of these three activities, the first activity had been performed during the Week 1 meeting. The team shifted their focus to identifying the internal activities that could be converted to external activities. This would mean more of the insert change activities were being performed when the press was still operational, thereby reducing the downtime.

Once all possible internal activities had been converted to external setups, the team focused on developing methods to streamline the internal activities to

maximize efficiency. The team was shown videos of NASCAR pit crew changeovers and the method of assigning a specific set of tasks to each individual.

Based on their analysis, a new set of insert change sequences was framed in which each operator would have a specific role and would perform his activities in a particular sequence.

Certain engineering modifications were recommended, as well, to optimize the insert change. These included changes to bolts and equipment used during the insert changes.

Week 4: Perform Insert Change with Discussed Changes

During Week 4, the changes discussed in the previous week's meeting were attempted during the insert changes. The researcher continued to film the insert changes and created Excel sheets based on the times in the videos.

The operators discussed their experiences with the new methods, as well as the advantages and disadvantages as they saw them. Modifications to the new insert change methods were discussed and agreed upon.

Week 5: Standardize New Insert Change Procedure

By Week 5, once the operators were convinced that the methods used for the insert change were optimal and convenient, the procedure was formalized in a document and labeled as the new standard for insert changes. The procedure

was depicted visually on a chart with the help of flowcharts and pictures, and was displayed by the press side to make it visible to all the operators on the three shifts. Figure 1 shows a summary of the SMED process.

Figure 1. Summary of SMED process

Chapter 6

Results and Discussions

The results of the research study concluded that the average time to perform an insert change was reduced from 137 minutes to 54 minutes. This was a 60% reduction in setup time. The average Process Cycle Efficiency (PCE) also increased from 6.3% to 15.3%. This was a 60% increase in PCE. In terms of money saved, the annual savings were estimated at approximately $80,000.

These results were consequent to the 5S event that was successfully conducted. This event helped raise awareness about housekeeping and order.

Building the Trust of Press Operators

Obtaining buy-in from the press operators was the most challenging aspect of implementing a quick changeover method or Single-Minute-Exchange of-Die (SMED). Although it was true that the press operators provided the best ideas for reducing insert change times, they were also the employees who provided the greatest resistance. The reasoning behind their thinking was that:

- They had been running the press for over twenty years, so why take orders from an intern?

- They believed that the method they were using was the optimal one for the process; if there were a better method, they would have thought of it themselves.

The researcher slowly and methodically obtained the trust of the operators over a six-week timeframe. This time was spent working side-by-side with the operators, often having personal and professional conversations. This helped the researcher understand the problems faced by the operators with regard to the equipment and material. By understanding the real problems faced by the operators, the researcher was able to distinguish the real problems from excuses during the actual SMED events conducted in the subsequent weeks.

The foremost question on the employee's mind was "What's in it for me?" Unless the operators perceived there to be a personal gain by implementing a change in process, they were not ready to cooperate. The researcher compiled this list of changes (as shown in Figure 5) that would directly benefit the operators:

- Less bodily strain - Excess movement was reduced or eliminated.
- Less frustration - Time spent looking for tools was reduced or eliminated.
- Greater profit sharing - Faster insert change meant that the press could run good material for a longer period of time. This also meant that the company would make more money at the end of the year. Since the

company had a profit sharing policy with its employees, quicker insert changes directly translated to larger shares in profit for the operators.

- Increased job security - Conversations between the researcher and the operators regarding the state of the economy and how other printing companies were going out of business eventually led to the conclusion that the company must provide competitive estimates. Quicker insert changes would result in more competitive estimates ensuring continued business and employment of operators.

At the end of six weeks, the researcher was able to obtain permission from the operators to record the insert change process using a video camera.

Results of 5S event

The 5S event that was conducted over two days improved the housekeeping at the area of focus – the Stevens web offset press. The pre-5S event audit sheet had a score of 29/80, which was a 36% rating (see Appendix C1). The scoring was done based on the number of violations for each category. The scores were from a high of 5 (0 violations) to 1 (5 or more violations). If a category was not applicable to an area the N/A (Not Applicable) option was checked on the audit sheet.

The main areas that required attention were the excess items around the press that were dispensable. A number of items were disposed of and significant

working space was achieved as a result. The press was physically cleaned and long-standing oil, ink, and grease stains were removed using strong chemicals. The Maintenance and Repairs (M&R) department crew worked with the 5S team to fix oil and air leaks on the press. This would reduce the oil that accumulated under the press. Light fixtures above the press were cleaned to remove the ink mist that had accumulated. This would provide better illumination and a truer representation of the colors that were being printed. Light bulbs that did not meet the required specifications for luminance were also replaced with new ones.

Labels that contained information pertaining to production standards, manufacturing practices, quality control initiatives, and safety hazards by the press side were updated and replaced with laminated sheets that would last longer. A shadow board was created to accommodate all the tools that were used on an everyday basis. The shadow board had the outline of every tool and was labeled so it was easy to identify the spot for a tool. The shadow board helped eliminate time spent searching for tools during changeovers and ultimately helped reduce the changeover times.

The audit done after the 5S event yielded a score of 63/80 that was a 79% rating (see Appendix C2). This exceeded the target of 58/80, which would have been double the initial score. After the 5S audit was done, the team brainstormed and came up with a weekly housekeeping checklist that would help sustain the

efforts of the 5S event. The checklist focused on visual, operational, as well as safety concerns (see Appendix C3).

Before SMED Initiative

When the researcher analyzed the videos of the changeovers prior to any SMED improvements – the baseline changeover – the potential areas for improvements were identified. These were brought up during the SMED meeting with the SMED team. The biggest reduction in time involved the operators not taking any breaks during the changeover. Though the operators had been already instructed to follow this rule, it was not being implemented. Including the lead in the changeovers solved this problem. The addition of the lead served the dual function of monitoring the operator breaks as well as serving as additional manpower that would help reduce times. On average, the operators not taking breaks during the changeovers saved 30 minutes.

The researcher also noticed the lack of standardized work when it came to performing the changeover. Lean manufacturing recommends following standardized work, which means performing the same sequence of activities every time. This would eliminate variations. In some cases, the operators would remove ink from the printing units, wash the units, and ink them up before the insert change started. At other times, these activities would be done during the insert change in the time between changing the inserts and the roller stripe settings. The SMED meeting helped establish a standard procedure of washing

and inking up the units before the insert change began in order to reduce the time associated with the actual insert change. As mentioned in the initial problem statement, the company was trying to reduce the time associated with the insert change time, which would directly decrease the overhead costs.

The insert change was being performed with only two operators. This was another reason for the increased times. The two operators would physically remove each insert, move it to the end of the press where the other inserts were stored, get the new insert, and then bring it back to the press each time. The researcher requested the operators to wear pedometers to measure the distance walked by the operators. Each operator took approximately 1750 steps (Refer Appendix C6).

The times associated with the changeovers that were done before the improvements are listed in Table 14.

Table 14. Changeover times before SMED event

Shift	Total Time (minutes)	Value added time (minutes)	PCE%
3	164	10	6.1
3	159	9	5.7
1	123	9	7.3
2	135	8	5.9
2	133	7	5.3
1	110	8	7.3
2	157	8	5.1
1	125	7	5.6
3	139	8	5.8
3	180	9	5.0
2	144	9	6.3
2	126	7	5.6
1	132	8	6.1
2	149	9	6.0
3	163	10	6.1
2	120	7	5.8
1	98	8	8.2
2	138	9	6.5
2	119	8	6.7
3	154	9	5.8
1	99	9	9.1
3	141	7	5.0
2	128	8	6.3
3	163	9	5.5
1	108	9	8.3
2	121	7	5.8
3	153	8	5.2
3	171	9	5.3
2	143	9	6.3
1	116	10	8.6
2	126	8	6.3
1	138	9	6.5

Mean	137	8	6.3
Std Dev	20	1	1.1
Range	82	3	4.1

Shift	**1**	**2**	**3**
Mean	117	134	159
Std. Dev	14	12	13
PCE%	7.4	6.0	5.5

When the averages for total time taken and the PCE were compared shift-wise, it was evident the first shift had better times than the second shift with the third shift having the slowest times. The main reason for this was the difference in experience between the operators working on different shifts. The first shift had the operators with more than twenty years of experience, the second shift had operators with ten years experience, and the third shift operators had less than five years. Three of the operators on the third shift had less than a year's worth of experience. The communication between the operators on a shift was directly related to the experience they had working together. The videos showed the helpers on the second and third shift often waiting for instructions from the main operators. At other times, the helpers would be performing activities during the insert change time that were not a part of the insert change. This was the reason the SMED team decided to standardize the operation and to clearly define the role of each person during a changeover.

The table also displays the calculation of the Process Cycle Efficiency, which is the parameter of success used for this research article. The PCE was calculated using the formula shown in Equation (2). The average time taken for an insert change was 137 minutes. The value added portion of this was an average of 8 minutes and this resulted in an average PCE of 6.3%. This meant that only 6.3% of the time spent during a changeover was for a value-added activity. In other words, the customer would agree to pay for 6.3% of the activities and time spent doing the changeover. Although the insert change activity was

treated as an overhead, meaning no customer was directly charged for it, the efficiency of a process is defined in terms of its value-added component.

After SMED Initiative

The changeovers were done with the discussed standardized operations. At the end of a job, the units were washed and the inks were changed before commencing the insert change operations. There were four people used for the changeover – Operators A, B, C, and D. As soon as the press stopped at the end of a job, operators A and B would start washing up the units. Operators C and D were given the responsibility of moving the auxiliary equipment, like the benches that stored chemicals, out of the way so the inserts could be brought close to the press. Once the units were washed up and inked up, operators A and B were responsible for removing the top bolts on the inserts that attached them to the press. With the improvements, pneumatic impact wrenches were used to undo the top bolts instead of the manual T-wrenches (see Appendix C5). The time was reduced from over a minute to less than 10 seconds for each unit. In all the savings was close to six minutes. The operators also worked as a team in undoing the lower bolts. By working in parallel, the time to remove the bolts was reduced from 6 minutes to 2 minutes.

Once the bolts were undone, the actual process of changing the inserts started. Operators A and B removed the inserts from the press and passed them on to a waiting Operator C. The third operator was responsible for bringing the

new inserts by the press side from where they were stored (approximately 50 feet away at the end of the press) while Operators A and B were engaged in actually removing the inserts off the press. This means operators A and B did not need to waste time moving the inserts to the storage point and back. The number of steps taken by each operator performing the change of inserts was reduced to 200 (see Appendix C7). Operator D started to re-attach the upper and lower bolts on the units that had been changed. This saved approximately 10 to 12 minutes compared to the earlier practice where the bolts would be re-attached only after all the inserts had been changed.

Finally, the roller stripe setting, the process of adjusting the pressure of water and ink form rollers on the plate, was done as a parallel activity. The activity used to take 45 minutes on an average when one operator set the stripes. When two operators did the activity in parallel, the average was reduced to 17 minutes – an average saving of 30 minutes.

Table 15 shows the insert change times with the improvements in place. The standardization of work helped reduce the difference in time and the PCE between the shifts considerably. The first shift still performed better than the other two and this was seen as natural considering the vast difference in experience.

Table 15. Improved Changeover times after SMED event

Shift	Total Time (minutes)	Value added time (minutes)	PCE%
1	48	9	18.8
2	53	7	13.2
2	50	7	14.0
3	57	8	14.0
1	46	8	17.4
1	52	8	15.4
2	48	7	14.6
2	55	8	14.5
3	63	9	14.3
3	58	8	13.8
2	59	8	13.6
1	49	9	18.4
2	56	8	14.3
3	71	10	14.1
1	44	8	18.2
3	52	9	17.3
3	63	8	12.7
2	44	8	18.2
1	48	7	14.6
2	52	9	17.3
3	58	9	15.5
1	47	8	17.0
3	50	9	18.0
2	52	8	15.4
3	57	8	14.0
1	49	8	16.3
2	56	7	12.5
2	49	7	14.3
3	55	8	14.5
3	62	9	14.5
2	58	8	13.8
3	60	9	15.0

Mean	54	8	15.3
Std Dev	6	1	1.8
Range	27	3	5.9

Shift	**1**	**2**	**3**
Mean	48	53	59
Std. Dev	2	4	6
PCE%	17.0	14.6	14.8
95% Confidence Interval	15.6-18.4	12.3-16.9	11.4-18.2

The average time to perform the changeover reduced from 137 minutes to 54 minutes (see Fig. 2) and the average PCE increased from 6.3% to 15.3% (see Fig. 3).

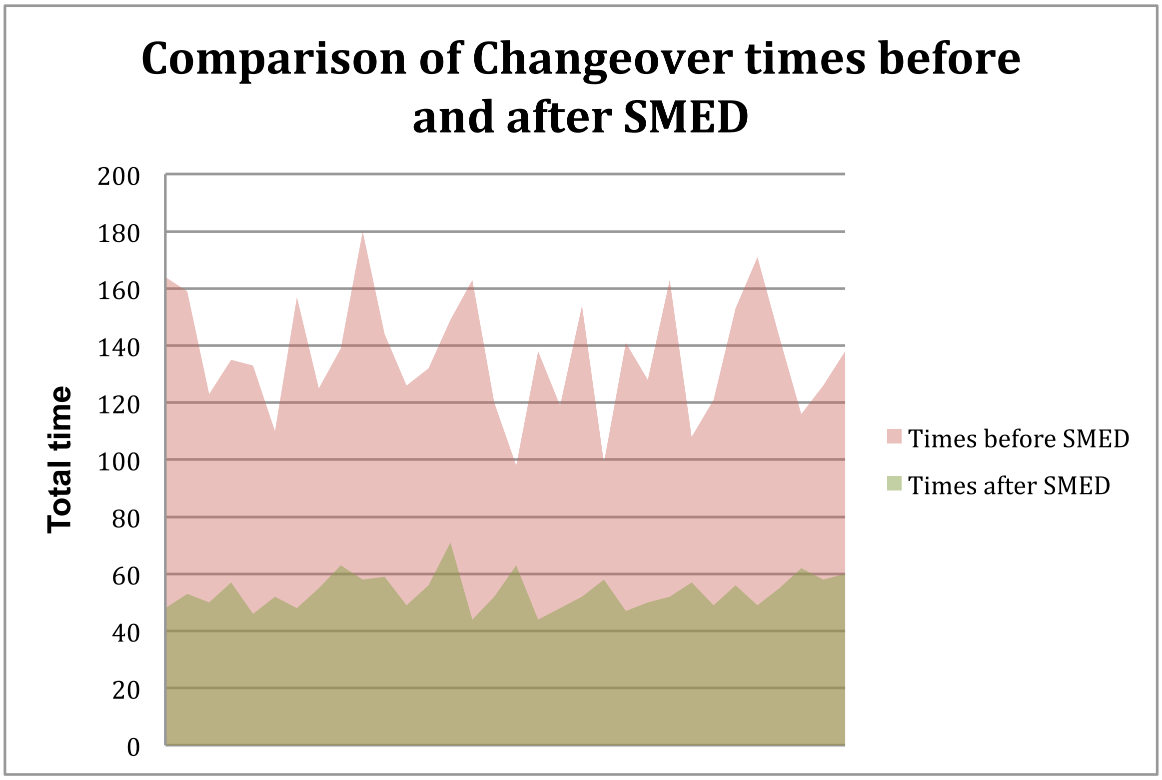

Figure 2. Comparison of Changeover times before and after SMED

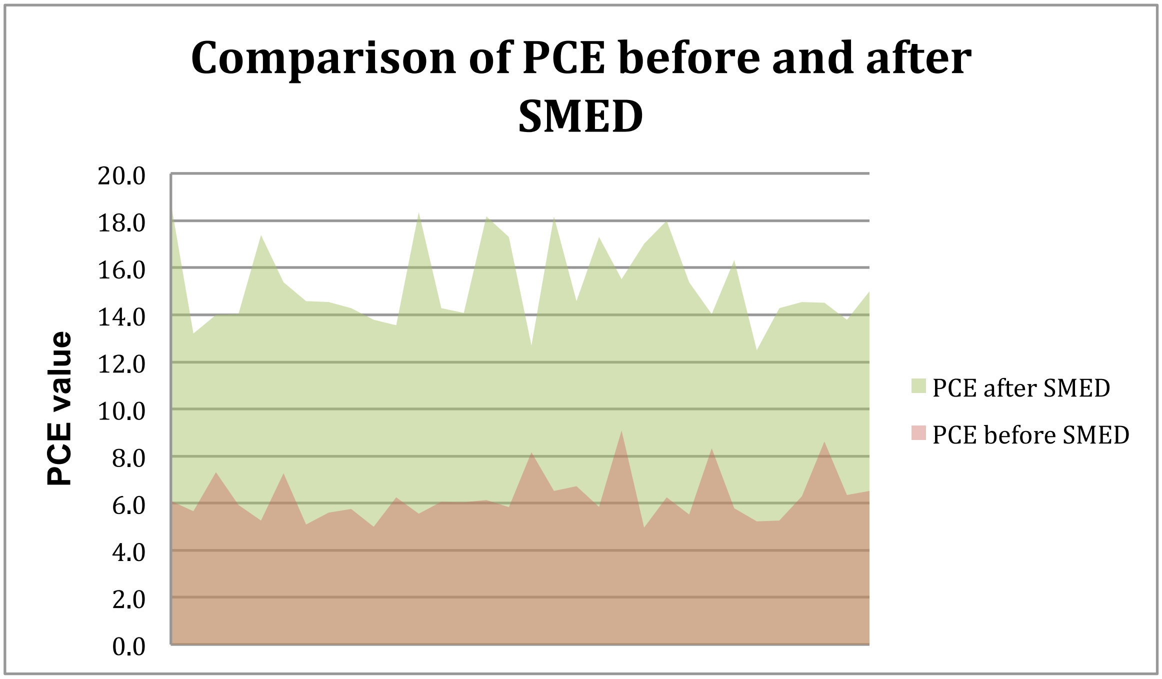

Figure 3. Comparison of PCE before and after SMED

Testing the Difference Between the Two Means of PCE

Assuming μ_1 is the population mean (mean of all PCE's taken over an extended period of time) for the PCE of changeovers *before* SMED, and μ_2 is the population mean for the PCE of changeovers *after* SMED, the hypothesis was stated as shown in Equation (3):

$$H_0: \mu_1 - \mu_2 \geq 0$$
$$H_A: \mu_1 - \mu_2 < 0 \quad \ldots(3)$$

The null hypothesis H_0 states that the mean PCE before SMED was greater than the mean PCE after SMED. The hypothesis was tested using a t-test for the difference between the means at a 95% confidence level.

Table 16. Results of t-test for comparison of means of PCE before and after SMED

	Before SMED	***After SMED***
Mean	6.26	15.30
Variance	1.12	3.25
Observations	32.00	32.00
Pearson Correlation	-0.17	
Hypothesized Mean Difference	0.00	
df	31.00	
t Stat	-22.88	
P(T<=t) one-tail	**2.82E-21**	
t Critical one-tail	1.70	
P(T<=t) two-tail	**5.65E-21**	
t Critical two-tail	2.04	

The confidence level $1-\alpha = 95\%$. Hence $\alpha = 0.05$

Since $p \ll \alpha$, we **reject** the null hypothesis at a 5% significance level. The mean PCE after SMED was significantly higher than the PCE before SMED.

Calculation of Annual Savings

The average reduction in changeover time was 60% (see Table 1&2). Based on 2007 times, the time spent in a year on insert changes was 310 hours.

A 60% reduction in this time will mean a time saving of 186 hours annually. At an hourly rate of $315 in 2008, the savings was approximately $60,000.

This was only a theoretical saving since there was no assurance all of the time saved can be spent producing good material. There could be other problems such as machine downtime, maintenance, and make-ready for additional jobs.

Chapter 7

Summary and Conclusions

Single-Minute-Exchange of Die (SMED) can be successfully used as a tool of Lean Manufacturing in reducing the setup times within a web offset pressroom environment and increasing the Process Cycle Efficiency (PCE) to above 15% thereby making it a lean process.

The Hypothesis statements were:

> **H_0** : Using SMED as a tool of lean does not help improve the Process Cycle Efficiency (PCE) of changeovers on a web offset press above 15%
>
> **H_A** : Using SMED as a tool of lean helps improve the Process Cycle Efficiency (PCE) of changeovers on a web offset press above 15%

The methodology described demonstrates that SMED can be practically implemented with the help of teamwork and cooperation. There are two main reasons behind the importance of teamwork:

1. There are more ideas generated as a team with brainstorming sessions. Additionally, the members of the team bring in the

practical experience and can share any problems there may be with trying out new ideas.

2. The new ideas are more effective when generated by those that will be putting them in practice. If the managers generate ideas without the involvement of the operators, there will be resistance in implementing the ideas.

Printing companies in particular, and any company in general attempting quicker changeovers, can use this study. The methods described are based on proven techniques used over the years by industry experts as well as companies. The important aspect for implementing Lean practices is that it needs to be driven by the upper management.

Often times, companies get started with trying to implement Lean Manufacturing and lose their way. One of the common reasons for this is the lack of follow through on the ideas that have already been successfully implemented. This is where the role of the management is important. The upper management must be directly involved in conceiving, implementing, as well as sustaining any measure that is being tried. The involvement of the upper management conveys a message of commitment to the employees on the shop floor.

Recommendations for Further Research

The researcher would recommend two studies for further research:

1. The study of implementing SMED for quick changeovers in a Union company vs Non-Union company.
2. The possibility of making a company's operations leaner by training customers to be lean in their pattern of placing orders.

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Appendix A

Appendix A1

Stevens Press

Figure 4. Stevens Press

Appendix A2

Insert

Figure 5. Stevens Press Inserts

Appendix A3

Value Steam Mapping Icons

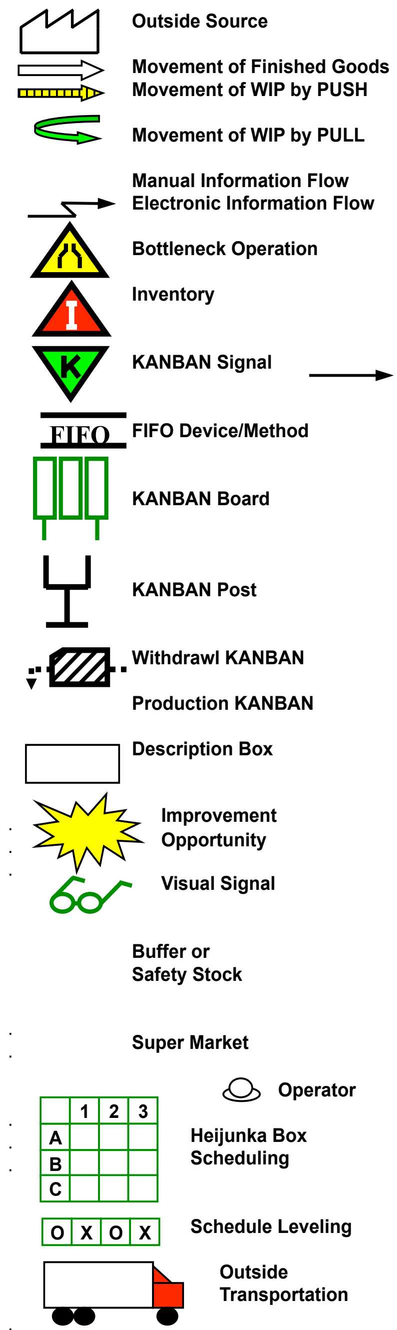

Figure 6. Value Stream Mapping Icons

Appendix A4

Value Stream Mapping Current State

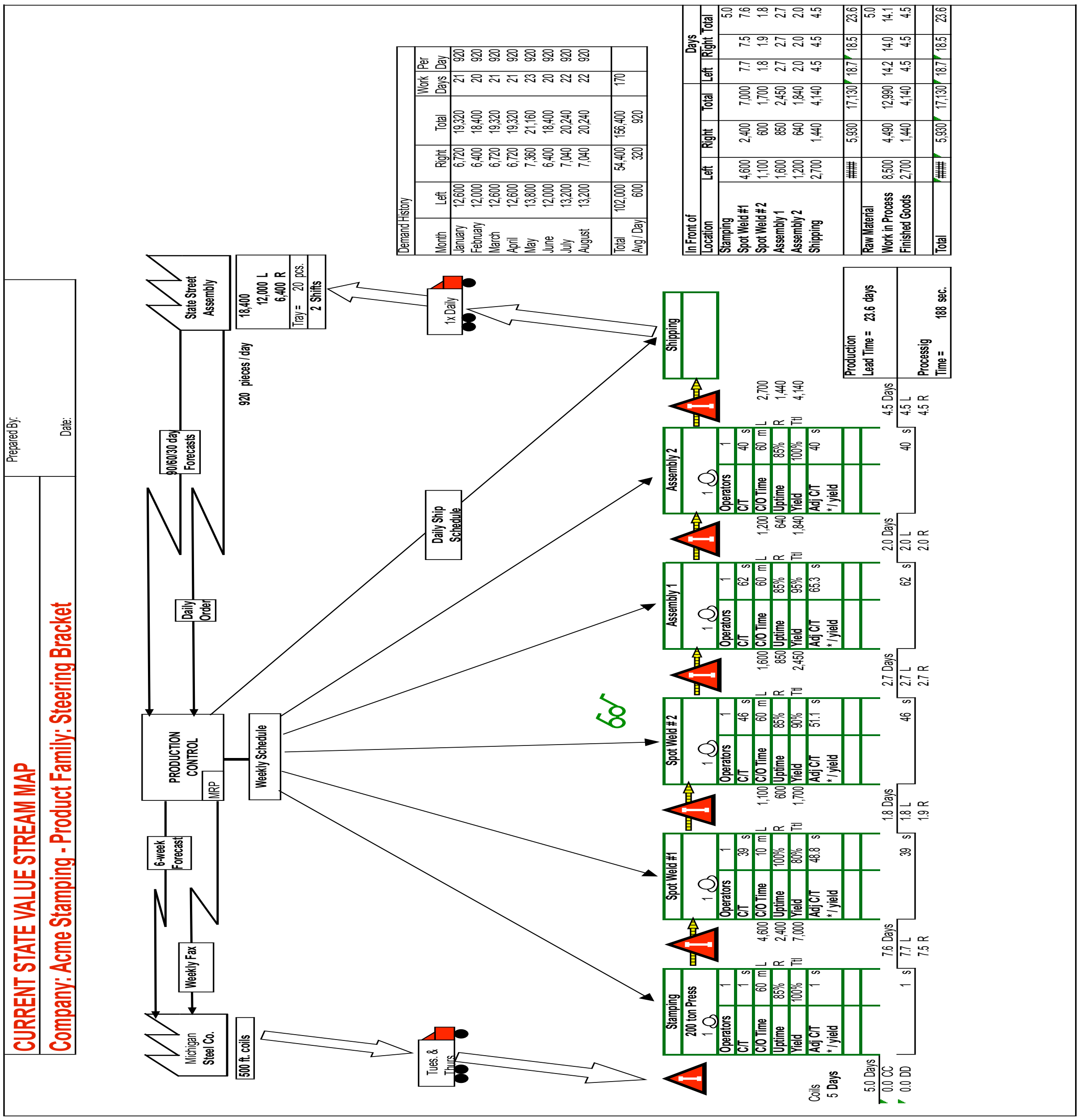

Figure 7. Value Stream Mapping Current State

Appendix A5

Value Stream Mapping Future State

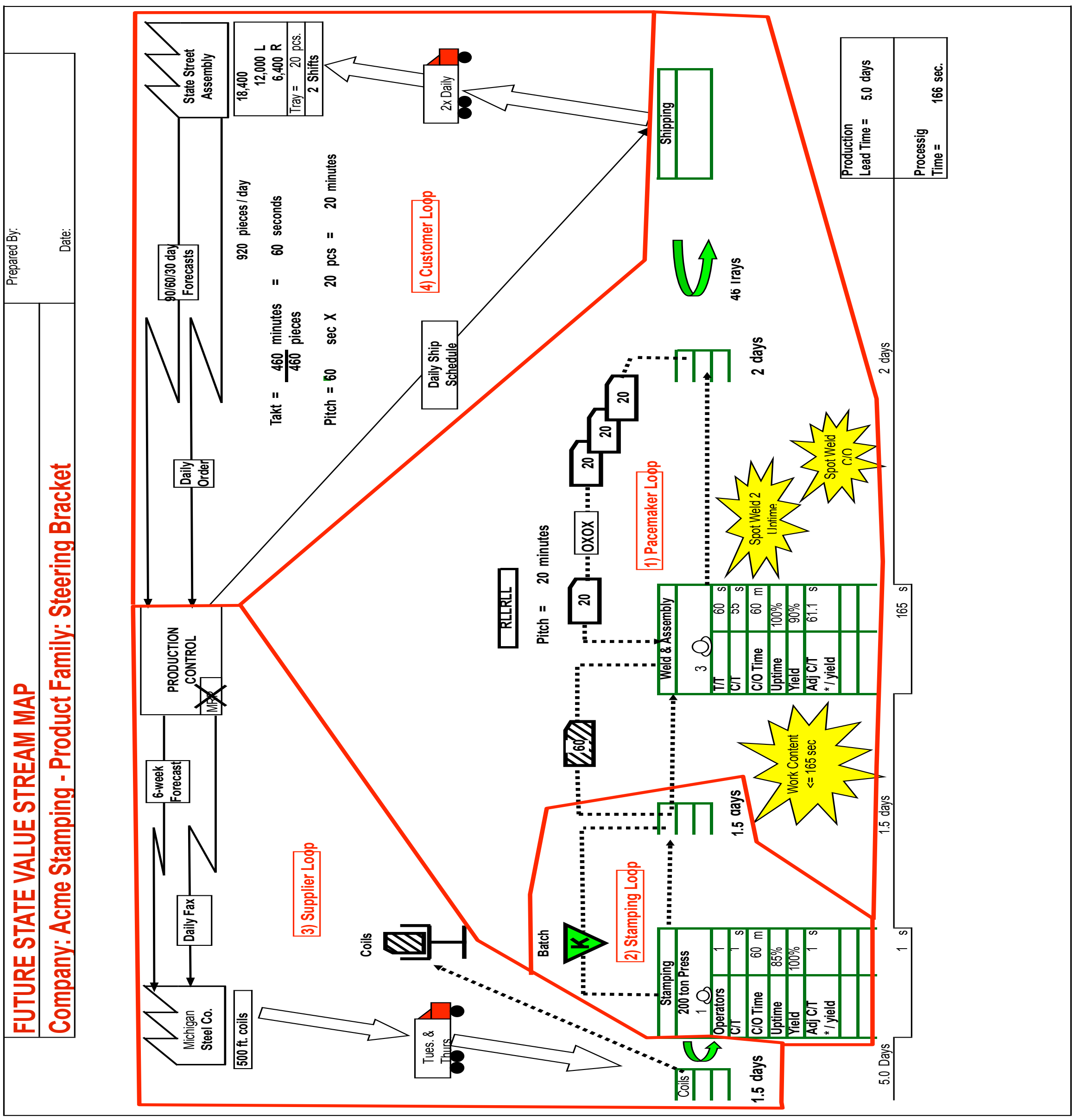

Figure 8. Value Stream Mapping Future State

Appendix A6

Fishbone Diagram

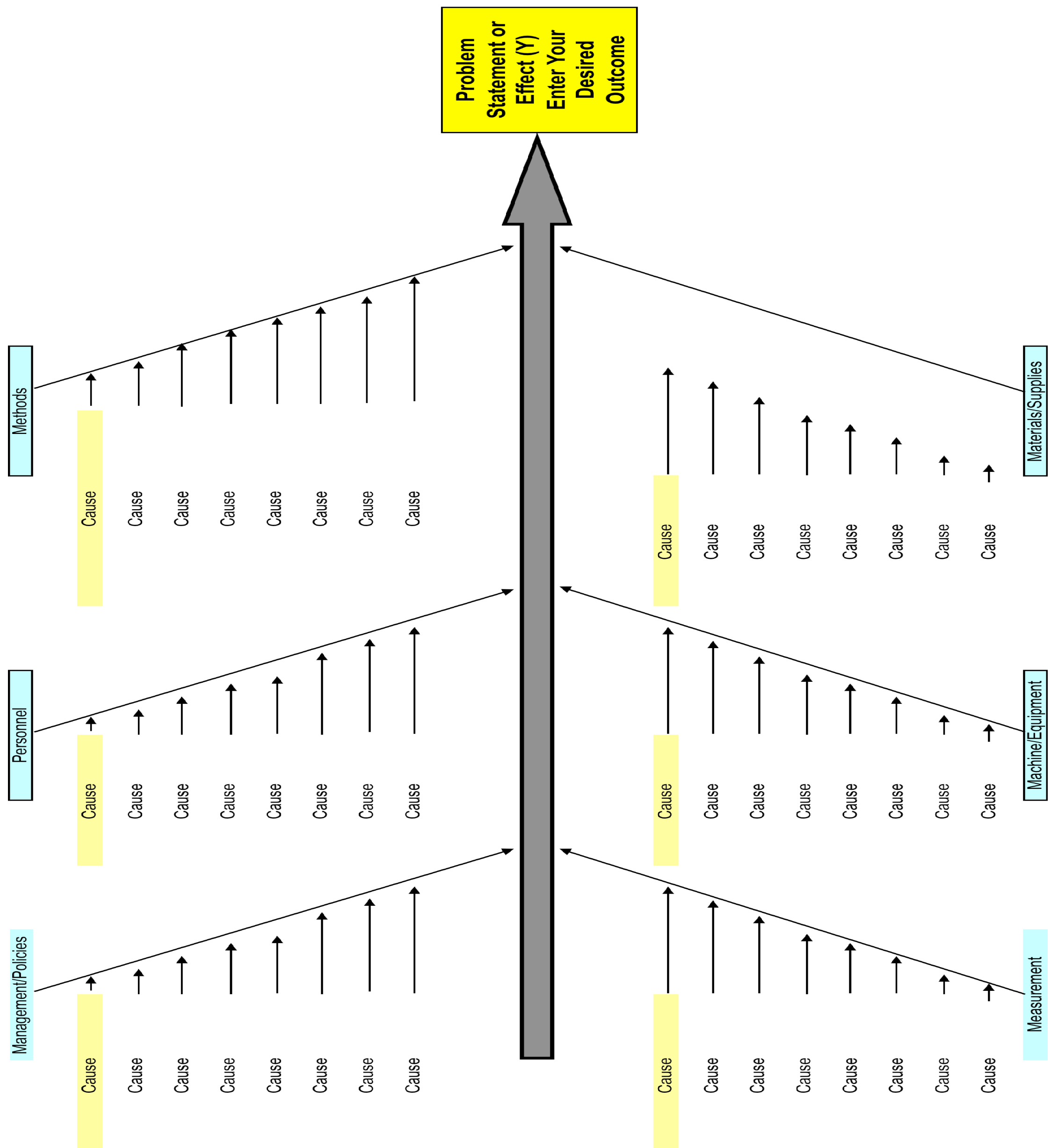

Figure 9. Fishbone Diagram

Appendix B

Appendix B1

5S Results Display

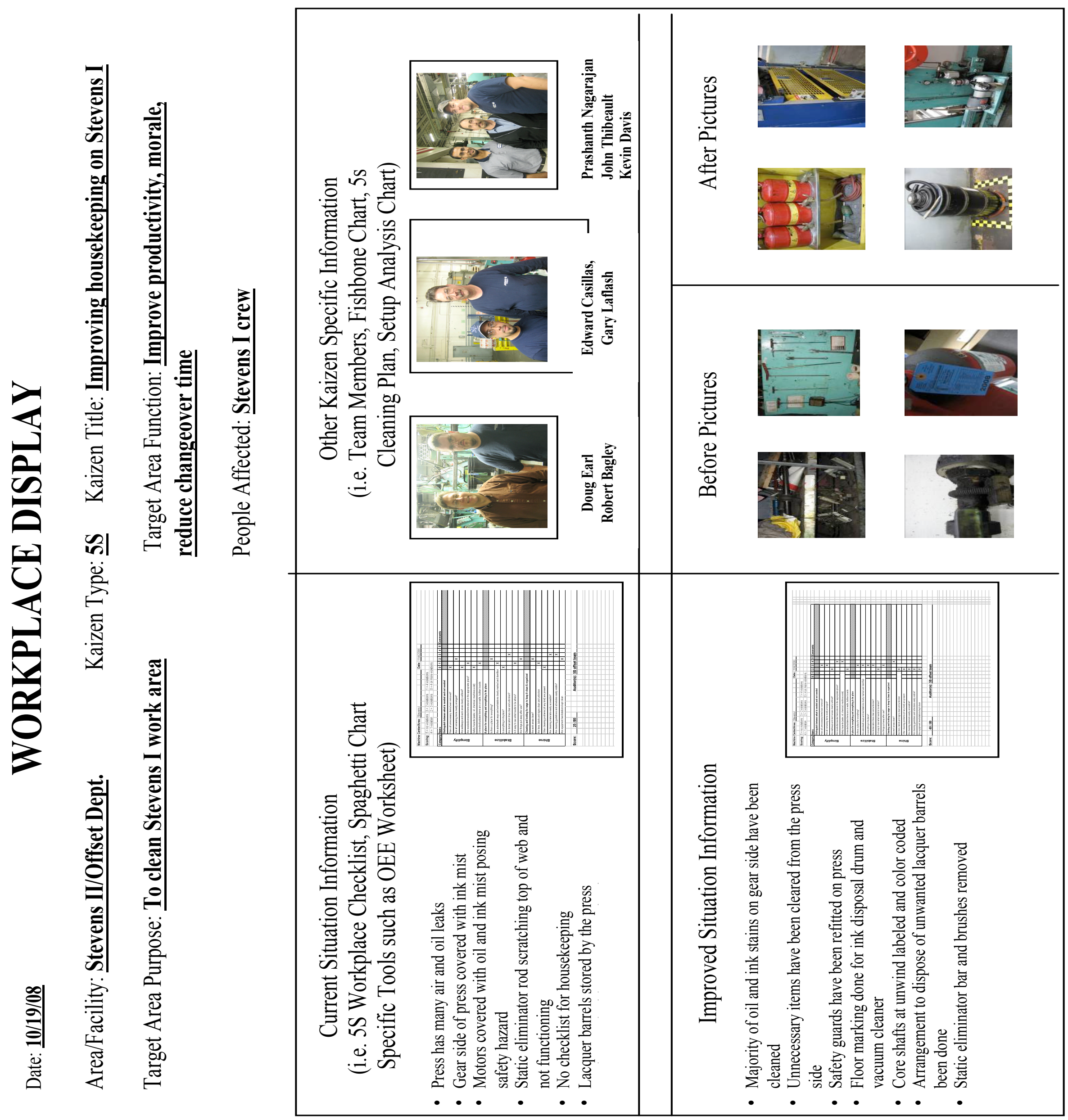

Figure 10. Stevens 5S Results Display Chart

Appendix C

Appendix C1

5S Pre-event Audit Form

Audit Date: 18-Oct-08 **Area Audited:** Offset Department/ Stevens I press

Auditor(s): Stevens I 5S team **Area Rep(s):**

Scoring Legend	Green	Yellow	Red	If item is not applicable to the area, score N/A and do not include in the final total
	>=70%	50%-69%	<=49%	

Category	Item	N/A	1	2	3	4	5	Comments
	# of Problems		5	3-4	2	1	0	
	Score		1	2	3	4	5	
SORT	Distinguish between what is needed and not needed							
	Are unneeded equipment, tools, furniture, etc. present in the area?		X					
	Are any Red Tagged items more than 3 weeks old?	X						
	Are personal belongings properly stored?				X			
SET-IN-ORDER	A place for everything and everything in its place							
	Are aisle/walk ways and workstations clearly marked and identified?			X				
	Are jigs, fixtures, tools, equipment, & inventory properly identified and in their correct locations?		X					No shadow board present
	Are items put away after use?			X				
	Are there max. and min. indicators for supplies?				X			
SHINE	Cleaning and looking for ways to keep the workplace clean/organized							
	Are cleaning materials easily accessible?			X				
	Are equipment and work station kept clean and free of oil, grease and debris?			X				
	Are designated walkways/stairs free of dirt, oil, grease and dust?			X				
	Are lines, labels and signs clean and unbroken?		X					Labels, Warning signs need to be updated
STANDARDIZE	Maintain and monitor the first three categories							
	Are display boards used, organized, current and tidy?		X					No labels on old tool board
	Are employees dressed appropriately and prepared?					X		
	Have specific cleaning tasks been assigned?							
	Are trash bins and scrap/recycle containers emptied on a regular basis?				X			
SUSTAIN	Stick to the rules							
	Is the 5S program discussed at Key Indicator/Crew Meetings?	X						
	Are the tools in place to sustain the 5S program?		X					
	Overall, is the area maintaining 5S rules and disciplines?		X					
	TOTAL	**29 / 80**						
	% SCORE	**36%**						

Figure 11. 5S Pre-Event Audit Form

Appendix C2

5S Post-event Audit Sheet

Audit Date: 19-Oct-08 **Area Audited:** Offset Department

Auditor(s): Stevens I 5S team **Area Rep(s):**

Scoring Legend	Green	Yellow	Red	If item is not applicable to the area, score N/A and do not include in the final total	# of Problems	5	3-4	2	1	0	Comments
	>=70%	50%-69%	<=49%		Score	1	2	3	4	5	

Category	Item	N/A	1	2	3	4	5	Comments
SORT	Distinguish between what is needed and not needed							
	Are unneeded equipment, tools, furniture, etc. present in the area?					X		
	Are any Red Tagged items more than 3 weeks old?	X						
	Are personal belongings properly stored?					X		
SET-IN-ORDER	A place for everything and everything in its place							
	Are aisle/walk ways and workstations clearly marked and identified?					X		
	Are jigs, fixtures, tools, equipment, & inventory properly identified and in their correct locations?					X		
	Are items put away after use?					X		
	Are there max. and min. indicators for supplies?				X			
SHINE	Cleaning and looking for ways to keep the workplace clean/organized							
	Are cleaning materials easily accessible?					X		
	Are equipment and work station kept clean and free of oil, grease and debris?					X		
	Are designated walkways/stairs free of dirt, oil, grease and dust?					X		
	Are lines, labels and signs clean and unbroken?					X		
STANDARDIZE	Maintain and monitor the first three categories							
	Are display boards used, organized, current and tidy?					X		
	Are employees dressed appropriately and prepared?						X	
	Have specific cleaning tasks been assigned?				X			
	Are trash bins and scrap/recycle containers emptied on a regular basis?					X		
SUSTAIN	Stick to the rules							
	Is the 5S program discussed at Key Indicator/Crew Meetings?	X						
	Are the tools in place to sustain the 5S program?					X		
	Overall, is the area maintaining 5S rules and disciplines?					X		
	TOTAL	63/80						
	% SCORE	79%						

Figure 12. 5S Post-Event Audit Form

Appendix C3

Weekly Inspection Checklist

Date inspection completed: ____________________ Location: ________________

Inspection completed by: __________________________________ ____________

Keep this document for your records

NA = Not Applicable Y = Yes N = No

General/Housekeeping:

_____ Do you address safety issues or concerns with your employees?
_____ Are work areas kept clean and free from excess amounts of dirt/dust?
_____ Are materials on racks stacked/stored in the proper fashion **(heavier objects on the bottom)**?
_____ Has proper safety training **(in topics relevant to your operations)** been given to all your employees?

Chemicals:

_____ Are chemicals clearly labeled and not stored on operating machinery?
_____ Are flammable chemicals stored in approved storage cabinets?
_____ Are employees wearing their PPE **(gloves, goggles/safety glasses, aprons)** when handling chemicals?
_____ Do your associates know where the nearest MSDS book is located?
_____ Is your chemical spill plan posted?

Slips, Trips, and Falls:

_____ Are work areas well maintained to prevent trips, slips or falls **(carpet, cords, boxes, mail trays, mats)**?
_____ Are aisleways, stairs, exit doors and other pathways accessible and clear of debris?
_____ Are exit doors properly marked and illuminated?
_____ Is there at least 18 inches of clearance below all sprinkler heads and smoke detectors?
_____ Is production material staged in a manner that allows adequate walking and maneuver space?

Machinery and Equipment:

_____ Do employees operate machines with guards removed **(Inspect machinery for removed guards)**?
_____ Do emergency switches (i.e. mushroom buttons) shut down the equipment when pushed?
_____ Does equipment automatically restart when resetting the emergency switch **(mushroom button)**?
_____ Is unsafe equipment locked out and tagged out **(removed from service in accordance with Lockout/Tagout Program)**?
_____ Are associates wearing their PPE **(goggles/safety glass)** when using air hoses?

Electrical Safety:

_____ Are combustible materials clear from heat generating devices **(heaters, motors, lamps, or coffee machines)**?
_____ Are electrical plugs missing the grounding prong, and/or the cord insulation is separated at the plug?
_____ Is there only one electrical cord plugged into an extension cord **(Multi-plug extension cords are not approved)**?
_____ Are electrical cords in good condition, with insulation not separated or electrical wires exposed?

Emergency:

_____ Are emergency phone numbers posted in highly visible areas **(911, or your security)**?
_____ Do you review emergency evacuation procedures and assembly area with your employees at least annually?
_____ Are emergency evacuation maps located throughout the facility?
_____ Is there someone in your department that has received fire extinguisher training?

Warehouse:

_____ Are dock areas sufficiently illuminated?
_____ Are palleted loads on racking free from loose material **(wood product, and banding material)**?
_____ Wood pallet on-site storage - no more than 4 stacks at no more than 6' high?
_____ Plastic pallet on-site storage - no more than 2 stacks at no more than 4' high?
_____ Do the forklift horns, emergency and standard brakes work properly?
_____ Is acid build up removed from forklift recharging stations, and is the PPE clean and serviceable?

Comments:

* Ensure you take the necessary action to mitigate any hazards found in a timely manner.
* Retain a copy of this inspection checklist within the company for 1 year.

Figure 13. Weekly Housekeeping Inspection Checklist

Appendix C4

Shadow board created during 5S event

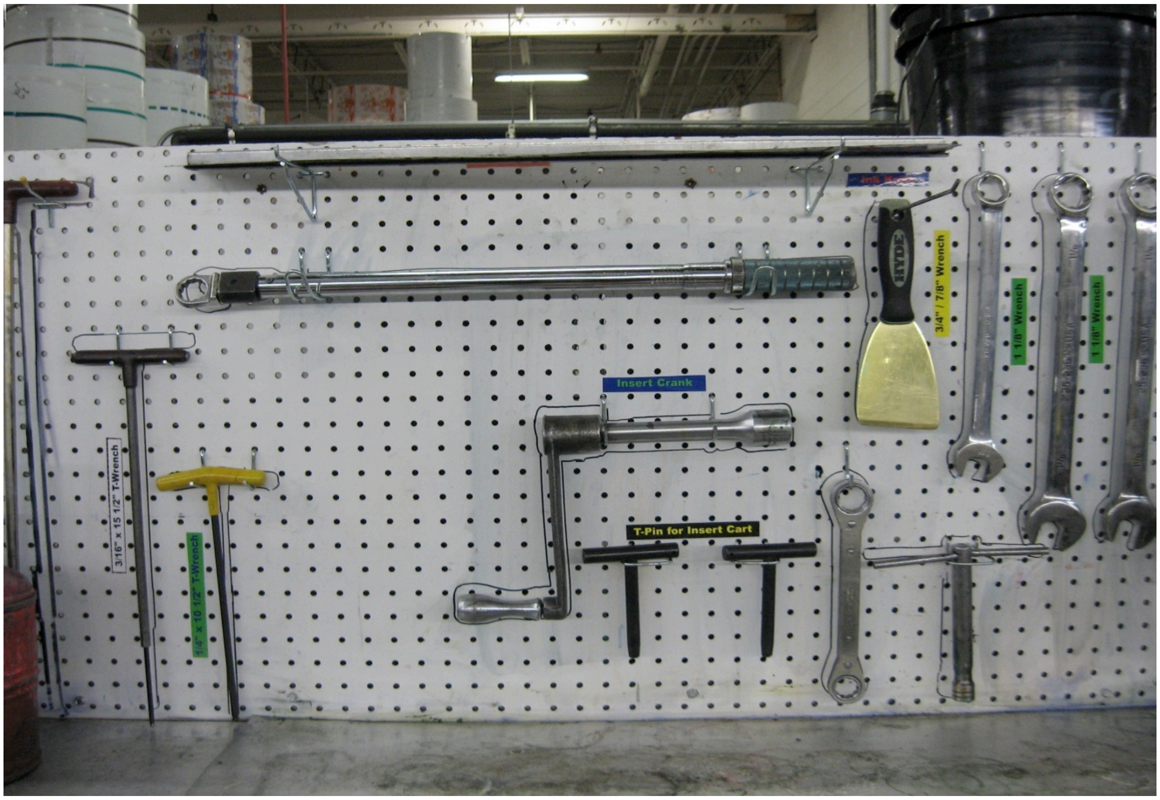

Figure 14. Shadow Board

Appendix C5

Pneumatic Wrench to undo and re-attach upper bolts

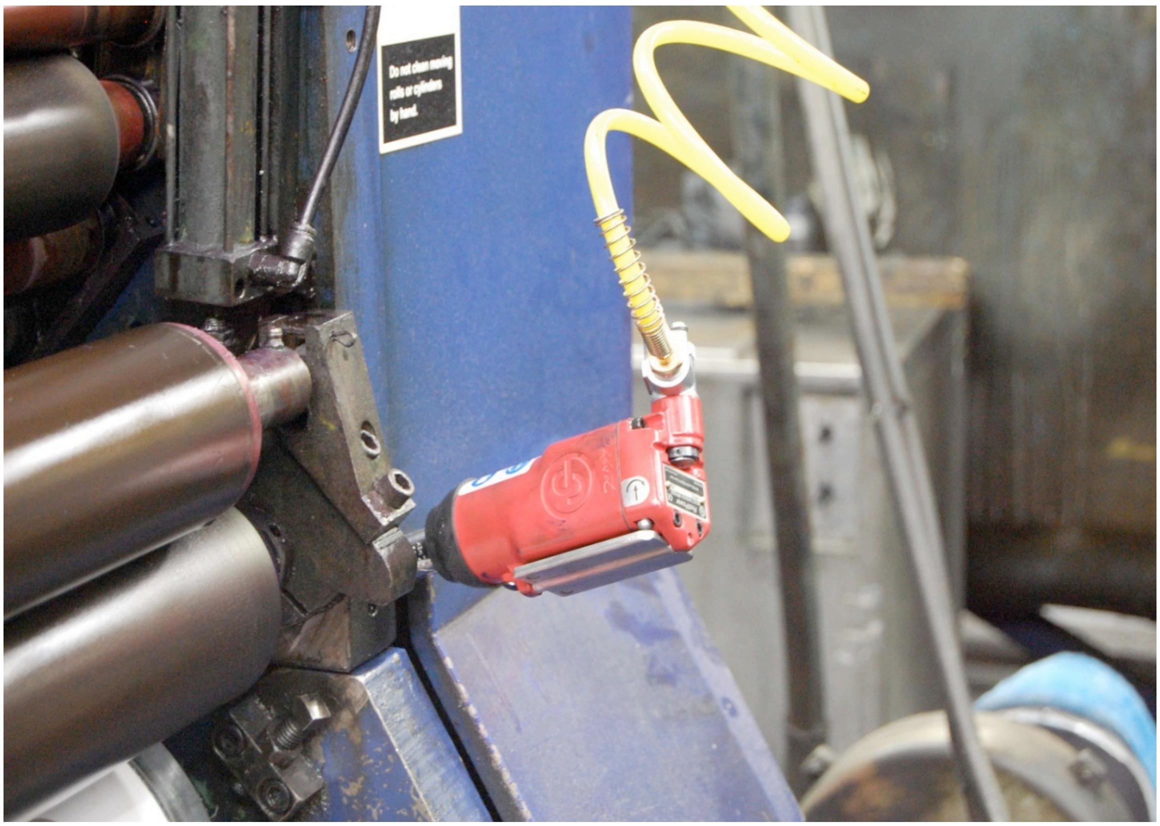

Figure 15. Pneumatic wrench used for upper bolts on Stevens Press

Appendix C6

Spaghetti Diagram – Before SMED

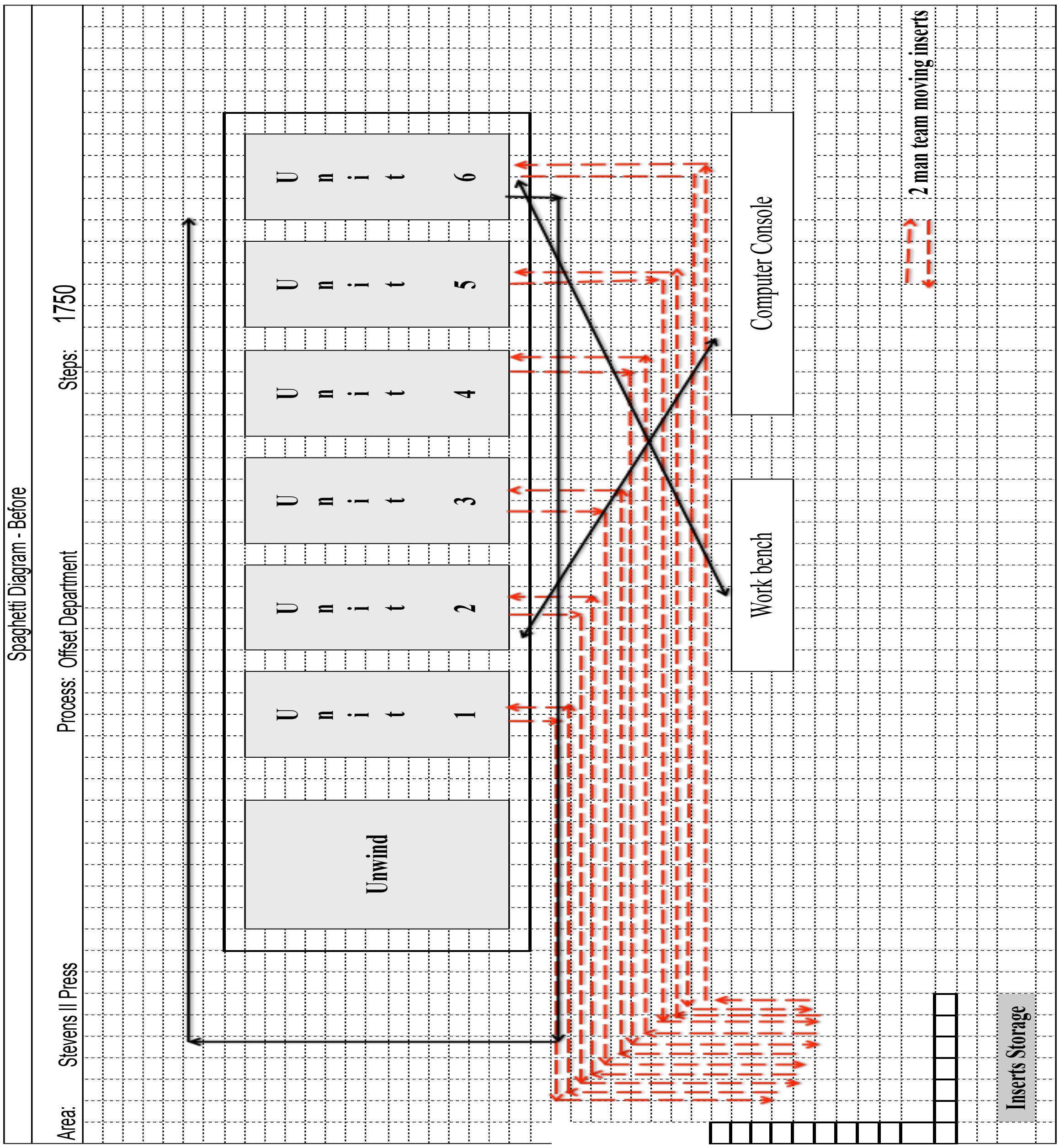

Figure 16. Spaghetti Diagram – Before SMED

Appendix C7

Spaghetti Diagram – After SMED

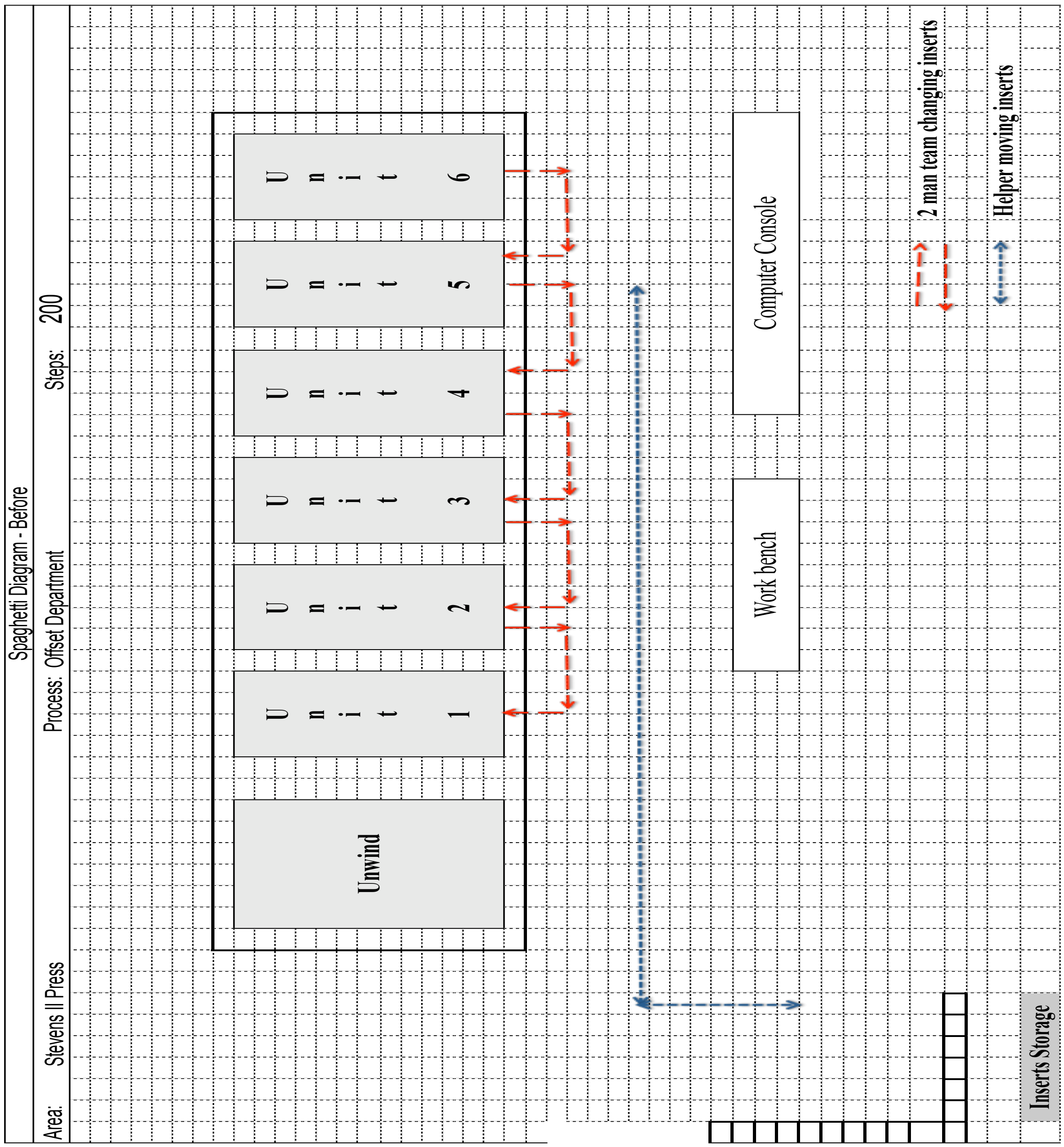

Figure 17. Spaghetti Diagram – After SMED

Appendix D

Appendix D1

Glossary of Acronyms

Acronym	Meaning
5S	Sort, Straighten, Shine, Standardize, Sustain
SMED	Single Minute Exchange of Dies
TPM	Total Productive Maintenance
TT	Takt Time
NCT	Necessary Cycle Time
MO-CO-MOO	Make One – Check One – Move One On
VSM	Value Stream Mapping
PCE	Process Cycle Efficiency
JIT	Just - in - Time
TPS	Toyota Production System

Appendix D2

Glossary of Lean terms

Term	Definition
5S housekeeping	A structured, five-step methodology for maintaining a productive work environment. The Japanese created the 5S concept with the letters representing Sort (seiri), Straighten/Set in Order (seiton), Self-discipline/Sustain (shitsuke), Standardize (seiketsu), and Sweep/Shine (seiso).
Audit	A timely process or system, inspection to ensure that specifications conform to documented quality standards. An Audit also brings out discrepancies between the documented standards and the standards followed and also might show how well or how badly the documented standards support the processes currently followed.
Changeover time	The time needed to adjust a machine to work on a new product.
Current state map	A map that helps you see the life of your product as a whole, not just as a series of isolated steps, and reveals to you which of your processes create value and which create waste.
Cycle time	The time needed to complete a specific process in the transformation of a product from raw material to finished product.

Error Proofing (Poka-Yoke)	Error Proofing is a structured approach to ensure quality and error free manufacturing environment. Error proofing assures that defects will never be passed to next operation.
Flow	A lean manufacturing principle that proposes continuous and progressive achievement of tasks aimed at getting the product to the customer as quickly and as effectively as possible.
Future State Map	A blueprint for lean implementation. Your organization's vision, which forms the basis of your implementation plan by helping to design how the process *should* operate.
Heijunka	Smoothing out the production schedule by averaging out both the volume and mix of products. Production leveling allows a consistent workflow, reducing the fluctuation of customer demand with the eventual goal of being able to produce any product any day.

JIT (Just In Time) Manufacturing	A planning system for manufacturing processes that optimizes the needed material inventories at the manufacturing site to only what is needed. JIT is a pull system; the product is pulled along to its finish, rather than conventional mass production, which is a push system.
Kaizen	The Japanese term for improvement; continuing improvement involving everyone - managers and workers. In manufacturing kaizen relates to finding and eliminating waste in machinery, labor or production methods.
Kaizen Blitz	A Kaizen blitz is a fast and focused process for improving some component of your business - a product line, a machine, or a process. It utilizes a cross-functional team of employees for a quick problem-solving exercise, where they focus on designing solutions to meet some well-defined goals. (Sometimes referred to simply as 'Blitz')

Lean Manufacturing	An approach using concurrent improvement projects to: ensure **value** and **quality** to the customer; create a work environment that maximizes potential; lower cost by the elimination of waste, encourage participation and working together to solve problems
Point of Use Storage (POUS)	Raw material stored at the workstation where it is used.
Product family	A group of related products that can be produced interchangeably within a value stream.
Quick Changeover	Quick changeover is a technique to analyze and reduce resources needed for equipment setup, including exchange of tools and dies. Single Minute Exchange of Dies (SMED) is an approach to reduce output and quality losses due to changeovers.
Takt Time	Takt time is computed based on the daily production number required to meet on-hand orders divided into the total number of work hours in a day. Tact time is used to pace lines in the production environments.

Waste	Any activity that uses resources but does not add value to the end product. Known by the Japanese term 'muda' in lean manufacturing. Lean manufacturing defines 8 types of waste: Defects, inventory, motion, overproduction, processing, transportation, underutilized people, & waiting
Toyota Production System	The Toyota production system is a technology of comprehensive production management. The basic idea of this system is to maintain a continuous flow of products in factories in order to flexibly adapt to demand changes. The realization of such production flow is called Just-in-time production, which means producing only necessary units in a necessary quantity at a necessary time. As a result, the excess inventories and the excess work force will be naturally diminished, thereby achieving the purposes of increased productivity and cost reduction.
Value Stream Mapping	A visual picture of how material and information flows from suppliers, through manufacturing, to the customer. It includes calculations of total cycle time and value-added time. Typically written for the current state of the value chain and the future, to indicate where the business is going.