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Hernandez, Heli Antonio. ***Developing a Waste Stream Map to Lean-out Waste Handling Operations in a Manufacturing Setting***

Abstract

The objective of this research project was to describe the current state of waste streams, identify flow patterns, recognize improvement opportunities, and recommend alternatives for waste handling throughout the window manufacturing process at Company XYZ. Due to the improper handling of the waste generated at different stages of the manufacturing process, the company incurred in significant operating costs. This project proposes improvement measures through the adoption of lean manufacturing tools to identify process deficiency indicators; striving to standardize the waste management process, achieve greater efficiency and cost reduction opportunities that enhance the company's bottom line. This was done by exploring applicable lean methodologies. Value stream mapping was utilized to identify the flow of byproduct waste throughout the manufacturing layout, data collection charts were used to quantify the amount and proportion of waste generated throughout the manufacturing process, and 5S methodologies coupled with visual management techniques were applied in order to contribute on the categorization of waste and ultimate uncover treatment alternatives. Most significantly, this project identifies a direct correlation between proper waste handling procedures and cost reduction opportunities, ultimately having a positive impact on the company's bottom line.

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Chapter I: Introduction

The growth of a nation's economy has owed its success to the wealth-creating industries, of which the manufacturing industry is critical (Luria, 2006). In the past few years the manufacturing industry has had an average investment three times higher than the service sector. However, with the recent state of the global economy, the housing market collapse in the United States, and the drop in demand for products associated with it, the supporting business sector of manufacturing for the construction industry has been among the most affected by this economic misfortune. As Czabke, Hansen and Doolen (2008) argued, over the last decades the U.S. wood-based industries have confronted market share losses due to tight profit margins and downsized overhead costs as a result of the growing global competition. In addition, the industry keeps relocating labor in an effort to reduce costs, yet without making all possible efforts to both significantly and substantially improve the efficiency of current operations (Ahrens, 2006).

The manufacturing industry, at its current stage, will not be able to sustain competitiveness with traditional manufacturing systems against the increased efficiency of global competitors (LaBissoniere & Bowe, 2006). Therefore, to boost global competitiveness it is imperative for businesses in the U.S to leave behind the old world of mass production and adapt new production and business models that aim towards higher efficiency and greater rewards. For this reason many industries in the United States are prompted to develop strategies to reduce costs and improve quality in an effort to differentiate their products and create a competitive advantage that would position them to compete against the forces of a globalized economy.

Cost control and efficient use of resources throughout all manufacturing stages has now become critical for success. However, a dwindling factor of the manufacturing industry is the waste stream as it generates significant handling and treatment costs. Finding a safe and cost effective way to properly handle, reduce, and dispose of waste generated in manufacturing operations can be a daunting task for any company. Likewise repairing the environmental damage and potential liabilities caused by the spread of waste is an issue that will not only require years or even decades to complete, but it can be extremely expensive. As a result, Laquatra (2011) argues that proper management of waste is an area for a business to identify significant improvements in operating efficiency at a significantly reduced cost to enhance profit margins.

An important management philosophy well suited to reach for these indispensable accomplishments is lean manufacturing. Lean manufacturing has emerged as a set of management values which continuously strive to reduce waste in a wide-ranging form. It requires far fewer resources capital, labor, equipment, and time to manufacture a given amount of products and services with higher quality and customization, compared with traditional manufacturing operations (Lean Enterprise Institute, 2009). According to the Lean Enterprise Institute, lean manufacturing practices have proven to be effective by eliminating waste and creating more efficient operations.

This paper reviewed the literature of lean manufacturing principles and value stream mapping design to identify the composition of waste streams generated in a manufacturing facility of 212,000 sq. ft. owned by Company XYZ. By monitoring the different stages of window manufacturing, an attempt has been made to identify, analyze and control the structure and composition of its waste stream from a lean perspective.

Statement of the Problem

Window manufacturing operations at Company XYZ generates significant amounts of non-hazardous waste on its various production lines. The lack of a proper procedure to handle and dispose the waste generated at different stages of the process leads to significant operating costs. In order to achieve lower costs of production and increase process efficiency, the company needed to identify the flow of waste material derived from the different stages of the window manufacturing process, apply corrective measures and recognize reduction opportunities and treatment alternatives in an effort to create a safer and more productive work environment.

Purpose of the Study

The purpose of this project was to recognize the current state of the waste stream across the window manufacturing process of Company XYZ, identify the flow patterns of waste material throughout different stations, recognize reduction opportunities, and recommend treatment alternatives. As a result, formulating a coherent and more appropriate flow of waste materials across different manufacturing stages was developed to achieve greater process efficiency, cost reduction and bottom line enhancement. More specifically the objectives were:

- To categorize the types of waste that moved through the waste stream, measure its quantity, and identify the sources.
- Reduce collection schedule, size of containers, and implement cost effective alternatives to lean out the waste management process.
- Identify opportunities in areas where technological measures may be applied to eliminate or reduce waste. This enabled the company to develop an automated waste management process to divert human resources to where it is most required.
- Recognize waste characteristics and apply alternatives to divert waste from landfills or incinerators by considering the Environmental Protection Agengy (EPA) solid waste management hierarchy (reducing, reusing and recycling).

Assumptions of the Study

1. Upper level management supported the project and agreed that developing a waste stream map created value while contributing to form a lean manufacturing processes.
2. Manufacturing associates understood the benefits of optimizing the waste stream and were willing to contribute towards the identification, analysis, evaluation, and treatment of waste generating activities by providing the best available information.
3. The project proposal was implemented and the results were continuously monitored for opportunities for improvement.

Definition of Terms

Current State (CS). All of the steps that are performed to complete the work as it is operating in today's environment (this is often quite different from how a written procedure states it should be done) as well as the issues and performance (metrics) of the process. (Martin, 2012)

Fenestration. According to Babcock (1981) fenestration is "the arrangement, proportioning, and design of windows and doors in a building" (p 838).

Five Ss (5S). Is the term used to describe a workplace methodology that derives from a list of Japanese words which are seiri, seiton, seiso, seiketsu and shitsuke. Translated into English these words describe five practices leading to a clean and manageable work area: sort, straighten or setting in order, sweeping or shine/scrub, standardizing, and sustaining. (Womack, & Jones, 1996)

Flow. The smooth and uninterrupted movement of a product or service through a series of process steps. In true flow, the work product (information, paperwork, material, etc.) passing through the series of steps never stops. (Martin, 2012).

Future State. A plan for how a process is projected to be running at a defined point in time in the future. Serves as the primary input for the development of an implementation plan. (Martin, 2012).

Gemba. A Japanese word for the "real place" or the place where the work actually occurs. (Martin, 2012).

Incidental work. This type of work includes the secondary activities that don't necessarily add value to the project, but must be done to support the value-added work. (Chen & Meng, 2010)

Kaizen. The term Kaizen is consistent with the phrase continuous improvement. It represents a basic tenet of human endeavor. It is also considered as the name for a group of methods that aim to improve work processes. (Huntzinger, 2002)

Kanban. A signboard giving instruction or triggering from downstream the pull system to manufacture or replenish a component based on actual usage of material. (Widyadana, Wee & Chang, 2010).

Layout. The plan, design or arrangement of something laid out; the act or process of planning or laying out in detail. (Merriam-Webster, 2012)

Lean Manufacturing. A management philosophy that provides companies with the necessary tools to maximize efficiency, competitiveness and profitability by removing waste in terms of over-production, inventory, motion, time, transportation, over-processing, scrap, rework and defects, under the principles of continuous improvement and respect for people. (Liker, 2004)

Muda. A Japanese word for waste. (Ohno, 1988)

Non value-added work. It is best known as waste and it includes non-essential activities that add time, effort, and cost, but no value to the project. Examples of non-value added work include excessive inventory, unnecessary transportation, waiting, excessive processing, waste of motion and defects. (Chen & Meng, 2010)

Operation. An activity performed on a product or service by a single resource. An operation is a component of Process. Also referred to as Task. (Martin, 2012)

Opportunity cost. "The value of a product forgone to produce or obtain another product". (Harris, Harris & Streeter, 2011, p. 66)

Pull System. Pulling system means to produce only what is needed in response to downstream demand, eliminating out-of-stock downtime and keeping a lid on excessive build-up. (Dossenbach, 2007)

Recycling. To recycle is to "pass again through a series of changes or treatments, as to process (as liquid body waste, glass, or cans) in order to regain material for human use. (Merriam-Webster, 2010)

Spaghetti Diagram. Is a tool that helps to determine actual paths and flow of information, supplies, and resources (equipment and people) throughout a process by using a hand drawn illustration to expose inefficiencies and determine the optimal layout based on workflow observations.

Takt Time. Takt time is referred to as a measure of the maximum time (in seconds) that the production of a product should take in order to meet customer demand in any given period. Takt time will contribute to set the pace of production as a benchmark to target processing time, representing the optimum state of production to meet the demand. In other words, Takt time is essential for calculating permissible time limits for process tasks. Takt time can be calculated by forecasting the total time available (in seconds) to perform a process and dividing it by the customer demand. Takt time is considered the primary component for creating a current-state value stream map (Womack, & Jones, 1996).

Value Stream Mapping. All the actions, both value added and non-value added required to bring a product through the main flows essential to every product. (Rother & Shook, 2009)

Value-added work. Refers to those activities essential to the operation and that will add value to a project in a way the customer is willing to pay for. (Chen & Meng, 2010)

Waste. Waste is defined as anything other than the minimum amount of equipment, materials, parts, space, and worker's time which is absolutely essential to add value to the product. (Ohno, 1988)

Limitations of the Study

1. This research project concerns a single manufacturing location owned by Company XYZ during a period of time from January 2012 to May 2012.
2. This research was limited to the study of indoor window manufacturing processes and did not involve any outdoor process.
3. The manufacturing process under study was limited to production factors and flow pattern exclusive to Company XYZ.
4. This study did not consider external limitations of the manufacturing process that might jeopardize the applicability of suggested measures.
5. The manufacturing layout under study was limited to a total space of 212,000 sq. ft. therefore any layout change proposal was limited to such.

6. Implementation of recommended improvement measures was limited to the company's approval and subject to its conditional terms.

Methodology

The complete flow of byproduct waste through different stages of the manufacturing process to its final buildup, treatment, and disposal was summarized by developing a waste stream map. This was addressed by applying various lean manufacturing initiatives to optimize waste management operations. The main rationale was to identify the different types of materials that compose the waste stream in order to identify and analyze areas of potential improvement regarding the waste handling and disposal process of non-hazardous materials. This research project applied lean principles as a state-of-the-art management alternative that sought to create a waste-free environment that resulted in greater efficiency, thus maximizing customer satisfaction and profitability.

Summary

The ability of U.S. manufacturers to compete against the increasingly strong global competitors is at jeopardy. Therefore, the manufacturing industry in the U.S. must plan for a shift from the old mass production model to new and more efficient manufacturing models where fewer resources are needed to make a high quality product that satisfies client demands. An important philosophy that suits the needs of U.S manufacturers for greater efficiency and enhanced competitiveness is Lean Manufacturing. Continuing to use old and inefficient management practices would ultimately deplete the remaining competitiveness of the U.S industry. This research project focused attention on the fenestration industry, particularly on the window manufacturing process at Company XYZ.

The amount of waste that window manufacturing generates and the lack of management procedures for proper handling and disposal of waste material created significant overhead costs. In an effort to create a more efficient process this project identified the flow of waste material throughout the company's manufacturing layout, applied corrective measures, and suggested reduction and treatment opportunities. The objective was to devise ways to minimize and treat waste residuals from different stages of the manufacturing process, creating a leaner, more efficient, and environmentally friendly operation that aims towards the creation of a highly competitive lean process.

Throughout the literature review conducted in the following chapter, the evolution of the manufacturing practices that preceded and ultimately set the path towards the development of the lean philosophy as a state-of-the-art management alternative are explored. The literature review also provided evidence of success stories from lean implementation in manufacturing settings similar to the subject of this study.

Chapter II: Literature Review

This chapter reviewed the literature to provide a theoretical foundation that was used as a source of reference to promote the application of the continuous improvement process as it applies to material flow patterns and waste reduction methodologies throughout the manufacturing stream. Different tools used to achieve waste reduction were explored as critical components of the continuous improvement process applied in today's manufacturing industries. From the historical developments of the different management techniques, to the maturity of the lean management philosophy and the different tools utilized to identify, minimize and control the various types of waste, this chapter explores a combination of alternatives that may lead toward significant process improvements.

Historical Development

Lean principles can be traced back to 1799 with the work of Eli Whitney, when he developed interchangeable parts for the production of 10,000 muskets for the U.S Army at a significantly low price. By the early 1900s Frederick Taylor developed the scientific management method that analyzed and synthesized workflows (Ahrens, 2006). Taylor believed that a more efficient way to do a job could be identified by the elimination of waste in terms of time and motion, observing workers and the work methods they applied. By recognizing the importance of workers as agents of change, Taylor suggested that more productive ways to do the job could be identified. As cited by Ahrens (2006), Taylor encouraged workers to become involved in process improvements and made management accountable for analyzing and implementing employees' suggestions (Chase, Aquilano, & Jakobs, 1998). As a consequence, the concept of time study and standardized work was born. Subsequently, Frank Gilbreth contributed by developing motion studies and process flow charts, focusing attention in different work elements including those of non-value added (Garza, 2005). In addition, during the 1910's Henry Ford made one of the greatest contributions of all times, and created the first comprehensive manufacturing strategy, integrating people, machines, tools, and products, with the invention of the mass production system and its Just-in-Time approach (Garza, 2005; Dennis, 2007). By the 1940's, and as a result of the increasing demand of war products for World Word II, the United States created the Training Within Industry (TWI) service. The TWI program consisted of a nation-wide network of industry professionals teaching valuable techniques to war contractors by focusing on training each worker to make the best use of his skills, maximizing his contribution to enable production to respond to war demands (Huntzinger, 2002). Despite its short existence (1940-1945), the effectiveness of the TWI program had a significant impact on the production efficiency of the U.S. war supply manufacturing industry. The following table shows a tabulated summary of the results of TWI at different intervals during its operation.

Table 1
TWI Plant Results: Percentage of Plants Reporting Results of 25 Percent and Over

	May 1943	Sept. 1943	Feb. 1944	Nov. 1944	April 1945	July 1945	Sept. 1945
Production increased	37	30	62	76	64	63	86
Training time reduced	48	69	79	92	96	95	100
Manpower saved	11	39	47	73	84	74	88
Scrap loss reduced	11	11	53	20	61	66	55
Grievances reduced	(Not Reported)		55	65	96	100	100

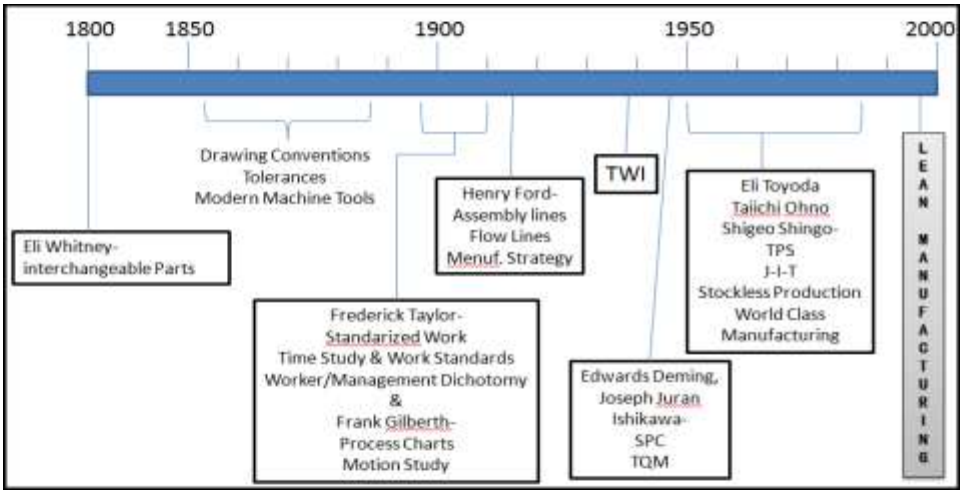
Note. Adapted from "War Production Board, Bureau of Training, Training within Industry Service," by n.a., 1945, *The training within industry report: 1940-1945*, p. *92*. Copyright 1945 by the U.S.: Government Printing Office.

The management theories previously discussed are thought to be ground zero of the latest management revolution in the manufacturing world. Such management revolution was ultimately known as Lean, and its development began in Japan after World War II (Liker, 2004). With a collapse in sales, a shortage of resources, and a manufacturing industry needing to be rebuilt, companies like Toyota turned their eyes to western production methods. However, Japanese companies soon realized that mass production systems used to satisfy the needs of a large demand would not fit the smaller scale and limited resources of the Japanese market (Acharya, 2011). As a result, Toyota's engineers concluded that Taylor's mass production was not efficient and Detroit's production methods would not work (Ohno, 1988; Womack, Jones, & Roos, 1991). However, they saw a way to build upon U.S. manufacturing achievements and improve them.

The combination of statistical and quality management techniques, developed by W. Edwards Deming, Joseph Duran and Kaoru Ishikawa (1947-1950), and learning from Ford's mass production system, allowed Taiichi Ohno, Eli Toyoda, and Shigeo Shingo to innovate their own production system (Dennis, 2007).

Ohno and his team developed a method to retrieve valuable first hand information from the production floor towards continuous process improvement, and named it "Kaizen". Over the following thirty years Ohno continued perfecting the new management philosophy using Toyota to foster the new manufacturing system. From this timid beginning was born what today we know as The Toyota Production System (TPS), more commonly known as lean manufacturing.

Figure 1. Timeline of advancements in Lean operations



Note. This timeline represents the most significant events that lead to the development of lean management theory.

Lean Manufacturing

Womack and Jones (1996) emphasize that the production floor was just one part of the organization that should consider lean initiatives. The true lean process aims at cost reduction by eliminating non-value added activities beyond the production floor and throughout the organization (Womack et al., 1991). Consequently, the spread of the lean philosophy throughout the entire value stream of the company, by using a true systems approach, creates a process that leads to the reduction of waste in terms of less human effort, less space, less capital, and lower cycle times with high quality standards, at a lower cost and increased profitability, compared with the traditional mass production systems (Lean enterprise institute, 2009). Furthermore, lean principles aim toward holding a minimum stock of inventory, producing very few defects, and providing greater flexibility to produce different products using the same production line. In other words, lean production is lean because it uses fewer resources compared to the traditional mass production model.

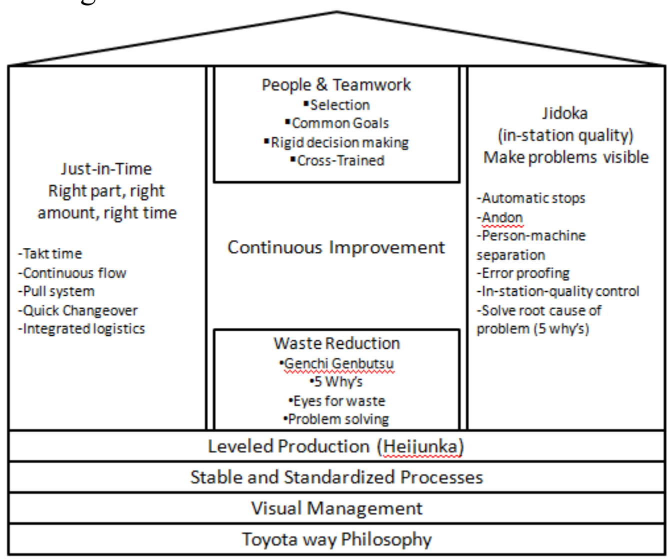
According to Liker and Morgan (2006), "the lean process is a systems approach that effectively integrates people, processes, and technology in a continual, comprehensive, and coordinated effort for change and learning throughout the organization" (p. 6). The main purpose of lean manufacturing is that it seeks to provide customers with a product that meets their expectations, in an efficient and timely manner, while minimizing non-value added activities at its source (Womak & Jones, 2005). Furthermore, as described by Little and McKinna (2005) "lean manufacturing is a set of operating principles which a company may apply to optimize its provision of value to customers," (p. 36), thus involving the elimination of waste and improving the material flow throughout the process. As noted by Pirraglia et al. (2009), the primary objective of lean manufacturing operations is to reduce or eliminate waste in terms of non-value added activities expressed in different forms (Ray, Zuo, Judd & Wiedenbeck, 2006). In order to better understand the concept of lean manufacturing it is imperative to focus attention on its roots, The Toyota Production System (TPS). The foundation of Lean is a result of the systematic research of best business practices and tools employed by the Toyota Motor Company working towards a comprehensive quality model. These tools represent the management approach that Toyota developed and today is best known as TPS.

The Toyota Production System (TPS)

Perhaps the greatest success story of lean implementation is the Toyota Production System (Womack et al., 1991). Developed as a new manufacturing process, TPS has set the roots of the new manufacturing era. This system is based on the lean philosophy that comprises a focus on customer satisfaction, continuous improvement, quality through the elimination of non-value added activities, and a tightly integrated process as a system. The majority of lean concepts developed during the 1950's and 1960's were focused on providing the best quality, at the lowest cost, and the shortest lead time. The core of such concepts has been successfully implemented by Toyota Motor Co. (Liker, 2004). Toyota has not only been successful on the implementation of lean but it has gone far along the path of developing it (Womack, Jones, & Roos, 1991). Toyota has served as the source for many lean principles to evolve as a proven alternative for achieving greater operational efficiency and cost reduction, while adding value for the customer. The father of TPS was Taiichi Ohno. By the 1940's he decided to redesign his machine shop into a U-shape manufacturing cell with employees who self-balanced their work loads, eliminating the need for line balancing. The principle of TPS is that the source of learning comes from actions where the work is done – "gemba". As a result, many control systems, inventory and production controls are implemented with the use of Kanban systems linking suppliers and manufacturing cells to one simple-to-operate interconnected manufacturing system.

The first pillar needed to support TPS is the implementation of Just-In-Time (JIT), pulling parts only when needed. According to Ohno (1988), in a flow process, Just-In-Time aims for the right parts, at the right moment, and only in the amount needed. Its main goal is to achieve a flow production with zero work in progress (WIP) inventory. The second pillar of TPS is the implementation of automation with a human touch Jidoka. The purpose of Jidoka is to minimize the frequency of defects by auto-enabling stops of production, preventing the production of more than one defect at a time. Similarly, when an operator shuts down production as a result of a problem, the line will stop immediately. Considering the low levels of inventory used by the lean manufacturing system, this causes a sense of urgency to immediately address the problem before it reaches the end of the line. For ease of better understanding, the principles of TPS can be represented as the structure of a house (see Figure 2). The house diagram is a simple representation of the production system that Toyota developed to teach their suppliers the fundamental principles of lean manufacturing.

Figure 2: The TPS house diagram



Note. The Toyota production system diagram. Adapted from *Creating a lean culture: Tools to sustain lean conversions,* by Mann, 2005, New York, NY: Productivity Press. Copyright 2005 by Productivity Press.

Kaizen. Kaizen is the Japanese word that best describes the continuous improvement philosophy initially developed in the United States at the end of the nineteenth century, and is first and foremost a critical concept of lean operations. The word Kaizen is derived from two ideographs, the first of which stands for change and the second for goodness or virtue. The continuous improvement philosophy was originally based on employees' suggestions (Ohno, 1988). However, it wasn't until its arrival in Japan when this management philosophy was combined with tools such as quality circles, giving birth to what today is known as Kaizen.

However, according to Conway (1994) most organizations don't understand the concept of Kaizen and commonly believe it refers to improvements made at low and middle levels of the organization (e.g. the shop floor). Indeed, continuous improvement includes changes at such levels, but the most important changes are those fundamental and major changes that only top management can lead. Finding, quantifying and eliminating waste –including waste of lost time, sales, opportunity, growth of the business and creating jobs– leads to continuous improvement and it is a specific focus that everyone should understand.

Just-in-time (JIT). According to Womack (2005), assembling the major components into a complete product, the primary task of many manufacturing plants, accounts for only 15% of the total manufacturing process. The bulk of the process involves engineering and fabricating 85% of the components, and usually takes place outside the company. The coordination of these processes is crucial so that everything comes together at the right time with high quality and at a low cost.

The Heart of TPS - Focusing on Waste

The main focus of the Toyota Production System is the elimination of waste throughout different stages of the process. This is done in order to improve efficiency and minimize cost. As a consequence, Conway (1994) argues that "focusing on finding waste is a powerful tool in coordinating continuous improvement efforts for organizations" (p. 26).

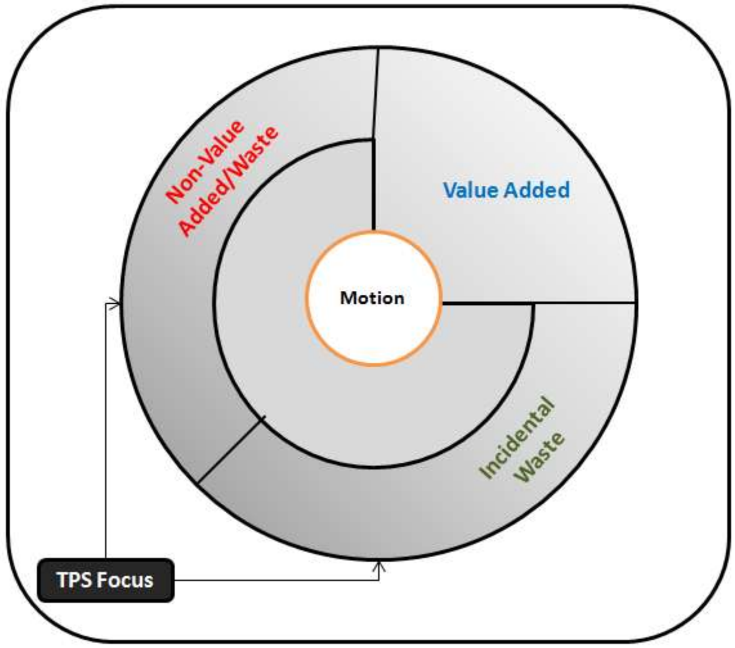
The key is to make people understand that there is a lot of waste and that lean principles apply a systematic approach to waste identification and elimination, rather than placing blame on anyone. Accumulating waste is a sign of deficiency of the management system that is in place. Interestingly enough, people find it hard to identify the different types of waste that have been generated simply because they are too close to it. But with the right tools, questions, and attitudes, the different types of waste are easily identifiable.

The essence of lean manufacturing principles is to help identify waste throughout the organization. According to Ortiz (2006) there are two different types of work activities that exist: value added work and non-value added work, or waste. The reality is that most of what people consider as “work” does not provide true value-added from a customer’s perspective (Kato & Smalley, 2011). The fact of the matter is that true value-added work is a small part of our normal job. Only customer requirements and specifications such as product functionality, content, appearance and fit for satisfying needs define true value.

Any transitional activity we use to achieve the end result is not entirely value added and can be classified as incidental waste or true waste. Incidental waste refers to those non-value added activities that need to be performed based on how the current system operates (Womack, 2005). Examples include the necessary movement of material from delivery trucks to the assembly line and back again to the shipping dock. An example of pure waste, on the other hand, would be to transfer scrap material from the manufacturing cell to a disposal collection area without planning for a shorter distance; this is a waste of time and resources that could otherwise be used in value-added activities.

In a strict sense, only the process inherently involved in reaching the product’s final specifications is value added. In other words "only the last quarter turn of the final bolt to specified tightening torque is value added to the customer (Kato & Smalley, 2011). As illustrated in Figure 3, TPS first focuses on non-value added and incidental wastes activities of the process.

Figure 3: Work versus waste



Note. Adapted from Toyota kaizen methods: Six steps to improve (p. 4), by I. Kato, and A. Smalley, 2011, New York, NY: CRC Press. Copyright 2011 by CRC Press.

Identifying the Different Types of Waste

To help organizations realize that not all activities are value-added, Ohno (1988) suggested the following terms: Muda (waste), Mura (inconsistency), and Muri (unreasonableness). The existence of such elements, according to Ohno, threatens the adequate flow of materials, thus jeopardizing the efficiency of the process and eventually leads to the production of defective products.

According to Ohno (1988) true efficiency is achieved by eliminating all types of waste and bringing the proportion of true work to its full extent. Table 2 summarizes the different types of waste as identified by Ohno (1988).

Table 2:
Eight Wastes of Lean Manufacturing

Source of Waste	Description
Overproduction	Refers to producing much more than what the customer is willing to buy, or too early when the customer is not interested. It is both a problem of magnitude and time. Overproduction is perhaps the worst form of waste as it requires additional needs for handling and storing excess inventory.
Waiting time	If things are not ready when required it represents wasted time. And as Benjamin Franklin would say, “time is money” and “is never found again”.
Excess conveyance/transportation	As mentioned before, excessive handling of materials is a form of waste. This type of waste is thought to be related to overproduction and excess inventory.
Overprocessing	Also referred to as inappropriate processing, is considered to be the fundamental waste as it causes most of the other types of waste. Overprocessing is the act of doing extra, non-value added work, after the product reaches customer expectations.
Excess inventory	Pertains to more than what is required to meet customer demand. Excess inventory has a risk of obsolescence and it also requires space and other resources to manage it.
Excess of motion	A certain amount of motion is required to complete any given task. However, similar to excess conveyance, excessive motion carried out by employees is a type of waste. Making employees realize that not all motion is value added to the customer is critical for the elimination of this type of waste.

Source of Waste	Description
Scrap and Rework	Batch production generates inevitable long wait time, larger inventory and excessive handling. Additionally these wasteful activities increase the likelihood for scrap and rework, consuming labor, materials, time, energy and more to get the work done appropriately.
Unused employee creativity	“Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees.” (Liker, 2004 p. 29)

Lean Tools to Identify and Minimize Waste

As previously discussed, the fundamental principle of the Lean philosophy is to identify and eliminate waste. Therefore, Lean recognizes work as a true value-added operation for the customer. Incidental work required in the current state of the operations, and pure waste in the system can be identified and depurated through the implementation of lean tools such as Value Stream Mapping within others. (Worley & Doolen, 2006)

Value stream mapping (VSM).

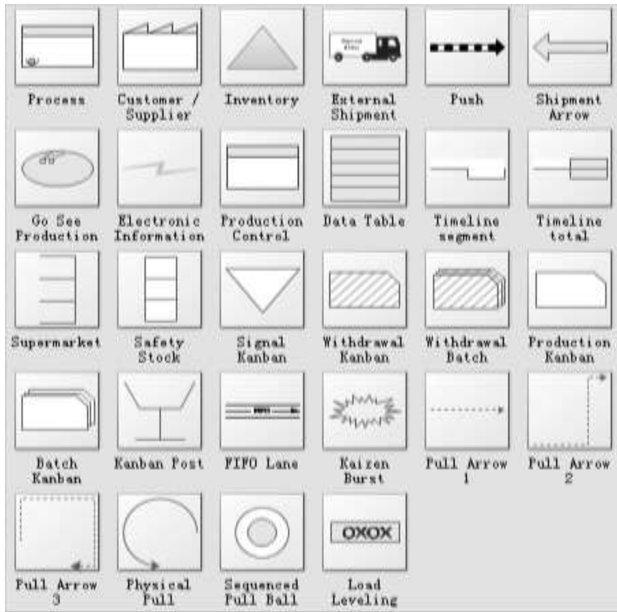
Value stream mapping has been the primary driver to implement a lean production system by identifying opportunities for process improvement. Therefore, it is imperative to understand the VSM concept as it has served as a model for identifying the waste stream of manufacturing operations. Value stream mapping provides a common language to identify and understand the flow of material and information as a product makes its way through the value stream. This technique consists of a hand drawn illustration of the different elements that constitute the value stream. According to Chen and Meng (2010) these elements are: “customer loop, production control, supplier loop, manufacturing loop, information flow and lead time data bar with critical path that make us have a full view of the whole supply chain from customer's requirements to supplier's delivery." (p.204)

Furthermore, according to the Lean enterprise institute the Value Stream Mapping (VSM) methodology consists of four essential components: The product family, the current state of the value stream map, the future state of the value stream map, and the comprehensive work plan designed to achieve the future state.

The product family. Choosing the product family, where your Lean implementation has been planned to begin, is a very important step towards value stream mapping. It would be very difficult or nearly impossible to create a value stream map of a whole manufacturing facility, but focusing on a family of products and its production process is most certainly manageable.

The current state value stream map (CSVSM). Once the product family has been identified, drawing the current state of the value stream map helps pinpoint areas of improvement. The key to creating the current state value stream map is to accurately document the different stages of the process as it is today. The current state VSM does not focus on how the process has been designed to work but how it actually works. The information is used to analyze lead times and sketch the design of a desirable future state of the process. The current state VSM will contribute to developing a comprehensive work plan to establish specific tasks, due dates, and determine individual accountability for each task. To better visualize and understand VSM, Figure 4 provides an example of the different symbols utilized to develop the value-added flow chart.

Figure 4: Value stream mapping template



Note. Adapted from "Value Stream Mapping Template," by EdrawSoft, 2012. Copyright 2004-2012 EdrawSoft.

Future state Value Stream Map (FSVSM). The FSVSM is designed as a prospect of the desirable future state of the process. It requires envisioning the future state of the process under a set of guiding principles to achieve a lean fulfillment stream (Martichenko & Grabe, 2010):

1. Focus on eliminating all the waste so that only pure value remains
2. Make customer consumption visible to all members of the stream
3. Reduce lead times
4. Level the flow of materials
5. Use pull systems
6. Increase velocity and reduce variation
7. Collaborate and use process discipline
8. Focus on total cost of fulfillment

The previously discussed guiding principles are taken into consideration when bringing up improvement ideas to draw the future state map effectively for a Lean implementation process.

Developing a work plan. The lack of a comprehensive work plan will most certainly lead companies to fall short on making the necessary changes to transition from CSVSM to FSVSM. The plan needs to be in place and provide a structure to work on problem solving, task delineation, due dates, and responsibilities. Additionally, periodic system checks need to be in place to track progress and support the implementation process with the necessary resources.

Applicable Methods for Achieving Zero Waste

According to the Zero Waste Alliance (ZWA), waste has always been a sign of inefficiency and the foundation for great loss of value and resources within a process. Learning to identify the different types of waste and implement elimination alternatives does not only help achieve more efficient operations, but it would actually contribute to save money. Achieving zero waste to the land fill and reducing the consumption of resources requires a series of upstream business strategies and downstream treatment alternatives (Black & Phillips, 2010). Moreover, the ZWA argues that in order to achieve zero waste each component of material must be used as efficiently and effectively as possible and must be selected (upstream) so that by the end of the cycle, it is either returned to the system or safely into the environment. Additionally, other methods for achieving zero waste have not only included downstream alternatives such as reuse and recycle, but also prevention through product design --considering lower materials consumption, recycled resources, longer product life cycles, as well as the use of non hazardous materials-- have been applied (Chalfan, 2001) . The zero waste strategy has lead organizations to search for opportunities of waste reduction at its source, and downstream waste treatment measures.

Developing partnerships throughout the supply chain. A key component contributing to achieving zero waste in industry has been the development of a partnership with providers (Harris, Harris & Streeter, 2011). Unfortunately, it is often the case that purchasing efficiency is measured solely by cost of the components that have been sourced. That is, the lower the cost per piece that the purchasing agent reaches, the better their performance is thought to be. Once the purchasing job has been done the next component is transportation. The transportation agent needs to figure out the way to determine how the component gets shipped from the supplier to the customer. The base measure for transportation has also been costs, without considering any input from the sourcing of the component, configuration, packaging alternatives, and other physical attributes of the product. This silo management approach has lead not only to significant transportation cost, inventory cost, storage cost, and material handling costs but also a significant loss of opportunity.

Performance measures and communication are critical components of any purchasing team that has proven to be efficient. In the realm of supplier development, certain key players are involved in active communication to create a successful partnership within the supply chain. These players work together as a team ensuring that all the decisions that are made act in coherence with company objectives, avoiding a silo perspective and thus moving away from the piece-price approach and into true costs. Developing suppliers into partners has not been an easy task for any organization but it can certainly be achieved if the right components are integrated into the team.

The continuous improvement team. Developing a continuous improvement team has contributed to understanding of how the system as a whole is linked together and how its different components interact. The team will bring valuable information from manufacturing, product engineering, workforce, scheduling and material handling all together. This information has been essential in the course of choosing suppliers and developing them into long term partners.

The purchasing team. The purchasing team has played an integral part in the supplier development process. They bring important knowledge of how purchasing is handled and how suppliers are currently dealt with. It has been of critical importance getting the purchasing team involved, and using their valuable knowledge as the organization moves towards reaching a partnership with suppliers. However, addressing performance measure issues for the purchasing department is critical. While organizations continue to measurement supply efficiency by price per piece, difficulties will persist; bringing the purchasing team on board with the approach of developing suppliers into partners will continue to be difficult. Just because a given component has the lowest price does not mean that is the best purchasing alternative. Therefore, many organizations have made sure that the purchasing role takes into consideration the complete value stream, and its performance is measured based on the efficiency and effectiveness of the system. Therefore, the purchasing team strives for negotiations with the supplier to dictate how the material is received in terms of packaging, frequency of delivery, and material configuration (Harris, Harris & Streeter, 2011).

Material handling. An essential component to make value flow throughout the manufacturing process has been the material handling factor inside the facility. This is a very important component of the supplier development process as well. Often times, once the component reaches the manufacturing facility it needs to be reconfigured or repackaged to meet the internal production system. Although, this reconfiguration of materials may be incidental, or compulsory, it is a waste of time and resources. According to Harris et al (2011) if the materials were shipped from the supplier to the manufacturing line in a proper configuration, then repackaging activities and the waste associated with it would be avoided. The materials handling organization has the best knowledge and skills to determine how the different components should be presented to the manufacturing line. Thus, for many organizations it has been imperative to have the material handling group involved in developing a partnership with suppliers. This has allowed agreements for suitable packaging and product configuration to be delivered, optimizing the internal value stream, minimizing material waste, and supporting the continuous improvement process.

Packaging. Working with suppliers to get the most efficient type of packaging for those components fed into the system has been a significant benefit. On one hand, standardizing the type and quantity of materials received per container has facilitated the internal material handling process. Packaging agreements between customer and supplier have also helped the customer avoid extra disposable waste in the facility. The customer decides whether to use returnable containers or disposable ones. This might help the company avoid after-use cost associated with storage, labor, and disposal or recycling cost. However, returnable containers also have after-use costs associated with them, such as transportation and maintenance. It is up to the customers' best judgment to decide which alternative is best, under a true cost model.

Research and development. The process of designing future products was taken into consideration by many organizations, not only at the beginning stage of Lean implementation, but most significantly, on the continuous improvement process. The team of engineers involved in this task is asked to communicate to the rest of the organization what their needs are, in terms of material requirements, and to consider how it affects the system. Furthermore, according to Harris et al (2011) research and development team may as well extend its reach into the capabilities of different suppliers so they can choose the supplier that is most capable of fulfilling specific component demands.

Quality. One of the biggest disruptors to the flow of value within any process is poor quality (Harris et al, 2011). Selecting the best suppliers in terms of quality is critical for the success of a Lean initiative. Creating partnership with suppliers has allowed organizations to identify witch suppliers are unable to provide high quality products at the right time. For this reason the quality organization has been on board to recommend suppliers that are good candidates to pursue a partnership with.

Green engineering and the five R's for achieving zero waste. Green engineering refers to the objective of producing zero waste to the landfill by focusing on social and environmental principles. Lean manufacturing focuses on achieving zero waste in all value added and non-value added activities from a process efficiency perspective. The Toyota Production System has taken these two different approaches of waste management and has developed the Refine-Reduce-Reuse-Recycle-Retrieve program, best known as the 5R's. By focusing on the lean principle of eliminating waste at its source, its purpose is to manage the generation of unnecessary material disposed from the manufacturing process in a manner that reduces both costs and a negative impact on the environment. Table 3 summarizes the 5R components of the lean-green initiative of TPS.

Table 3:
Toyota's 5R's for achieving zero waste

Category	Measures	Category	Description	Responsibility
Waste Source Control	Conversion	Refine	Expansion of reduce, reuse, recycle by changing design and raw materials	Production technologies and other departments
	Reduction of amount of waste	Reduce	Reduction of amount of waste generated at source	
After treatment measures		Reuse	Reuse within production process	
	Recycling	Recycle	In-plant reuse or generated waste	
		Retrieve Energy	Recovery of energy from waste materials that cannot be refined, reduced, reused or recycled	Environmental technology departments

Note. Adapted from "The lean to green evolution" by Black, and Phillips, 2010, *Journal of Industrial Engineer*, 42, p. 46-51. Copyright 2010 by the Institute of Industrial Engineers, Inc.

The zero waste culture developed by Toyota began to spread throughout companies all around the world. Since then, many organizations have taken different approaches to improve employee awareness and promote the importance of waste reduction initiatives as an environmental conservation and resource development alternative. The following is an example of how businesses have adapted the zero waste culture to their processes.

Zero waste to landfill by the Ricoh Group: a five-R's approach. Based on the Five R's program developed by Toyota, the Ricoh Group has taken its own approach towards achieving zero waste towards landfill (Ricoh Group Sustainability Report, 2001). Their Five-R system identifies the different components of the zero waste initiative under the concept of refuse, return, reduce, reuse, and recycle, using them as the core values for the zero waste programs.

This has been done as an important step towards achieving a “perfect production” as a result of zero waste throughout and beyond the manufacturing process. An interesting aspect of the Ricoh Group five Rs program is that it extends its scope outside company borders, striving towards developing a partnership with suppliers and recycling companies.

Refuse. According to the Ricoh Group Sustainability Report (2001) the company makes every effort to avoid purchasing any material that may become waste. By refusing any unnecessary material the company embraces a culture where only the minimum amount of resources is utilized on production and thus only such amount must be purchased. This is extended to suppliers by working with them to simplify the packaging for parts and raw materials. As a result Ricoh Industries France has been able to reduce up to 98% of waste toward its goal of 100% reduction by using methodical purchasing controls to eliminate PVC substances.

Return. Returning packaging and scrap material to the suppliers is also another way of striving for zero waste at Ricoh Group. By working with engineers and designers Ricoh has managed to come up with new creative ideas for delivery containers and packaging material to be reusable and easily returnable to suppliers. This has been done not only from an environmental perspective --reducing resource exploitation-- but also from a costs perspective that benefits the whole supply chain. As an example, Ricoh Industries in the U.K. returns paper tubes and packaging buffers to their source. Ricoh has also designed its own foldable shipping containers that minimize handling efforts and cost.

Reduce. The Ricoh Group considers residual materials to be waste if mixed together, but when sorted it considers them to be an opportunity. Waste reduction initiatives along with an efficient sorting of material is considered to lead towards a material recovery rate that can generate profits if sold as a resource. As a result, several sites have eradicated the use of wastebaskets and replace them with sorting bins in an attempt to further reduce the amount of waste directed to landfills and to promote the recovery of resources.

Reuse. Ricoh has applied a system to sort the plastic waste generated in the manufacturing process to combine it with new materials to manufacture recycled parts using a third party service. Furthermore, it encourages administrative personnel to reuse office supplies that have been used only once, conserving resources and reducing costs.

Recycle. In addition to studying resource recovery methods and simply reusing materials without changing their form, the Ricoh group aims toward establishing long term contracts with recycling companies. The treatment of materials includes chemical recycling methods to reuse materials after processing, and energy recovery activities to reuse materials as fuel to generate heat energy.

Summary

This chapter introduced the different management theories developed throughout history, and how these have transitioned into state-of-the-art management practices under the umbrella of the Toyota Production System and the Lean philosophy. By exploring the literature, different concepts of the Lean philosophy were revealed as examples of waste reduction opportunities that contribute to the continuous improvement process. It has provided details on how different methodologies have been used to implement Lean enterprise systems in an effort to minimize both process waste and general waste. Furthermore, this chapter has presented a solid theoretical foundation as a source of reference that promotes the continuous improvement process as it applies to material flow patterns and waste reduction methodologies throughout the manufacturing stream. This chapter has provided a synopsis on how companies have integrated

Lean initiatives as an alternative that proposes a feasible, reliable, and cost effective solution to reduce waste and produce quality products at a lower cost.

Chapter III: Methodology

Lean manufacturing is anticipated to help companies achieve operational excellence by improving productivity and enhancing quality; while aiming towards reducing waste and saving costs. The purpose of this study was to provide a framework for a more efficient waste management process through the development of a waste stream map that identified areas of process improvement, cost-effective waste reduction opportunities and treatment alternatives.

The problem addressed by this research was the implementation of lean manufacturing principles in the waste handling system of Company XYZ, a window manufacturer. The company had not been using lean manufacturing techniques for waste reduction. In an effort to improve the flow of materials and to boost and maintain a competitive edge, the different cost centers within the organization were prompted to define the objectives of lean manufacturing within their own process, promoting the deployment of lean tools in specific manufacturing areas.

One of these areas concerned the handling and disposal process of non-hazardous waste, generated as a byproduct from different stages of the window manufacturing process. The flow of movement and the handling and disposal of byproduct waste in the manufacturing process requires a great deal of resource consumption, thus creating significant costs with a negative impact on the company's bottom line. The waste handling flow and disposal process of byproduct waste is considered a non-value added activity, yet necessary for a sound manufacturing operation. Such activity was optimized by the implementation of lean tools, striving to standardize process plans, streamline the system and save costs to boost productivity.

This chapter explored the methodology implemented for data collection and analysis procedures used to identify a scope of improvement for the waste management process, including generation, collection, storage, treatment, and disposal alternatives. It addressed the subject of waste management by applying value stream mapping methodologies and other relevant concepts previously discussed in the literature review.

Sample Selection

Twice a week during consecutive weeks, plant walks were scheduled throughout the process layout. During this period a total of seven manufacturing cells dedicated to manufacturing and assembling operations of two different product series were under observation. These were subject to evaluation in order to identify weaknesses and opportunities on waste disposal operations.

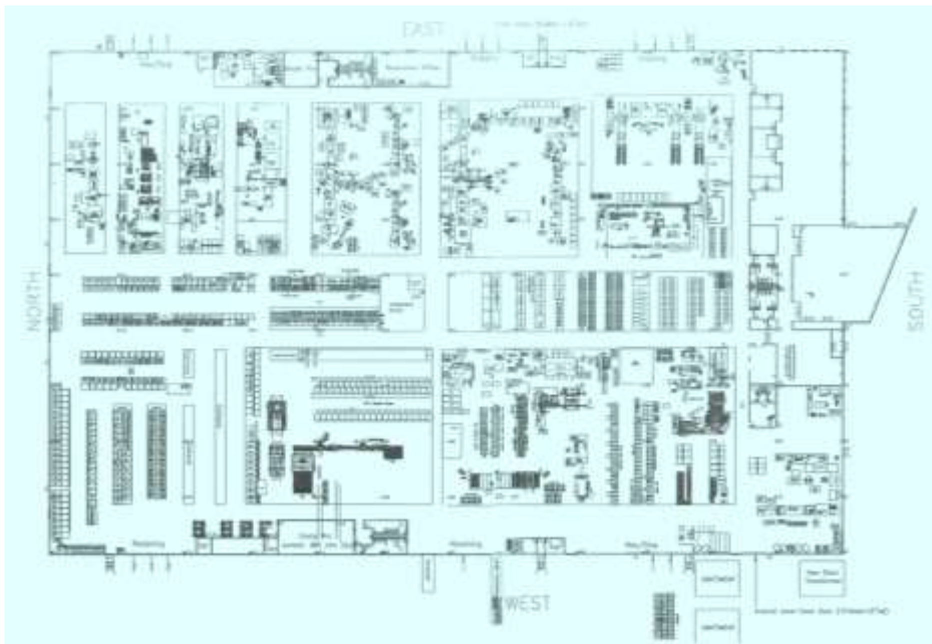
Lean assessment

In order to determine potential areas of improvement a lean manufacturing assessment was performed throughout different work stations within the facility. With the waste handling and disposal process being the focal point of this project, the lean assessment was aimed at the flow of byproduct waste throughout the process, and how it was handled until its final clearance. The route and flow of waste was addressed from the standpoint of finding ways to streamline the process, reveal waste minimization alternatives, and devise treatment opportunities to divert waste from the landfill.

Instruments

The lean manufacturing assessment was carried out by describing the general layout of the window manufacturing process. –Figure 5 shows the general layout of the shop floor, including the different manufacturing cells utilized in the production of various product model series. Then developing a value stream map of the process as it is (current state Value Stream Map). Then drawing a spaghetti diagram to distinguish the different routes of the waste handling process. Following that a future state VSM that illustrates the process after applying potential improvement measures. In order to understand the intricacies of waste management and to portray the current state of the process it was critical to perform a close observation at the Gemba and actually see what was happening.

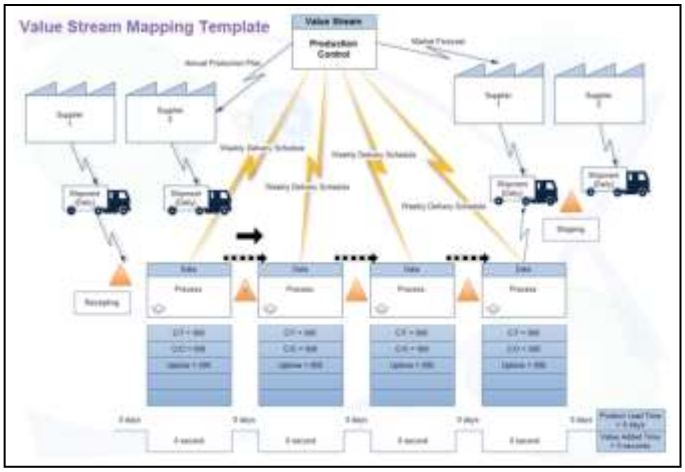
Figure 5: Plant-Manufacturing Layout



Drawing the Current State for the waste handling process

Analyzing the current state of the waste disposal process began by creating a sketch of the overall waste handling flow throughout the plant (as shown in Figure 6). This snap shot of the process was critical for analyzing the current state of the process and identifying areas of concern and opportunities for improvement. It served as the stepping stone toward designing a more efficient and desirable future state of the waste disposal process. This methodology was completed while performing close observations on the shop floor and was done by hand drawing the process to avoid delays that can interfere with the direct observation, and to allow a better understanding of the flow of information.

Figure 6: Value Stream Map example for a manufacturing process



Note. Adapted from "Value Stream Mapping Template," by EdrawSoft, 2012.

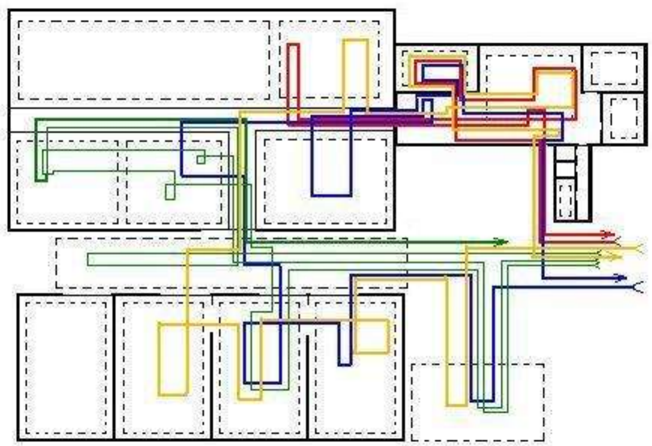
Future State VSM

The future state value stream map was geared towards foreseeing potential improvement of the waste management process and projecting those two to six months ahead. This required a comprehensive combination of actions to define activities and quantify the time dedicated to non-value activities, such as waste disposal. The idea was to work simultaneously on different improvements in order to have show significant benefits of the process. This allowed tracking the operational benefits of the applied actions and kept the improvement progress on track.

Motion/Time Study

A motion study was performed by utilizing a spaghetti diagram (shown in Figure 7) as a tool to illustrate the flow of byproduct waste generated on different work cells throughout the manufacturing layout. The purpose of the spaghetti diagram was to measure the distance from the waste source (work cell) to its final accumulation container, where it was then intended for treatment or disposal. This diagram also served as a time study tool helping quantify the time that such non-value added waste handling activity takes, and how it actually depletes the efficiency of the manufacturing process.

Figure 7: Example of a spaghetti diagram



Note. Spaghetti diagram, Adapted from “Diagram spaghetti kilka produktow” by Siemieniukk, 2007. Copyright 2007 by Siemieniukk

Data Collection

In order to quantify and identify the different types of waste generated by manufacturing operations a combination of survey methods and statistical estimation procedures was used. By utilizing a census method on different waste collecting containers the study identified the most significant types of waste generated at the manufacturing plant. Administrative information sources such as waste collection service orders, data sets for environmental agencies and other documented data pertaining to waste management were used.

Lean-5S Application

The sorting of byproduct waste generated on each manufacturing line was a critical step towards leaning out the waste management process. During this first step of 5S the different types of waste were identified by type, according to its physical and chemical characteristics, and potential for recovery/recycle or disposal alternatives. The different types of waste were categorized as metal, vinyl, plastic, wood, solvents, resins, oily rags, paints, and other.

During the second step, the different types of wastes were "set in order" in a table that compiled waste generation data from different work cells. Such data quantified the total weight generated by type of material on each production line. The purpose was to identify the most critical sources and recognize the types of waste produced throughout the process to ultimately find routes to reduce, reuse, and recycle, or understand disposal purposes. Figure 8 represents an example of a data collection chart used to manage and organize the collected data.

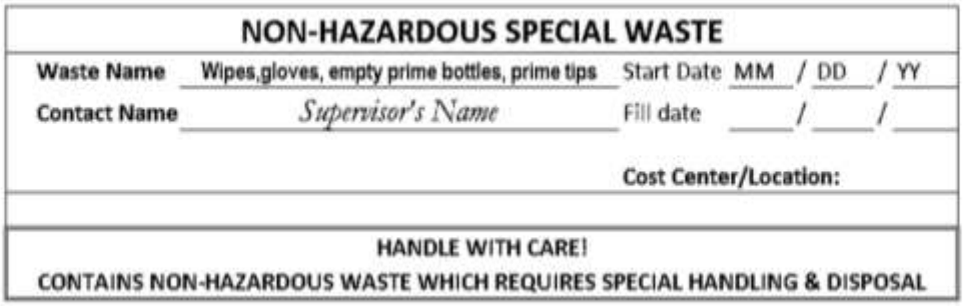
Figure 8: Sample data collection chart

Waste Composition Chart				
Product Line	Location	Types of Waste	% Total	Total Amound of Waste Generated (pounds per day)

The following step for 5S, sweep or shine, was accomplished by establishing a uniform waste categorization system. This was done by removing all multi-purpose waste baskets and replacing them with new containers that allow the users to classify the different types of waste according to its final treatment. Such containers were located adjacent to work stations, at no more than five feet away from the operator, and kept away from heat sources or incompatible materials. Different waste type containers were strategically positioned according to the category of the waste generated by the work cell.

To standardize the waste management process the different types of waste containers were labeled according to its intended content: type of waste, name of the waste, contact information of the person responsible, and the empty and fill date. Figure 9 is an example of the labels used on the containers.

Figure 9: Waste container label example



NON-HAZARDOUS SPECIAL WASTE

Waste Name Wipes,gloves, empty prime bottles, prime tips Start Date MM / DD / YY

Contact Name *Supervisor's Name* Fill date / /

Cost Center/Location:

HANDLE WITH CARE!

CONTAINS NON-HAZARDOUS WASTE WHICH REQUIRES SPECIAL HANDLING & DISPOSAL

This label was designed with the purpose of avoiding confusion at the time of waste disposal. Proper labels such as the one shown in Figure 9 avoid having numerous employees asking directions for proper categorization of waste, which could result in improper disposal and a missed recycling opportunity.

Finally, continuous monitoring of onsite solid waste storage and disposal procedures was followed to maintain a standardized operating procedure thorough the waste collection process.

Data Analysis

Statistical data analysis was conducted by utilizing a computerized data analysis package. The tool was utilized as descriptive statistical analysis to determine the composition and the amount of waste generated by each production cell.

Limitations

The main limitation of the data collection methodology was the time constraint for sample gathering at the source; also the results valued upon market demand of the product series manufactured for a given period of time. This condition jeopardized the reliability of the data. Furthermore, the collection of administrative data was limited to the volume of waste handled by the disposal service and did not necessarily reflect the true generation of waste at the plant.

Summary

With the company's decision to identify areas of opportunity throughout its manufacturing process, this project developed a methodology to implement lean manufacturing tools to assess process deficiencies on waste management tasks. This chapter has explored applicable lean methodologies to identify process deficiency indicators, and has proposed alternatives for improvement on the existing waste management processes. Value stream mapping and spaghetti diagram methodologies were utilized to identify the flow of byproduct waste throughout the manufacturing layout. Data collection charts were used to quantify the amount and proportion of waste generated in the manufacturing process, and 5S visual management techniques were used to help the different work cells categorize the waste that was produced and ultimately find treatment alternatives.

Chapter IV: Results

The purpose of this project was to recognize the current state of the waste stream across the window manufacturing process, identify the flow patterns of waste material throughout different work stations, identify waste reduction opportunities, and recommend treatment alternatives. The purpose was to formulate a coherent and more appropriate flow of waste materials across different manufacturing stages to support a framework by which best manufacturing practices can be devised to achieve greater process efficiency, cost reduction, and bottom line enhancement.

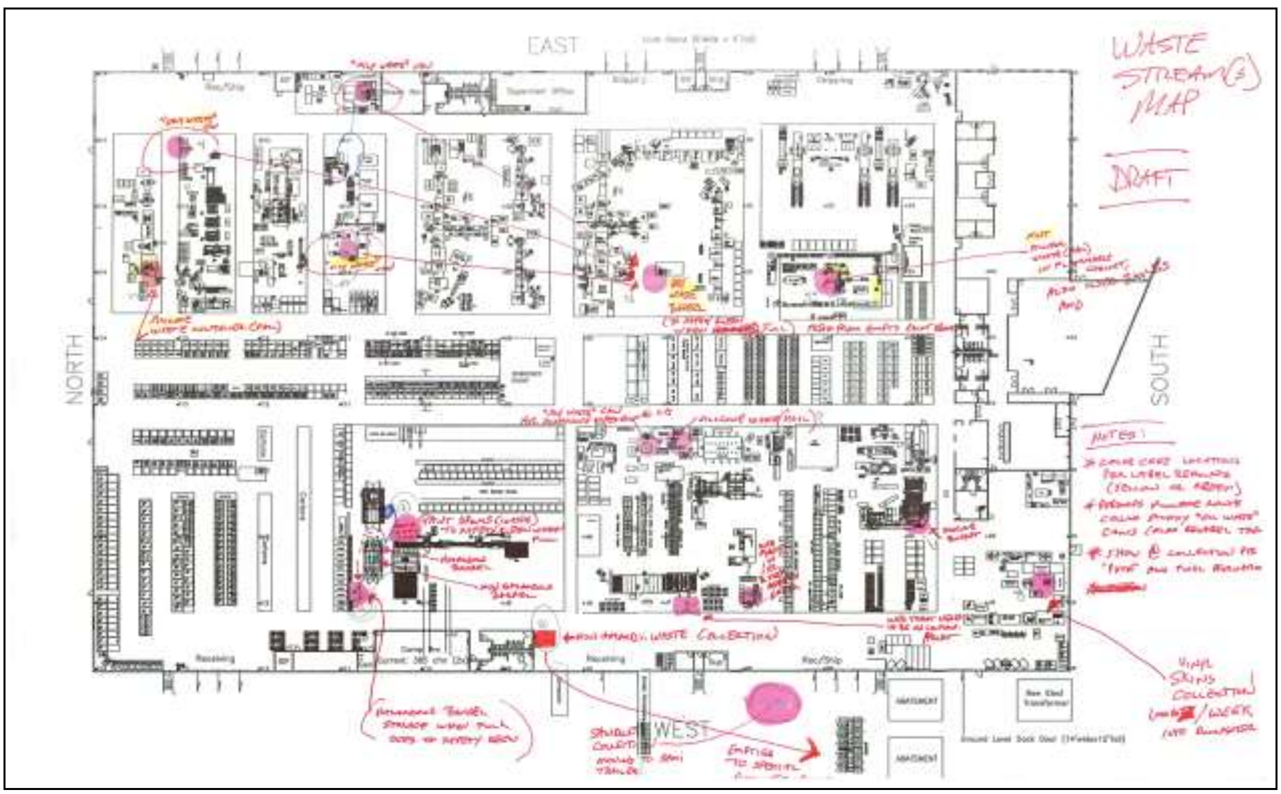
Window manufacturing operations at Company XYZ create significant amounts of byproduct waste on its various production lines. The lack of a proper procedure to handle and dispose the waste leads to significant operating costs. In order to achieve lower costs of production and increase process efficiency, lean tools have been applied to identify the flow of waste material resulting from the different stages of the manufacturing process. A spaghetti diagram was created to measure the time consumed in waste disposal activities in their current stage. Furthermore, utilizing VSM methodologies, inefficiencies were identified as a consequence for poor waste management procedures and a lack of control throughout the process. Lean 5S principles, visual systems, and Kanban were utilized to create a leaner environment that promotes a standardized process of greater efficiency.

This chapter reviews the results obtained by the identification, standardization, measurement, and evaluation of the waste management process throughout the window manufacturing process of Company XYZ; through the utilization of lean tools as the cornerstone for creating a significantly more efficient waste handling process. Some of the results obtained were cycle time reduction, distance and manpower minimization to perform the waste disposal tasks.

Waste Management Process Evaluation

Gemba walks were performed as a basis of deployment of lean methodologies and as part of the planning process for developing improvements. During this process a total of 17 waste disposal containers were identified throughout the plant layout. Figure 10 represents the stream map of waste handling throughout different working stations and its final accumulation area for ultimate treatment or disposal.

Figure 10. Waste stream map



Results from Stream Map Application

The current state of the waste stream summarizes the flow of waste handled during disposal activities. This process was randomly performed on a first-fill first-serve basis. The activity was completed on numerous waste containers, arbitrarily distributed throughout working stations.

The nature of the waste generated throughout the plant depended on the manufacturing process, the type of product that is produced and the materials used. However, a commonality found throughout the waste management process was the inconsistent use of waste containers. It was evident that there is a lack of knowledge and practice of a standardized procedure to properly categorize the various types of waste produced at different production lines. The poor or nonexistent labeling and information to support a standardized procedure for waste disposal exacerbated the problem. As a consequence, waste was not properly sorted out in a manner that constituted proper treatment or disposal alternatives. Figure 11 shows an example of waste containers with all sorts of unclassified waste products.

Figure 11: Examples of poor classification of waste

In addition to the previous illustrations, the following table summarizes the observations documented during the inspection process. Perhaps one of the most noticeable issues was the improper sorting of waste prior to its disposal, resulting in improper routing of waste and a loss of after treatment opportunity to reduce, reuse or recycle. Table 4 summarizes the findings on waste misclassification.

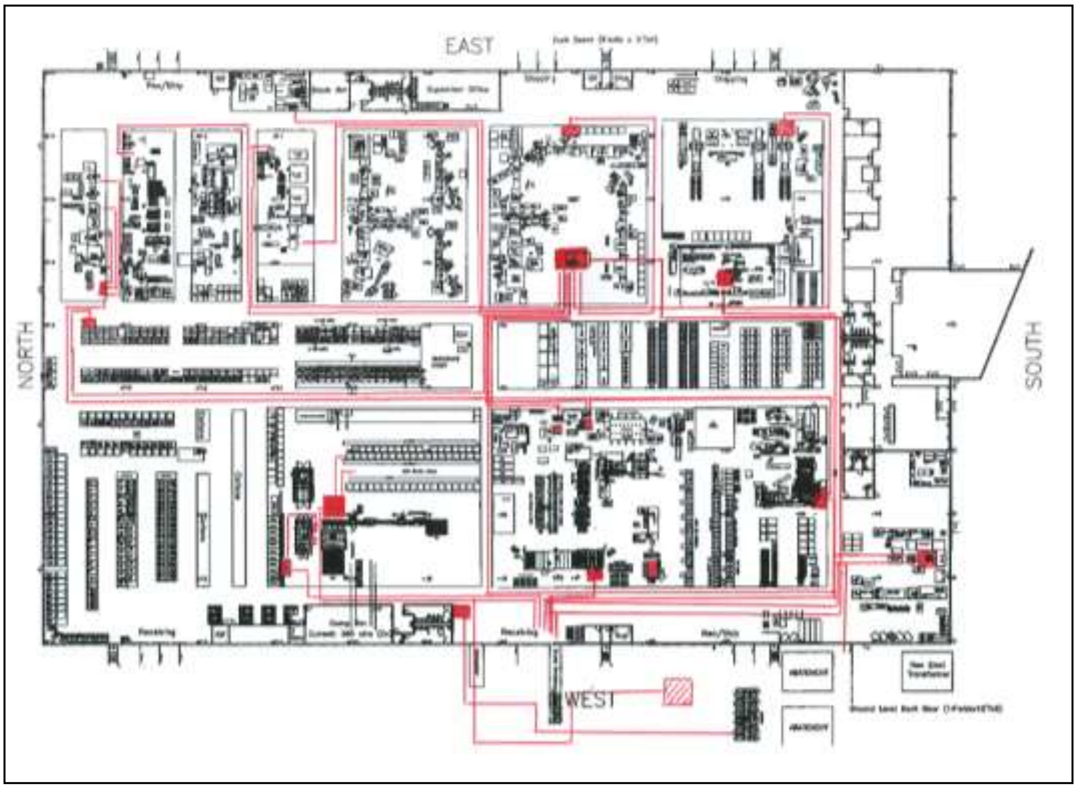
Table 4: Waste container inspection summary

AREA	CONTAINER TYPE	FINDINGS/OBSERVATIONS
Maintenance	Used ballast disposal container	Also contained used batteries
	Flammable liquid storage cabinet	Contains flammable materials (dust masks, plastics, etc.)
200-series line	Dry waste barrel	Also contained oily rags and disposable gloves
	Vinyl skin waste (PVC)	Collection: > 10.000lbs per week. Goes to landfill
A-series line	Adhesive waste container	Contained adhesive byproduct in addition to paper towels, wood, and flammable residues / Located next to circuit box
	Silicon waste container	Non-labeled
200-series supermarket	Oily waste container	Contained other materials such as metal, plastic, and wood dust.
Paint and Finish	Paint drums	Hazardous materials with Improper labeling
	Landfill waste container	Contained silicones, metals, plastic, etc
	Chemical waste drums	No containment measures and improper labeling

Time Study Using Spaghetti Diagram

The spaghetti diagram shown in Figure 12 illustrates the actual routes that the different operators take to discharge waste containers into accumulation drums. On average each operator performed this activity two times per shift. The amount of distance travelled and the total time dedicated to such non-value added activity is summarized in Table 5.

Figure 12: Spaghetti diagram and motion analysis



The main concerns of the current flow of waste material were: (1) the crossing movement of waste throughout the plant, (2) the improper categorization of waste produced by different product lines, (3) an unsuitable accumulation of waste, and (4) an excessive material movement that jeopardizes the overall process efficiency.

Table 5 shows the areas where changes to the waste management process had the greatest impact on the overall improvement of cycle times, and an overall increase in productivity.

Furthermore, the data collected in Table 5 lead to the development of improvement strategies throughout the waste management process, in terms of time spent on waste handling and material disposal.

Table 5: Loss of time and motion on waste disposal

Area/Source	**Waste Type**	**Accumulation location**	**Distance (feet)**	**Handling Time**	**Per day**	**Total Handling (min/day)**
Maintenance	Used ballast	WC4 200	Var.	15	0.16	2.5
	Flammable liquids	WC4 200	100	30	3	90
200-series operations	Dry disposable materials	WC4 200	200	15	3	45
	Vinyl skins (PVC)	FIXED units	40	45	3	135
A-series operations	Adhesive waste	WC4 200	200	25	3	75
	Silicon waste	WC4 200	350	15	3	45
200-series supermarket	Oily waste	WC4 200	400	25	3	75
Paint/treat	Paint drums	FINISHING	50	30	3	90
	Landfill accumulation container	R. DOCK #2	100	20	3	60
	Chemical waste	Treatment	100	45	3	135
		Totals	**1690 feet**			**842.5 = 12.5hr**

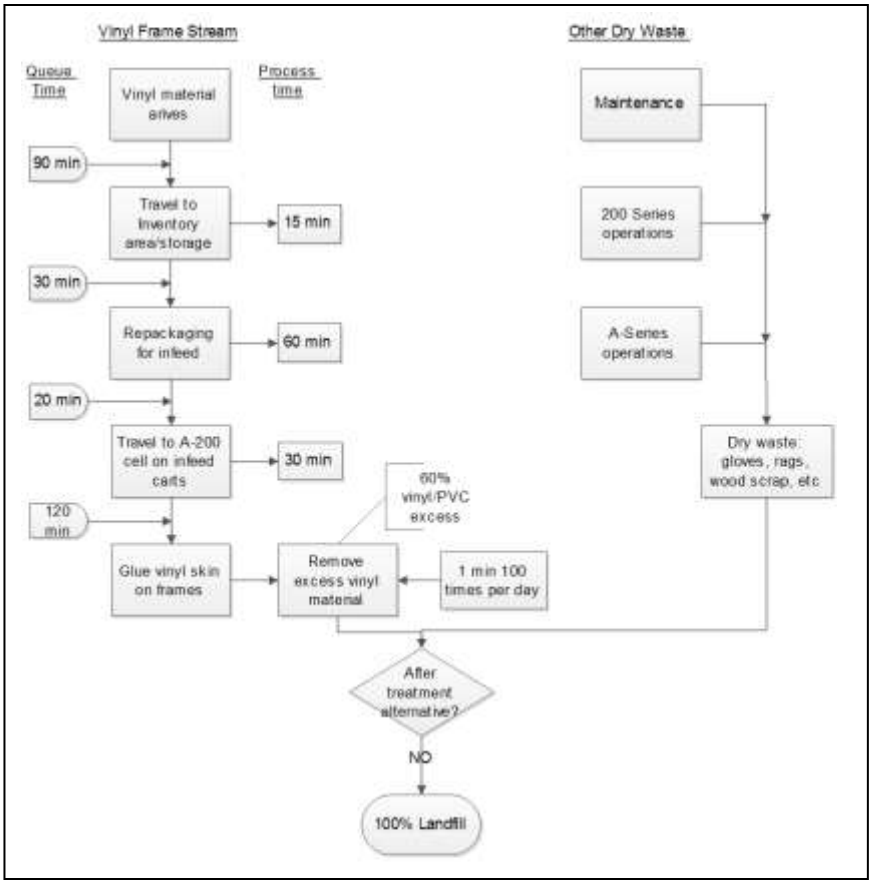
In addition, Table 6 quantifies the composition of waste generated by manufacturing operations on different production lines and summarizes the proportion of waste generated per day; this would facilitate the quantification of waste by type of material. Furthermore, it contributed in identifying proper disposal and treatment alternatives, in an effort to minimize costs and ultimately boost profitability. The waste locations used in Tables 5 and 6 are those defined during the waste stream analysis. The areas of greater opportunity for improvement, in terms of the greatest impact on minimizing costs and increasing productivity, are circled in Table 6.

Table 6. Waste stream composition

Types of Waste	Product Line/area	Total (%)	Waste Generated (lbs per day)	per week (lbs)
Packaging	A-Series and 200-Series	2%	10.53	52.63
Hazardous waste	Paint both	15%	78.95	394.73
Wood	A-series operations	12%	63.16	315.79
Glass	200-series supermarket	2%	10.53	52.63
Metals	Maintenance/Creform	5%	26.32	131.58
Other Dry Material	A-Series and 200-Series	20%	105.26	**526.32**
Off-specification products	A-Series and 200-Series	2%	10.53	52.63
Vinyl/PVC	200-series operations	38%	200.00	**1000.00**
oils	A-Series and 200-Series	1%	5.26	26.32
solvents	Finishing	1%	5.26	26.32
resins	Finishing	2%	10.53	52.63

Based on the data collected in Tables 5 and 6, several areas were identified as opportunities for improvement. The most significant areas for potential improvement were the waste stream of vinyl frames and the dry waste handling procedures. Figure 13 illustrates the waste stream of vinyl frames utilized on the A-200 series production unit.

Figure 13: Waste stream map



Potential areas for improvement on the waste stream of vinyl frames and other dry waste materials are summarized as:

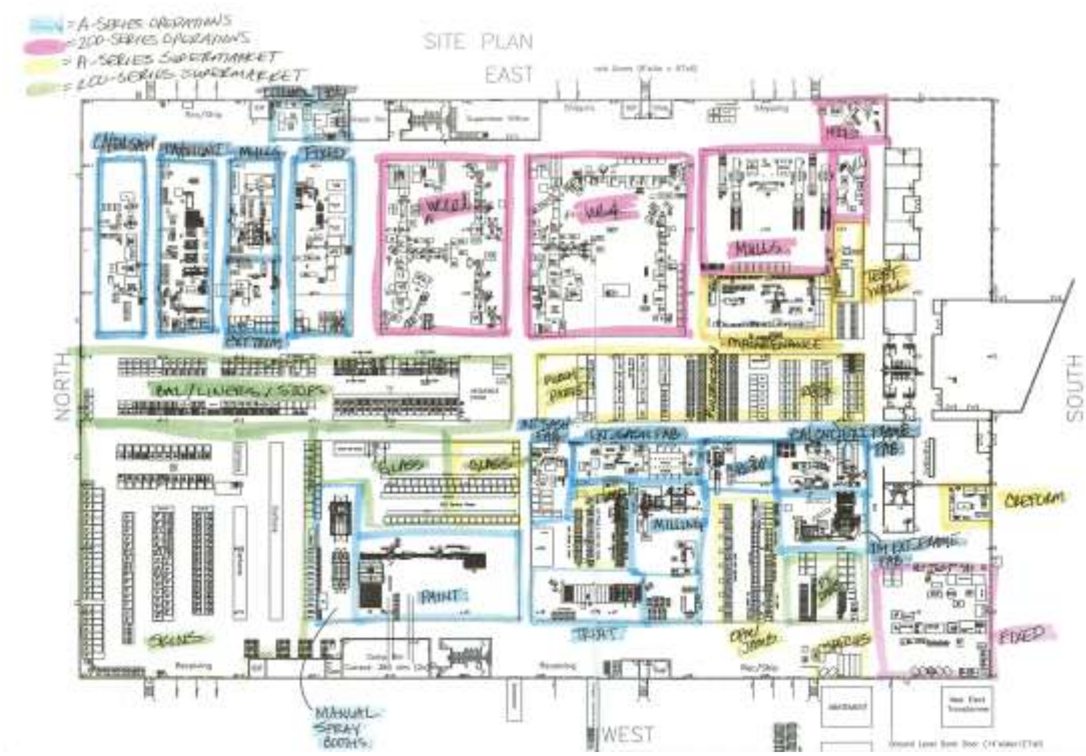
- Reduce the distance of transporting the vinyl frames from receiving to storage and inventory
- Minimize the transportation time and distance of the vinyl frames from the inventory area to the manufacturing line
- Eliminate the vinyl inventory by pulling materials from providers as needed (JIT)
- Reduce the amount of byproduct waste generated after scrap material is removed from the vinyl frames (60% waste). Reengineer raw material configuration

- Redirect the vinyl waste residues from the landfill to other alternative waste treatments, such as recycle and recovery
- Sort and categorize waste materials by type and treatment alternative (metals, wood, plastic, etc)
- Minimize the staging time of vinyl waste on the side of the production line
- Create a waste disposal and accumulation site outside the manufacturing area

5S and Visual Management Application

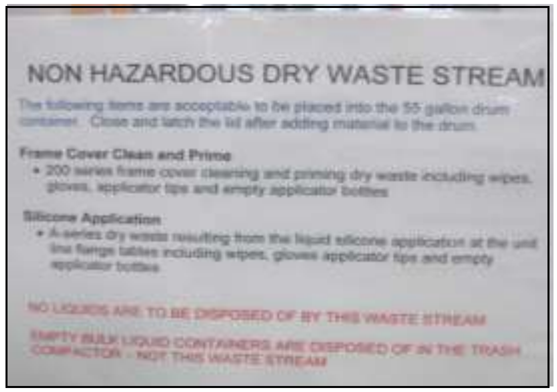
After identifying potential areas for improvement, the methodology led to utilizing lean manufacturing tools to minimize time and resources applied to the collection, transport, recovery, and disposal process of waste. This was done with the purpose of eliminating non-value added activities, thereby boosting productivity and improving production cycle times. Through the 5S methodology waste containers were sorted out by type of waste. On average, 25% of all disposed items belonged to other waste categories; thus, unwanted items were removed and reclassified into proper containers. As a second step, waste bins and accumulation drums were reorganized in a manner that minimized the distance traveled from the source of waste to the accumulation area. Furthermore, each operational area was provided with suitable containers according to the amount and the type of waste handled. Figure 14 shows the codes assigned to each waste handling location. Floor area markings were performed according to the desired location of waste containers.

Figure 14: Coded waste areas



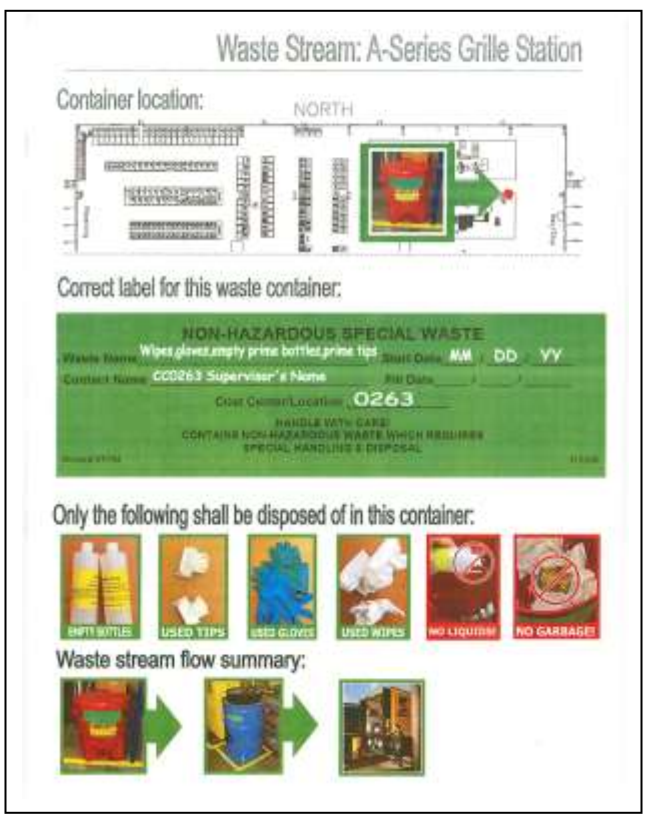
During the third step of the 5S methodology, the vinyl skin waste was relocated to the former Creform® area –south-west of the building, until further action to remove vinyl waste to an outside location was carried out, as recommended. The Creform® area was relocated to the north-east end of the building. In order to standardize the handling and disposal procedures, containers were properly labeled according to type of waste intended to be disposed into it. A standardized waste disposal procedure was communicated by detailed written instructions on the type of waste handled by any given disposal container. This allowed any new or existent operator to clearly understand the waste management process and sustain proper procedure. Figures 15 and 16 provide examples of the waste stream management processes available to operators throughout the different manufacturing areas and disposal sites.

Figure 15: Example of waste stream operating instructions



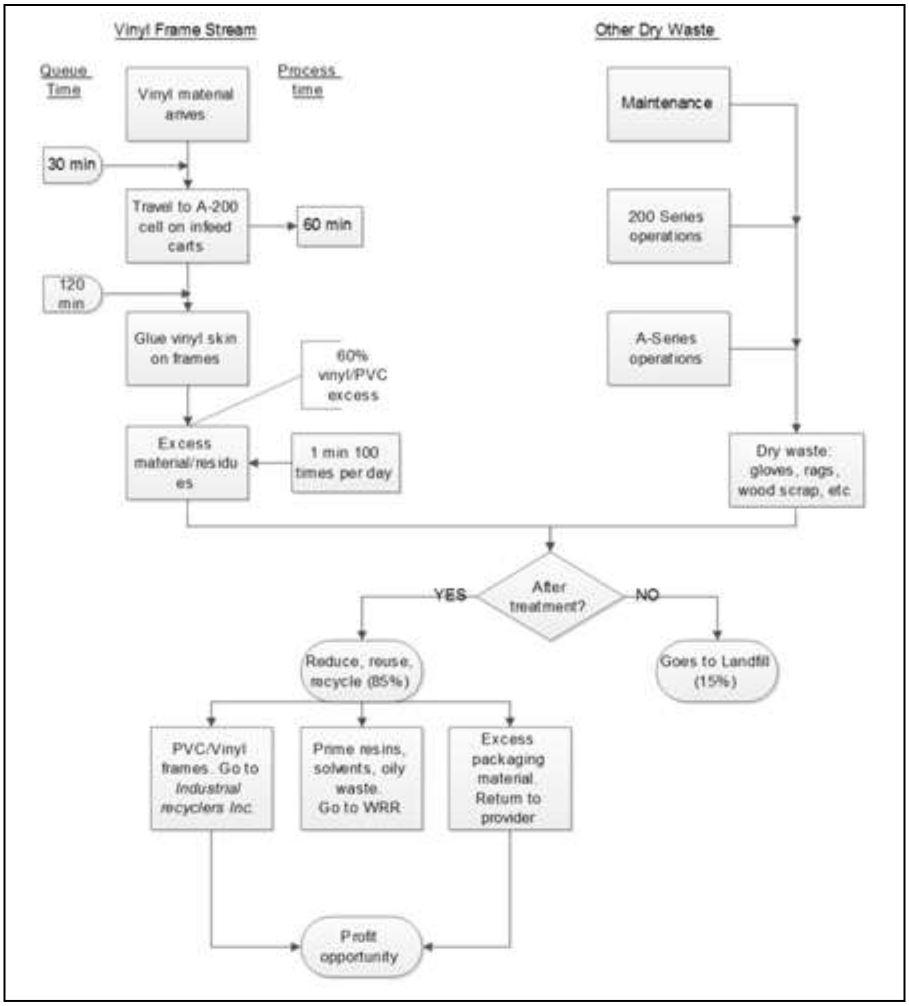
In addition to the detailed instruction provided to operators, visual management procedures were applied by creating waste stream posters over each waste container area. The intent was to create a workplace environment setup with signs to provide detailed information regarding the proper location of the waste container, the type of container to be used, and the type of waste allowed in that container, and a waste stream flow summary for proper discharge.

Figure 16: Example of waste stream visual tool



After identifying areas of potential improvement and applying lean methodologies to the overall waste management process, the future state waste stream map was developed. Figure 17 illustrates the waste management process as is expected to be in the future.

Figure 17: Future state waste stream map



Interpretation of Results

After comparing the initial stage of the waste stream against its future state, significant improvement was identified on the waste handling process efficiency. The overall time of the waste handling process was reduced from 365 minutes to 210 minutes. This represented a 57.7% decrease on the total handling time, in addition to the total handling distance reduced by 25%

and an overall increase of efficiency throughout the window manufacturing process. This was done by significantly reducing the foot print on the handling of vinyl skins, from the time of its shipping to its final utilization and the handling of byproduct waste. Furthermore, the methodology applied for the proper categorization of waste allowed the organization to divert the amount of waste that ended up in the landfill to other after treatment alternatives. The amount of landfill waste was reduced by 85% as a result of proper categorization; this was achieved by applying 5S methodologies and visual management tools so that everyone had a clear understanding of the process and knew how to do it correctly.

Summary

The intent of this chapter was to develop waste handling procedures and process improvements utilizing lean manufacturing principles. First, the stream of waste was drafted as an illustration of the current procedures and practices carried out as part of the waste handling process. Preliminary results were obtained by identifying and measuring waste management tasks throughout the window manufacturing process of Company XYZ. By utilizing spaghetti diagram the different routes of disposal were identified and then quantified in terms of the distance traveled and the amount of time engaged on such non-value added activity. After identifying vinyl skin waste and other non-categorized dry waste as the areas of greatest potential for process improvement, a waste stream map was developed. After evaluating the process, the methodology led to the application of 5S in an effort to optimize the process of collecting, transporting, recovering, and properly disposing of production waste. Different production areas were coded in order to relocate collection bins and accumulation drums, minimizing the distance traveled by an operator to dispose of waste material in their work cell.

The standardization of proper waste handling procedures was completed by applying visual management tools in the form of written instructions and waste stream posters, supported with pictures, over each waste container area. The use of such visual management tools improved the understanding and performance of the waste management process. Due to these process modifications significant improvements were observed in terms of waste handling time, distance and manpower reduction, and a significantly more efficient waste categorization process that translated into profitability opportunities as a result of the inclusion of recycled waste as a potential profit center.

Chapter V: Discussion

This project addressed the conditions of waste handling procedures across the window manufacturing process of Company XYZ. It identified flow patterns throughout the plant layout, recognized improvement opportunities, and recommended treatment alternatives.

The purpose of this project was to formulate a strategy that minimized and treated waste generated during different stages of the window manufacturing process to create a leaner, more efficient, and environmentally friendly operation that lead to a more efficient and competitive organization. By applying lean tools, the different stages of window manufacturing were identified, analyzed and controlled to address the structure and composition of its waste stream from a lean perspective.

For Company XYZ, the flow of byproduct waste required a substantial use of resources, downgrading process efficiency and negatively affecting the company's bottom line. As a result, lean principles were applied to identify, monitor, evaluate, and sustain process improvement efforts; striving to streamline, standardize and document the waste handling process while contributing to the overall operational efficiency of the organization.

Limitations of the Study

The results of the lean implementation pertain to a single manufacturing location of 212,000 sq. ft., owned by Company XYZ. The study was restricted to an specific time frame comprised from January 2012 to May 2012. The study addressed the window manufacturing process taking place within company premises, thus, the study did not involve process other than the ones involved in manufacturing operations. The project was completed within the following limitations:

1. The manufacturing process under study was limited to production factors and flow patterns exclusive to the waste composition of window manufacturing operations.
2. This study did not consider external factors that might have the potential to jeopardize the applicability of the measures suggested by this project.
3. The research was limited to current manufacturing layout, process and flow patterns attributed to the current state of the manufacturing process.
4. Any applicable improvement measures concerning process layout configuration and work flow change did not modify the conditions of the process subject of this study.
5. Proposed measures were subject to the marketable conditions of waste products, its financial feasibility, and the technology available.
6. The implementation of improvement recommendations was limited to the company's approval and subject to the conditional terms of the management team.
7. The waste stream under the scope of this project was limited to manufacturing operations within the organization. Further analysis of extended waste streams might reveal other improvement opportunities not considered in this project.
8. This project was limited to the physical conditions of the work area and did not consider workforce behaviors into the collection and interpretation of results.
9. The scope of this project did not address employee training to ensure a clear understanding of implemented procedures

Conclusion

As an overview of lean manufacturing, this project has highlighted significant traits of the implementation of lean manufacturing principles. It has identified the different types of waste that can be generated in a manufacturing process, and has analyzed the tools utilized by lean manufacturing to identify and eliminate byproduct waste from the window manufacturing process.

The company under study has shown a significant level of awareness of lean manufacturing, aiming at systematic improvements in cost reduction, quality enhancement, customer satisfaction, and social responsibility. For this organization, a full lean implementation seems to be a logical step for process improvement and bottom line enhancement. Numerous lean initiatives have been embraced by management to pursue a full implementation of lean manufacturing. However, the organization still has room for process improvement by implementing some other lean manufacturing tools, particularly on non-value added activities, such as waste handling and disposal.

Throughout this project, the application of lean principles has allowed a better understanding of the conditions regarding the waste stream of window manufacturing. This has been possible through applying value stream mapping to the waste handling process, the implementation of 5S principles, and the use of visual management tools; all proven to contribute on significant process improvements.

Lean manufacturing can be described as a continuous and collective effort of process improvement that pursues system integration and operative excellence of performance under the shadow of perfection. This project was successful in applying lean philosophy to the waste stream of window manufacturing, allowing the company to work smarter and improve overall process efficiency, but most significantly, it has identified a direct relation between proper waste handling procedures and cost reduction opportunities that have a positive impact on the company's bottom line.

Recommendations

- Identify responsible staff: In order to have a successful waste management program, employees should be assigned accountability for both the initial implementation and continuous improvement efforts. Proper designation of the employee responsible and a clear description of their role will most certainly result in an effective waste management program. Designate a person responsible to guarantee proper labeling of all waste containers. Designate the person responsible to ensure proper waste disposal procedures are in place. Designate work shift teams responsible for the collection, accumulation and disposal of waste.
- Employee training: Proper handling and disposal will be achieved by ensuring that all employees are familiar with the procedures for waste handling, related to their day-to-day responsibilities during manufacturing operations. The company should develop a training and information program for all employees who are expected to be dealing with waste in their work area. Training would be the best method to ensure that employees are well informed and understand the waste disposal procedures, thus minimizing errors in the categorization and handling of waste. Employees should be trained at the time of the initial waste management implementation procedure, whenever a new product is introduced to the work area, and whenever insufficient knowledge on waste management procedures is identified by the supervisor.

- Assigning accumulation time limits: It is recommended that large quantities of waste do not accumulate for a period of time greater than two days from the date is generated, unless a waste designated area is built outside the facility. The length of time the waste has been accumulated should be demonstrated by applying proper labeling to the container with the earliest date that the container was utilized.
- Labeling: The primary source of information should come from container labels. The purpose of labeling containers is to inform the operator about the material that it contains. These labels should include a marking of the individual items of waste, with the earliest date any type of waste was received.
- Waste locations: Different waste containers should be relocated to meet the needs of the waste pattern. These containers should be located according to the configuration of waste on different production lines.
- Develop a written waste management program: Employees should be properly informed about the waste management performance that is expected from them. This is to be accomplished by means of developing a written waste management program. The written program is a record of what the company has done to guarantee that employees conform to company expectations regarding waste management procedures. This document should include the company's waste management policy, the types of waste generated by work cell, the physical and chemical properties of waste products, treatment alternatives, and contact information of waste management contractors, employee training, and labeling requirements.
- Treatment and disposal: It is recommended that all the types of waste generated as a result of manufacturing operations be treated before it can be considered for landfill

disposal. This should be done by contracting specialized services to classify, manage and treat waste after it's generated on site.

- Energy recovery alternatives: The company should look into implementing onsite energy recovery technologies as a means to generate their own electricity, minimizing costs and reaching a green status of 100% no-landfill waste.
- Periodic waste analysis: It was recommended that before considering any treatment, storing or disposal of waste the company performs a detailed physical and chemical analysis of the type of waste. This analysis must be kept under record for future reference and to guarantee an appropriate treatment and disposal alternative.
- Team work enhancement: Other opportunities for waste identification and handling should be accomplished by allowing active participation of everyone in the organization. This would reinforce the lean value of workers' collaboration at every level, promoting a teamwork environment for the attainment of process improvements.
- Periodic audit planning: Scheduled and unscheduled audits should be performed to evaluate the process against the written standards.

Further analysis on the waste stream of window manufacturing should be conducted in order to further identify areas of potential process improvement pertaining to reduction, recovery and recycling alternatives for the entire waste stream throughout the organization, including non-manufacturing areas.

References

Acharya, T. K. (2011). Material handling and process improvement using lean manufacturing principles . *International Journal of Industrial Engineering*, 18(7), 357-368.

Ahrens, T. (2006). *Lean production: Successful implementation of organizational change in operations instead of short term cost reduction efforts*. Lean Alliance.

Babcock, P. (Ed.). (1981). Webster's third new international dictionary. Springfield, Massachusetts, U.S.A: G. & C. Merriam Company, Publishers.

Black, J. T., & Phillips, D. T. (2010). The lean to green evolution. *Institute of Industrial Engineer*.

Chalfan, L. (2001). Zero waste - key to our future: The case for zero waste. *Zero Waste Alliance*, Retrieved from http://www.zerowaste.org/publications.htm

Conway, W. E. (1994). *Winning the war on waste: Changing the way we work*. Nashua, NH: Conway Quality, Inc.

Chase, R. B., Aquilano, N. J., & Jakobs, F. R. (1998). *Production and operations management: Manufacturing and services.* (eight ed.). McGraw-Hill.

Chen, L., & Meng, B. (2010). The application of value stream mapping based lean production system. *International Journal of Business and Management*, *5*(6), 203-209.

Czabke, J., Hansen, E.N. & Doolen, T.L. 2008, A multisite field study of lean thinking in US and German secondary wood products manufacturers. *Forest Products Journal*, vol. 58, no. 9, pp. 77-85

Dossenbach, T. (2007). Using pull systems for higher profits part 1 - inventory control. *Wood & Wood Products*, *112*(8), 27-28

Dennis, P. (2007). *Lean production simplified: A plain-language guide to the world's most powerful production system.* (2nd ed.). Productivity Press.

Edraw. (2004-2012). *Value stream mapping template*. Retrieved from http://www.edrawsoft.com/Value-Added-Flow-Chart.php

Garza, L. A. (2005). *Integrating lean principles in automotive product development: Breaking down barriers in culture and process*. (Master's thesis, Massachusetts Institute of Technology).

Harris, C., Harris, R., & Streeter, C. (2011). *Lean supplier development: Establishing partnerships and true costs throughout the supply chain*. New York, NY: Productivity Press..

Huntzinger, Jim (2002). The roots of Lean. Training Within Industry: The origin of Kaizen. Association for Manufacturing Excellence, 18, No. 2. pages 9-22. Retrieved January 16, 2011 http://www.leaninstituut.nl/publications/Roots_of_Lean_TWI.pdf

Kato, I., & Smalley, A. (2011). *Toyota kaizen methods: Six steps to improvement*. New York, NY: CRC Press

Martin, K. (2012). *Lean terminology*. Retrieved from http://www.ksmartin.com/resources/terminology.html

Layout. (2012). In Merriam-Webster online. Retrieved from http://www.merriam-webster.com/

Laquatra, J. (2011). Toward more sustainable construction. *iGreenBuild,* Retrieved from http://www.igreenbuild.com/cd_3589.aspx

LaBissoniere, M. D., and Bowe, S. A. (2006). Estimating the impact of foreign competition on the Wisconsin wood furniture industry. Part 2. A qualitative analysis, *Forest Products Journal* 56(3), 23-28.

Lean Enterprise Institute. (2009). *What is lean?*. Retrieved from http://www.lean.org/WhatsLean/

Liker, J. K. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer.* New York: McGraw-Hill Education.

Little., & McKinna, (2005, June). A lean manufacturing assessment tool for use in SME's. Paper presented at Proceedings of the seventh SMESME international conference: stimulating manufacturing excellence in small & medium enterprise , United Kindom.

Liker, J. K., & Morgan, J. M. (2006). The toyota way in services: The case of lean product development. *Academy of Management Perspectives* , 5-20.

Luria, D. (2006, April). *Manufacturing matters and you matter to manufacturing*. Work force strategies forum.

Mann, D. (2005). *Creating a lean culture: Tools to sustain lean conversions.* New York, NY: Productivity Press.

Martichenko, R., & Grabe, K. (2010). *Building a lean fulfillment stream* . Cambridge, MA, USA: Lean Enterprise Institue.

Ohno, T. (1988). *Toyota production system: Beyond large-scale production*. Cambridge, MA: Productivity Press

Ortiz, C. (2006). *Kaizen assembly: Designing, constructing, and managing a lean assembly line*. Boca Raton, FL: CSR Press.

Pirraglia, A., Saloni, D., & Dyk, H. (2009). Status of lean manufacturing implementation on secondary wood industries including residential, cabinet, millwork, and panel markets. *Bioresources.com*, *4*(4), 1341-1358.

Ray, C. R., Zuo, X., Judd, M., & Wiedenbeck, J. (2006). The lean index: Operational lean metrics for the wood products industry. *Wood and Fibers Science Journal, 38*(2), 238-255.

Ricoh, G. (2001). Ricoh group sustainability report. *2001*, 01-76. Retrieved from http://search.ricoh.jp/rgl/search.x?q=zero waste to landfill&ie=utf8&unit=rgl&mode=rgl&page=4

Rother , M., & Shook, J. (2009). *Learning to see*. (Student ed. ed.). Camridge,MA: Lean Enterprise Institute.

Siemieniukk, (2007) Diagram spaghetti kilka produktow extracted from http://en.wikipedia.org/wiki/File:Diagram_spaghetti_kilka_produktow.PNG

War Production Board, Bureau of Training, Training within Industry Service. (1945). *The training within industry report: 1940-1945*. Washington DC: U.S.: Government Printing Office.

Womack, J. P., Jones, D. T., & Roos, D. (1991). *The machine that changed the world*. Harper Perennial

Womack, J. P., & Jones, D. T. (1996). *Lean thinking: Banish waste and create wealth in your corporation*. New York, NY: Free Press.

Womack, J. (2005). *Problems with creativity. Manufacturing Engineer, 84*(3), 5-5.

Worley, J., & Doolen, T. (2006). The role of communication and management support in a lean manufacturing implementation. *Management Decision*, *44*(2), 228-245.

Widyadana, G., Wee, H., & Chang, J. (2010). Determining the optimal number of kanban in multi-products supply chain system. *International Journal of Systems Science*, *41*(2), 189-201.