Value Stream Mapping of a Rubber Products Manufacturer

by

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ABSTRACT

The purpose of this study is to develop a plan for reducing lead-times and increasing throughput in a rubber product manufacturing plant by using value stream mapping. The plant produces rubber screening media and wear products used in the mining and aggregate industry that is sold throughout the western hemisphere. A worldwide increase in demand for raw materials has caused sales to increase tremendously for screening and wear media products. The increased workload at the plant has resulted in longer lead-times even though the plant's capacity has not been exceeded. The rubber products manufacturer is inefficient because it produces products in batch quantities and has poor product flow due to operations being departmentalized. The increase in lead-times could cause a loss in the market share to its competitors. The rubber products manufacturer must reduce its lead-times in order to remain competitive and continue its growth by providing quality products in a timely manner.

A study will be carried out using value stream mapping to determine areas of potential improvement on the plant floor. A current state map will be developed and analyzed to pin point areas that have potential for improvement. A future state map will then be created to suggest ways to reduce lead-times and increase throughput. The map will include lean manufacturing methods to reduce wastes in the system; increasing throughput and reducing lead-times.

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This research paper is dedicated to my beautiful and caring wife. She always has provided me with love and support in all my efforts, giving me the encouragement to always challenge and better myself. I would also like to thank my advisor for his assistance in guiding me through this process.

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Chapter I: Introduction

The company researched is a midsize manufacturer of screening and wear media for the mining and aggregate industry. The products the company produces are sold and used throughout the western hemisphere; from the artic to the southern part of Chile, South America. The company has seen a dramatic increase in sales due to the increased worldwide demand for raw materials. Mines are in full production trying to satisfy the demand for steel and metals, aggregate plants are busy supplying gravel and sand for concrete and asphalt. The company has seen record numbers in the past two years and is growing at a steady rate. Although the company is achieving record sales, their profit margin is decreasing and product lead-times are increasing. The company is growing but working harder at making less. The increase in customer orders has turned the company into chaos; production workers scrambling to get material to build product and managers struggling to keep orders on time.

The company manufactures several lines of product producing hundreds of different parts, many of those being custom. Many refer to the business as a job shop, however most parts can be broken down into just a handful of part families. The focus of the study will concentrate on rubber modular screen panels; a family of parts that comprise approximately 55% of all the rubber products produced.

The rubber manufacturer builds to customer orders; very few products are stocked. There are so many styles and sizes available that stocking would not be practical. Jobs on the factory floor are run in a batch mode, usually comprising the entire order. If the order calls for 20 parts, 20 parts are in a batch; if the order calls for 500 parts, 500 parts are in a batch. High levels of work in process (WIP) are created as pallets of products move from one department to the next. In addition, many processes are only manned on one shift; piles of product are queued in front of machines as pallets are dropped off from the other two shifts. Products move slowly though the plant as they wait for processing. This creates high levels of work in process (WIP), long lead-times, and a reduction of available floor space.

Statement of the Problem

This study will address lead-times for rubber modular screen panels at company XYZ. Current lead-times are higher than in the past and may lead to lost market share and stunt planned growth. Batch processing of parts and departmentalized machines are key contributors to long lead-times. In addition, complex production scheduling and planning are required, frequent planning mistakes and miscommunications add to the long lead-times.

Purpose of the Study

The purpose of the study is to suggest ways to reduce lead-times and increase throughput of rubber module panels at a rubber products manufacturer. Reduced lead-times will help the company retain and expand its customer base while increased throughput will help get more products out the door to existing and new customers. To accomplish this, value stream mapping will be used to help identify potential areas of improvement and suggest ways to fix problem areas. A current state map will help identify areas that cause excessive lead-times. Lean manufacturing methods will be used to create a future state map. The future state map will suggest ways to reduce manufacturing lead-times and increase throughput.

Assumptions of the Study

First assumption: All preexisting data is reliable and accurate.

Second assumption: Top-level management will give support and backing.

Third assumption: The model is created and the suggestions given are based on one product line; factors outside this product line are not considered.

Forth assumption: Not all suggestions may be effective at reducing lead-times or increasing throughput.

Fifth assumption: The results of the study will only apply to the company that is the focus of the research.

Definition of Terms

Batch mode: Producing large quantities of product before it is needed by the subsequent operations.

Changeover: The time required to change a process or machine from one product line to the next.

Continuous flow: The process where a product moves from one manufacturing operation to the next, one piece at a time without stopping.

Current state map: A diagram that models the present day conditions of a manufacturing process of a particular product family.

Cycle time: The time that elapses from the beginning of a process or operation until its completion

ERP: Enterprise Resource Planning.

First-in-first-out System: An inventory system used when continuous flow is not possible. WIP that is put into the system first is the first to leave the system.

Flow: The movement of information or material. The idea of flow in lean manufacturing is to have information and material move uninterrupted as little as possible.

Future state map: A diagram that suggests ways to reduce lead-times and increase throughput.

Lead-time: The time is takes to produce a product from beginning to end.

Lean Manufacturing: The concept of minimizing waste.

Manufacturing cell: A group of machines or workstations that work in a continuous flow fashion.

Muda: Japanese word for waste. Used in reference to wastes in a manufacturing system

NVA: Non-value added

Product family: A group of parts or products that share the same resources or manufacturing process.

Pull system: An alternative to scheduling individual processes, where the customer process withdraws the items it needs from a supermarket and supplying process produces to replenish what was withdrawn. (Duggan, 2002)

One piece flow: See continuous flow

Supermarket: An inventory system to control a set quantity of WIP or inventory for upstream processes.

VA: Value added

Value: Information or material in the form that a customer is willing to pay for.

Value stream: Involves all the steps, both value added and non-value added, required to complete a product or service from beginning to end.

Value stream mapping: Visual representation of a value stream. A tool that helps reveal wastes and problems with flow.

Waste: Anything within a value stream that adds cost or time without adding value. (Tapping, Luyster & Shuker, 2002)

WIP: Work in process. Unfinished product that is in queue or waiting for additional processing

Work order: Documentation used on the shop floor to build the product, includes prints.

Limitations of the Study

- The research was limited to the manufacturing process of rubber modular panels at division 3 of company XYZ.
- There is a significant cost to complete the changes and implement the new system.
- There are a limited numberof people and resources that can be dedicated to the implementation and training.
- Manufacturing space is very limited. The current facility has many structural walls and features that would be too difficult or expensive to move; changes must be made within the limits of the facility itself.

Methodology

This study first started with the gathering of information from the company's ERP system and collecting data from the shop floor. The information that was collected was used to develop a current state map of the production of rubber modular panels. The current state map was then analyzed to identify potential areas for improvement. Lean manufacturing techniques were then utilized to develop a future state map. The future state map suggests ways to reduce lead-times and improve manufacturing efficiency. The maps, both current and future, were then presented to management and plant floor employees to obtain feedback. The feedback was used to make other improvements and suggestions for future process improvement action items.

Chapter II: Literature Review

The literature review will concentrate on giving an overview of lean manufacturing and will describe how value stream mapping is a fundamental component of lean manufacturing.

Lean is described as the removal of "muda." Muda is a Japanese word that means waste, specifically any human activity which absorbs resources but creates no value (Womack & Jones, 1996). Lean thinking is a systematic approach for identifying and eliminating wastes. In a manufacturing environment, piles of excess product or WIP waiting in queue are a waste; consuming floor space and increasing the time a product takes to flow through the plant. Forklifts transporting goods from one point to the next are waste. Unnecessary movements of people during the course of their work are wastes. These examples are considered wastes because they are activities that absorb resources but create no benefit for the customer. Lean is identifying and eliminating any wastes that do not create value.

Lean revolves around the elimination of muda or waste, therefore it is important that this concept is well understood. The seven major forms of waste are listed below (Conner, 2001).

1. Wastes from over-production
2. Wastes from waiting
3. Transportation waste
4. Processing wastes
5. Inventory wastes
6. Waste of motion

7. Waste from product defects

The first form of waste is over-production. Over-production is making anything ahead of demand. An example of over-production would be making drawings before they are needed. Finishing a task before required is considered a waste because this taxes resources at the wrong time and leads to excess work in progress (WIP).

The second form, waiting, is another form of waste. Waiting is caused by delays from previous steps or processes. For instance, when an operator must stop a task due to unavailable or incorrect information, this is a waste. Waiting also refers to the job or part itself having to wait; parts that are in queue are waiting for available resources. Any waiting, by a person or job, is waste because it increases the lead-time and creates inefficient use of resources.

Transportation is the third form of waste; it absorbs time and resources to perform a task that has no value to the customer. Even though moving product from one station to another may be necessary, it still creates no value. Steps should be taken to ensure that only minimal transportation occurs. It is common to see departments spread out on opposite sides of a facility where product crisscrosses a plant several times before completion. This transportation is a waste.

The fourth form of waste is over-processing. Over-processing is doing more than necessary. An example would be generating more data then is required. Time and resources are consumed to obtain and enter data; if this data is not used, it is a waste. Over-designing or over-analyzing are also a forms of over-processing. Again, these consume time and resources which are a waste if they are not needed.

Inventories, the fifth form of waste, are work or product that is beyond the absolute minimum needed. Stocking parts before they are sold is a waste; they tie up dollars and occupy space while they sit. The idea in lean manufacturing is to not make anything before it is needed. Another form of inventory is work in progress (WIP). Product in queue wastes floor space and increases the time that a product is on the production floor. Large quantities of WIP are indications that a product has much higher lead-times than necessary.

The sixth form of waste is excess movements or motions. If an employee has to walk to access data storage or has to bend down to reach the next job, these are excess motions or movements. Excess motions or movements are often some of the most frequent and easily remedied wastes. Simply moving the data storage area to a centralized location or placing a cart close to the work area can reduce or eliminate the excess motions or movements.

The seventh and last waste is product defects. Anything that does meet the customer requirements is considered a product defect. Defects are waste because they require product rework. Time, material, and resources are consumed twice to produce the product.

Lean is eliminating wastes from a manufacturing system. The problem arises in how a manufacturing facility becomes lean. There are five steps to becoming lean (Womack & Jones, 1996)

1. Define the value
2. Identify the value stream
3. Flow the product

4. Pull
5. Strive for perfection

The critical starting point for lean thinking is value. Value is the information or product that the customer is willing to pay for and can only be defined by the ultimate customer (Womack & Jones, 1996). The value is defined by the customer and created by the producer. From the customer's standpoint, this is why the producer exists (Womack & Jones, 1996). Many producers only want to make what they are already making and the customers will often settle for what they are offered. Producers do not see what the customer or consumer really wants. When the customer no longer accepts what they are given, producers tend to use techniques such as lowering pricing or offering a variation of the same in order to entice buyers to purchase their product. The first step in lean thinking is to determine what the value is in terms of the customer.

The second step in lean thinking is to identify the value stream. A value stream comprises all of the actions, both value added and non-value added, required to bring a product from raw material into the hands of the customer (Duggan, 2002). A value stream map is a tool used to chart the flow of materials and information from the raw material stage, through the factory floor, to the finished product. The purpose of the map is to help identify and eliminate waste in the process. It is a systematic approach that empowers people to plan how and when they will implement the improvements that make it easier to meet customer demand (Tapping, Luyster & Shuker, 2002).

Value stream mapping is a visual representation of the material and information flow of a particular product family (Tapping, Luyster & Shuker, 2002). Value stream mapping consists of the creation of a current state map and a future state map. The current state map charts the present flow of information and material as a product goes through the manufacturing process. Its purpose is to help understand how a product currently flows. The future state map is a chart that suggests how to create a lean flow. The future state map uses lean manufacturing techniques to reduce or eliminate wastes and minimize non-value added activities. The future state map is used to help make decisions and plan future process improvement projects.

Value stream mapping has many benefits. Mapping will help visualize the entire production of a product at a plant level, not just single process level. It is important to be able to understand the entire flow of a product at a plant level to best understand what to fix. A particular process may appear to be a problem, but when looking at the entire manufacturing process it may not be a problem at all. Value stream map will help identify the source of the real problems. Value stream maps will help show wastes and more importantly help identify the sources of waste.

The third step in lean thinking is flow. Flow is the progressive achievement of tasks along the value stream so that the product proceeds from raw material into the hands of the customer with no stoppages, scrap, or backflows (Womack & Jones, 1996). Once started, product will advance through a manufacturing plant without stopping. A product should seamlessly move forward from process to process without having to wait. Value added time to the product needs to be maximized and non-value added time minimized. In order to accomplish this, the product must continually be undergoing processing until finished. Efforts need to be directed at eliminating all impediments to continuous flow.

The fourth step in lean thinking is pull. Pull is the concept of letting the customer pull the product from you as needed rather then pushing products onto the customer (Womack & Jones, 1996). Pull is only making what the customer wants and only when the customer wants it. There is no forecasting or stocking. The idea is that nothing is made until it is needed, and then made as quickly as possible. Pull is created by having the ability to design, schedule, and make exactly what the customer desires when the customer wants it.

The final step in lean thinking is perfection. There is no end to the ability to reduce costs, scrap, mistakes, space, etc. Perfection is an unachievable goal; therefore, there is always room for more improvement. Lean is always working towards improvement.

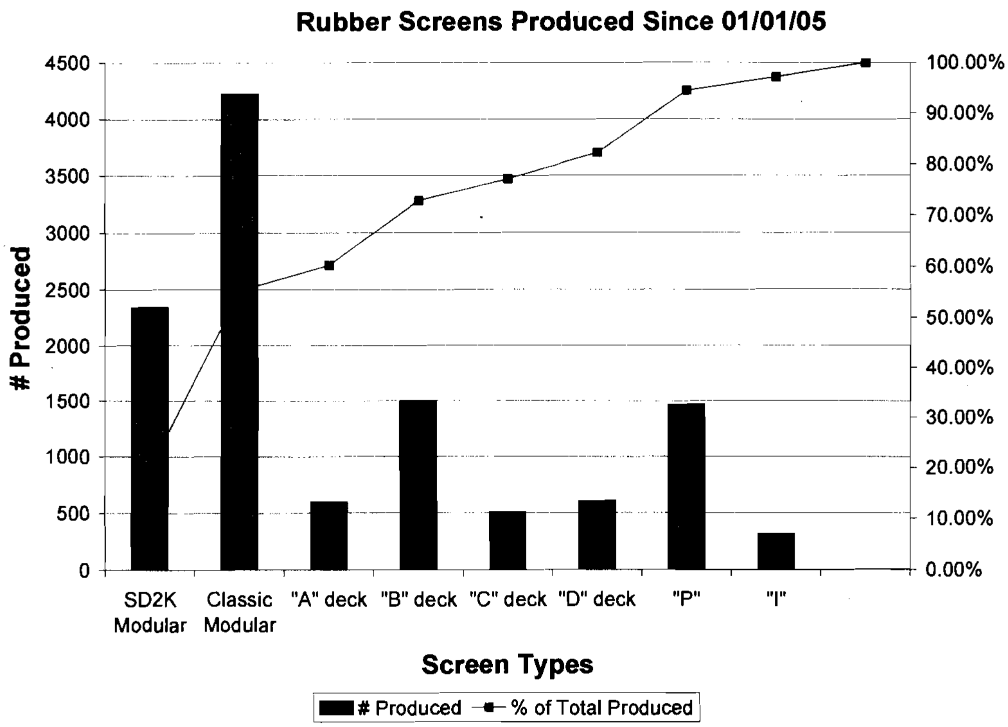
Chapter III: Methodology

The purpose of this study is to find ways to reduce lead-times and increase throughput for rubber modular screen panels at company XYZ. Current lead-times are higher than in the past and may lead to lost market share and stunt planned growth. Batch processing and departmentalized machines are key contributors to long lead-times. Value stream mapping will be used to help identify areas of potential improvement to reduce lead-times and increase throughput. Information will be gathered using information stored in the company's ERP system and by observations made on the shop floor. This information will be used to construct a current state map that will show the flow of information and material for a rubber modular screen panel. The data will then be analyzed to determine areas that need the most improvement. These areas will be further analyzed and lean manufacturing techniques will be suggested to lower the lead-times and increase throughput. The suggestions will be used to create a future state map that will provide a guideline for improvements that can be made.

Subject Selection and Description

The study will focus solely on rubber module screen panels at division 3 of company XYZ. Rubber modular screens were selected because they comprise approximately 55% of the screen panels that are produced in rubber. Hundreds of different styles of rubber modular screen panel are produced at company XYZ. Almost all of these panels require the same manufacturing steps to produce them; making modular rubber screen panels a good part family to concentrate the study on. Table 1 shows the PQ analysis of the rubber screens produced.

Table 1: PQ Analysis of Rubber Screens



The first step in the current production method is customer service releases an order to production. Production control will review the order and check the bill of materials to verify that the correct materials are on hand. Any materials that are not in stock are ordered. Production control then releases the work order to the shop floor. Scheduling and planning are discussed between the plant supervisor, planner, and production leads. Orders are often scheduled based on ship date and resources available. The first step in the fabrication of the panel is in the metal fab department. Metal is cut and welded to make the internal support structure for the panel. Stock bars are often used as parts in the internal frame construction. The operation currently runs in a batch mode were all the frames are cut and welded before being transported to the next station or department. The thinking behind this mode of production is to avoid having to change set ups and produce parts more efficiently by not stopping processing. After the parts for the order are cut and welded they are transported by forklift to the next operation; media blasting. All internal framework needs to be blasted in order for an adhesive to work properly. Large piles of WIP accumulate in front of the blast machine because the blast machine is only manned full-time on second shift. Some blasting does occur when operators from other departments blast their own parts. After blasting is completed, the entire order is placed in queue until just before the frames are ready to be used in the rubber pressing operation. When the order is ready to be processed in the rubber press, the rubber press operator goes and looks for the blasted framework. Space is limited so finding the framework can be difficult because there is no set staging area for WIP. The frames are then brought to the priming booth where an adhesive is applied. The adhesive assures a good bond between the internal metal framework and the rubber that will be pressed around it. The application of adhesive is not done in a batch mode; the adhesive is applied only to the framework that will be used next in the rubber press. This is often only 2 to 4 pieces, common order or batch sizes can ranges from 20 pieces to several hundred pieces. At the rubber press, the frames are placed in an open mold. Unvulcanized rubber is cut and weighed, then placed into the mold. The mold is then positioned into a press where heated platens press the rubber around the framework into the mold. The pressure is held for several minutes until the rubber is molded and vulcanized. At this point, the mold is removed from the press and demolded. The demolded part is then placed on a pallet nearby the rubber press. This process of applying the adhesive and molding the part is repeated until the entire order is complete. When the entire order is on the pallet, it is moved from the rubber department to the finishing department. The finishing department consists of three processes. The first process is trimming, where flash that is produced in the molding operation is removed. The second operation is a clickering process where a punch removes a film of rubber that is produced over the screen openings. The third operation is sawing where the panels are cut square and to length. When the panels are finished at the rubber press, they are transported via forklift to the finishing area. The panels are first trimmed to remove flash. Again, this is an operation done in a batch mode. All the parts are picked up one by one from the pallet and carried to a trim table. The part is trimmed and then carried by hand to another pallet. The parts are not moved to the next operation until all the panels are trimmed. It should also be noted that there are often large piles of WIP in front of the trimming table because most of the trimming only occurs on first shift. After the entire order of parts is trimmed, they are moved to the clicker. The clicking operation will also often have large amounts of WIP around the machine as large pallets of parts are passed to clickering from trimming. The parts are picked up by hand from the pallet and clickered. After the clickering operation, the parts are then again placed on a pallet to await a sawing operation. The saw is in relative close proximity to the clicker therefore it is not necessary to move the pallet. Once again, large amounts of WIP are on the floor as sawing is only performed on the second shift. The panels are picked up off the pallets by hand by the saw operator and placed onto the saw. The sawing operation trims the panel to length and assures a square edge. After sawing, the panels are then placed on a pallet. The sawing operation will continue until all the panels are sawed. The pallet will remain on the floor next to the saw until shipping is ready to pack and ship the product.

Instrumentation

Value stream mapping was the tool used to map the processes and create a possible scenario to reduce lead-times and increase throughput. The main source for providing the steps used to create the maps was the book Value Stream Management (Tapping, Luyster & Shuker, 2002). The researcher determined that the information in the book could provide the tools to create useful and informative maps.

Data Collection Procedures

The method to obtain data for the mapping was accomplished by retrieving information from the company's ERP system and by making observations on the plant floor. The first step was to determine what product to map. A part vs. quantity analysis was conducted to select a part family to study. A table was created showing the type of screen panels and the quantities produced of each type. The two most common panels produced are the SD2K and the Snapdeck Classic screen panel. The researcher decided to group the two panels into the same map since both styles of panels are modular style panels and essentially identical from a production standpoint. They both are very similar in function and use the same processes to produce them; the only major difference is the tooling used to mold them. These two styles of panels would account for approximately 55% of the panels produced in rubber. The next step was to map the current state of the rubber modular screen panels. Information was gathered from the company's ERP system as well as from the shop floor. Information was collected on cycle times, changeover times, number of operators, number of shifts, inspection points, and the quantity of WIP. Only details of the process were recorded and not the exceptions. A current state map was then created showing the flow of both information and material. The data collected was added to the map to give a picture of what was happening on the shop floor as a rubber modular screen panel was produced. The third step was to analyze the map and investigate lean manufacturing techniques to use for possible improvement to lead-times and throughput.

Data Analysis

A current state map was created using the information collected for rubber modular screen panels. Appendix B shows the current state map. The symbols and definitions are shown Appendix A.

As shown on the current state map, orders are taken daily by customer service and entered into the ERP system. A significant portion of the total lead-times promised to customers is used in the order entry process. There appear to be large areas for improvement in this area. However, the focus of this study will concentrate on the production of rubber screen panels on the shop floor. The orders are then sent to division-3 production control each morning. Planning and scheduling activities are performed by the plant supervisor, planner, and department leads. Job direction is communicated to each person at every machine daily. This is represented by the arrows pointing from the production control box to the individual operation boxes on the current state map (Figure 1). A work order and traveler are printed and sent along to each operation with the job. The first operation that the work order and traveler will go to is to the welding operation. When steel is ordered for a job, the material will sit on the floor for an average of 3 days before processing begins. This is recorded on the timeline chart below as a non-value added activity (NA). The average set up time in welding for a modular panel is 30 minutes. This must be done before each job is started. This is recorded on the map in the operations box for welding as C/O or changeover time. After the set up is complete, each frame only takes 4 minutes to weld. These 4 minutes are added to the timeline chart as 4 minutes of VA or value added time. These 4 minutes are also recorded on the map as C/T or cycle time. The welding operation utilizes one operator on each of two shifts. This is shown as an operator symbol in the data box. See Appendix A. The shifts in which operations are manned are also noted in the box. After welding, the frames are then sent to media blasting. Large quantities of frames are in queue waiting for blasting. In this case, there are 110 pieces waiting for an average of 5 days. This is depicted by a tombstone shape symbol indicating inventory or WIP. Blasting has a set up time of 30 seconds and each part takes on average 5 minutes to blast. The blaster is mainly operated only on second shift. After the frames are blasted, they are placed on pallet and stored in any available floor space near the priming area. Again, large amounts of WIP wait in queue before being primed; in this case, a 107 pieces are waiting to be primed. The parts are left in queue until the rubber press is ready to utilize the frames. When a frame is needed in order to mold a part in the rubber press, the operator of the rubber press goes to the priming area and applies the adhesive only to the frames that are going to be pressed next. This is a pull system where frames are pulled from priming to the rubber press only when needed and only in the exact quantities needed. This is indicated on the map as an arrow in a circular shape. Because an operator primes only the frames that are needed and only when needed, there are no parts in queue between priming and rubber. This is recorded on the timeline as zero non-value added time. The applying of the adhesive in the priming station takes 15 minutes with a set up time of one minute. When the rubber press operator finishes priming the frame it is taken by hand to the rubber press department. Here the frame is placed in a mold along with a specified amount of raw natural rubber. The mold is placed in the press and the platens are closed. The cycle time for the rubber press is 45 minutes. This long cycle time gives the operator time to set up the next mold and prime the next frame. The changeover time for a new mold is 1 hour. To avoid making unnecessary changeovers, entire batches are processed through the press before changing to another mold. All the panels produced at the press are set on pallets until the entire order is completed. After the entire order of panels is pressed, they are sent via forklift to the finishing department. The first operation in the finishing department is to remove flash at the trimming table. There are typically long wait times and large amounts of WIP in front of trimming because trimming is primarily performed only on first shift. The operator at the trim table will have the screens produced from both the second and third shift of the day before to trim before the panels produced that day can be trimmed. Trimming on average takes 7 minutes with a 1-minute changeover time. The next operation in the finishing department is clickering. Parts are moved from the trim table to the clicker and put into queue. Clickering primarily is performed only on the first and second shifts; therefore, large amounts of WIP are piled around the clicker as panels from multiple shifts are processed. In this case, 40 panels are queued in front of the clicker with an approximate wait in queue of a one-half day. The last process in finishing is to saw the panels to the correct length. Rubber is hard to control dimensionally while processing. Therefore parts are made over-sized and then cut to length. The saw is manned only on second shift. Panels from the first and third shifts are piled around the saw. As recorded on the map, there are 20 panels in queue with a wait time of a one-half day. The time to saw a panel takes on average 6 minutes. The sawed panels are then placed on pallets on the floor around the saw. The panels will wait there until the order is ready to be prepared to ship which on average is three-quarters of a day. When an order is ready to be shipped, a person from shipping will pick up the pallet from the finishing department and take it to the shipping department where the screen panels will be packed and made available for shipment. Shipments are made daily to the customers as needed.

The current state map contains all the key steps to produce a modular rubber screen panel. Each process is recorded on the map in a process box with significant data such as the number of operators, shifts the processes are manned, changeover time, and cycle time recorded below. The average WIP is recorded and placed under a tombstone symbol between processes. Value and non-value added times are recorded on the time line shown below the map. From the current state map, it is apparent that large quantities of parts are waiting long periods of time for the next process. The average value added time for a modular rubber screen panel is 89 minutes. The amount of non-value added time that the screen panel experience is 12-1/4 days. This is to say that once the set ups are made, it typically only takes 89 minutes of processing time to make a screen panel. However, because of the poor flow the screen panels are not finished for over 12 days after they were started. With 21 hours of production available during the day at the plant, only 6% of the time value added processing was taking place. That means that 94% of the time no value added activity is occurring.

Limitations

The value stream map is a model that is intended to help pin-point areas of improvement in the processing of rubber modular screen panels. The study was focused only on these panels and other product mixes were not considered even though they share the same resources and machines. In addition, there are often expediting activities and frequent scheduling changes due to customer demands, these are also not considered. To keep the model simple, only panels that were repeat orders and did not require engineering or outside fabrication were mapped. Even though over half the products that are produced are not repeat orders and do require some engineering, the core processes are the same. Once the design is is sent from engineering and new tooling is made, manufacturing the product is essentially the same. Lastly, efforts were made to record and map only the details while ignoring the exceptions. The goal is to get a good picture of the overall manufacturing process and not worry about slight differences.

Chapter IV: Results

Introduction

The purpose of the study is to reduce lead-times and increase throughput of rubber module panels at a rubber products manufacturer. Reduced lead-times will help the company retain and expand its customer base while increased throughput will help get more products out the door to existing and new customers. To accomplish this, value stream mapping was used to help identify potential areas of improvement and suggest ways to fix problem areas. A current state value stream map was created to give a model of the manufacture process of rubber modular screen panels. The map indicated how much WIP was on the factory floor, mapped out information and product flow, and showed how much value added and non-value added time was spent during the manufacturing process. The information obtained from the current state map will help the researcher identify areas of improvement and create a future state map. The future state map will be used by management to plan future process improvements.

Analysis of the current state map

By analyzing the timeline on the current state map, it has been identified that only 6% of the time value added processing was being done to the part while 94% of the time non-value activity was occurring. This is largely due to product being produced in a batch mode and poor product flow. Jobs are currently produced in a batch mode where the size of the order often determines the size of the batch. For example, if the order calls for a 100 screens, 100 screens are welded and do not move to the next process until all 100 parts are completed. This increases lead-times because the parts are in queue while downstream operations could be working on the job simultaneously. Batch processing also leads to an inefficient use of floor space as pallets of products are waiting for the next process. The one exception to products being produced in batch mode is priming. Here the frames are primed just before the rubber operators plans to press the panels and only the exact numbers of frames are primed for the planned press. From the current state map, it can be seen that there is no non-value added time spent between priming and pressing and there is no inventory or WIP produced. This portion of the process is a pull system and is relatively efficient from the standpoint of flow and wasted time.

It can also be seen from the current state map that there is poor scheduling of human resources. Between many of the processes work flow stops because there is no person at the next process to work on the job. Therefore, the product stops and becomes WIP, a pure waste. The finishing department is a good example. Large amounts of WIP are stationed in front of the trimming area from the second and third shifts because trimming is done primarily on first shift. When the product reaches the trimming table, it will sit on the floor for up to a day waiting for a 7-minute trimming process. The same type of wasteful waiting due to operator scheduling is seen in blasting, trimming, clickering, sawing, and shipping.

The current state map also shows the information flow for production. It can be seen that there is an abundance of communication that must occur for the production of a rubber screen panel. When the orders are received from customer service, the production control group schedules the job. Scheduling is communicated to the plant floor by supervisors and production leads. The arrows extending from production control to each individual process represents information flow. In the current production method there is so much disjointed flow that scheduling must be communicated to each operator of each shift. Even though large amounts of the supervisor's and production lead's time are spent on scheduling and planning, frequent mistakes and over-sights are made. Scheduling must also take into account that some processes are only manned at certain times. Therefore, that operator has to be informed of all the jobs that are in queue. In addition, since some stations are manned regardless of workload, work is given to that operator in order keep that machine busy. The wrong jobs are being worked on at the wrong time creating even more WIP and wasted floor space.

The map also shows that inspections are being performed at several processes while some processes have no inspection at all. Inspections are being performed at the processes where there could be high degree of unconformity. Both set up and part inspections are performed. Not every part is inspected but frequent inspections are being encouraged. In the current state conditions, inspections play an important role due to the high loss that could occur if an entire batch would be missed. If an unconformity was not detected the entire batch could receive many hours of processing before the mistake is caught. For example, if a welding error was not caught until the rubber press operator placed the first frame into a mold; the entire job would be rejected. The entire time and resources dedicated to welding and blasting the frames would be lost and have to be redone. Current quality efforts are aimed at avoiding errors and not at minimizing the consequences of an error.

Future state map

A future state map will be created to suggest solutions to the inefficiencies that have been identified in the current state map. The inefficiencies can be summarized as the following.

1. Batch mode production
2. Poor product flow
3. Human resource utilization
4. Complicated information flow
5. Quality checks focusing on elimination of errors and not minimizing risk

The purpose of this study is to reduce lead-times and increase throughput. The future state map suggests a proposed solution. The future state map utilizes several lean manufacturing techniques; the first is the idea of one piece flow and cellular manufacturing. The future state map appears very different from the current state map; instead of individual processes such as welding, blasting, and priming, they are now combined together in a cell or group of processes manned by either a single person or a team. The idea is to move one piece or a small batch at a time from one process to the next without stopping. The machines are physically located close by and arranged to facilitate a smooth uninterrupted flow. Product is transferred between the cells and the rubber press by the use of first-in-first-out lanes and supermarkets. First-in-first-out lanes and supermarkets are designed to limit the amounts of inventory that can accumulate between processes where continuous flow is impractical. Cross-training is utilized to balance workstations and improve product flow, eliminating the problem of poor worker utilization. The future state map suggests that scheduling should be controlled at the bottleneck, in this case the rubber presses. This simplifies scheduling and the potential for communication errors. In a cellular environment, quality checks do not need to occur as frequently or by every process. Since product is moved quickly from one process to the next in one piece or small batches, parts can be checked after several operations and corrected without the risk of large losses.

The most obvious changes to the manufacture of rubber modular screen panels in the future state map are the utilization of manufacturing cells. The cells are groups of processes that are manned by a single person or a team. The idea of the cell is to promote one piece or small batch flow from one process to the next without stopping. Machines are placed in such a way that facilitates easy movement of the product from one process to the next. Taking a look at the finishing cell, one can see that three processes, trimming, clickering, and sawing are manned by one person. As product arrives from the rubber press, the operator of the cell removes parts from the first-in-first-out lane. This means the first part to arrive in the queue is the first part to be processed in the cell. The operator first trims the part, then clickers the part, then saws it before placing it back on a pallet. This is repeated until all the parts in the job are completed. Effective cross-training is required since operators will need to operate all the machines in a cell. A benefit to cross-training is it will eliminate the WIP that is created when product must wait for an operator. A balanced production line can be created as worker move to the process that needs an operator. The most profound benefit of a cell can be seen in the time that the part is waiting in process. In the current state map, a screen panel would have had to wait in queue 1 day for trimming, ½ a day for clickering, and ½ a day for sawing for a total of 2 days in queue. In the future state map utilizing the finishing cell, the part would have only been in queue for only 3 hours and processing completed only 22 minutes later. This is accomplished without having any new, faster machines or the operator working any harder or faster. Lead-times in the future state have been cut from 2 days to 3 hours; that is an 86% time reduction (Based on 21-hour workday). Similar results are also seen in the metal fab cell. Furthermore, there is more floor space available due to less WIP sitting on the floor between each process. Currently it is common to see up to 5 pallets sitting in front of each process for a total of 15 pallets between trimming, clickering, and finishing. The cell would limit a maximum of 3 pallets in front of the cell and since a part does not hit the floor again until sawing is completed, no more pallets are in queue in the finishing cell. This could be up to an 80% reduction in space required for WIP. With an average pallet size of 40" x 42", this would translate into a 140 square foot gain in open floor space.

As can be seen from the finishing cell example alone, large lead-time reduction and improved flow can be made by one piece or small batch production. This however is not practical at all stages in the manufacturing process of screen panels. Every manufacturing process will have at least one operation that is slower than other operations; this is referred to as a bottleneck. In the future state map, a controlled bottleneck has been created at the rubber press. The rubber press has longer cycle times then the other operations and is an expensive piece of equipment for which to buy extra capacity; therefore, the rubber press is a good choice to make the controlled bottleneck. Scheduling is focused on the rubber press, the maximum amount of throughput that can be produced in a given period of time will be controlled by the amount of product that can be processed through the rubber press. To maximize throughput, it is important that the rubber press is never waiting on upstream operations to feed it. Therefore, an inventory system has been placed in front of the press. In this case, first-in-first-out and supermarket inventory systems are used. These systems assure that there is always product to be processed at the rubber presses without letting inventory numbers get out of control. A first-in-first-out inventory system is also placed after the pressing operation. This system is used because a continuous flow out of the press would be impractical. Downstream operations are not close to the press requiring parts to be transported to the finishing cell. It would not be cost effective to move the press and there is limited space around the press to move downstream operations closer. Therefore, jobs are moved in practical batches to a queue in front of the finishing cell. Here parts are processed in the order they are received. Production control schedules only the rubber presses. The metal fab department receives instruction from the rubber press leads on frames that will be needed. Frames are built only by request and in order of the scheduled press date. The frames enter a first-in-first-out or supermarket inventory system for use in the presses. The finishing cell receives no scheduling instruction, the cell simply processes the products that are outputted from the rubber press in the order they are received. Any of the operators in the cell that get ahead of the rubber press will go to the rubber press area to help there. The future state scheduling system is much simpler and less time consuming then the current state system. The added time can be dedicated to better scheduling of out of the ordinary orders, outside vendors, expediting activities, and training. Simpler scheduling should lead to less scheduling mistakes and allow for better control over an order. Currently a job is only being worked on by one operation, thus every operation is working on different jobs at the same time. It is difficult manage so many jobs all at once leading to mistakes and oversights; often the wrong jobs are being done at the wrong time. In the future state, only a few select jobs will be worked on at any given time; most of time the press and the cells will be working concurrently on the same job. Supervisors and production leads can now concentrate on the few jobs at hand instead of managing many jobs all at once.

Lastly, quality checks are done at operations that pose a high probability of unconformity. The quality checks focus on finding errors. Operating in a batch mode, quality checks are critical because if not caught, large quantities of parts go through several operations before the error is discovered leading to large quantities of scrap or rework. In the future state, quality checks do not need to be done as frequently and the consequences of an error are minimized. In one piece or small batch production, parts flow quickly through several processes in small numbers. For example, in the metal fab cell a frame is welded, blasted, and primed in only 15 minutes. Even if no inspections occurred until after priming, only a few frames would have been produced. In the current state, if an inspection did not occur until priming and the batch size was 100 pieces, up to 100 pieces would be scrap and all the time spent in welding, blasting, and priming would be lost. Producing in large batches creates a high risk for loss; producing in a one piece or small batch mode has little risk and is easy to correct. A common problem in producing modular rubber screen panels is having the frames made correctly. A high number of variations in frames and print errors lead to incorrect frames that inspections often do not detect. Often, incorrect frames are not discovered until the pressing operation. The future state map shows that frames are inventoried in a first-in-first-out system before the pressing occurs. This creates quantities of frames that could be potential scrap that will not be discovered until pressing. The future state does address this problem. Frames are queued in quantities to insure that the press does not have to wait on upstream operations. This introduces the risk that the entire batch in queue could possibly be unusable. However, the risk is minimized by the fact that the queued quantities are only the amount that can be pressed in one day or shift and not the entire order quantity. For example, metal fab will produce 20 frames of a 200-piece order for a scheduled press in the afternoon. A quality check is performed; nevertheless, a print error was never caught in engineering and a batch of 20 frames has been sent to the queue in front the rubber press. That afternoon, the rubber press operator noticed that the frames do not fit in the mold. The frames had to be scrapped. The rubber press operator continued with the next job in the first-in-first-out inventory system to minimize press downtime. The following shift was informed from the rubber lead that the frames were constructed wrong and the print was corrected. Metal fab made the correct frames for the following scheduled press. In this scenario, 20 frames were lost and some time lost in the set up of the scheduled press. The current state scenario the results would have been much more disastrous; 200 frames would have been scrapped, 200 frames would have to be re-produced, and the press would not have been producing until another order could be found. Lost time on a bottleneck is lost throughput.

Overall results of the future state map

The purpose of this study was to reduce lead-times and increase throughput for the production of rubber modular screen panels. A future state map was created by implementing lean manufacturing techniques. The future state map suggests that lead-times can be reduced greatly. The current non-value added time for panels are 12.25

days. Using one piece flow or small batches combined with manufacturing cells the wait times that a product spends in queue can greatly be reduced. The future state map suggests that non-value added time can be reduced to 4.125 days, a 66% reduction in non-value added time.

12.25 days * 21 hours available per day = 257.25 hours

4.125 days * 21 hours available per day = 86.625 hours

% reduction = 1 – (86.625 hours / 257.25 hours) * 100 = 66.33%

With the addition of 5S and quick changeover set-ups, current state production time can be reduced from 1 hour 29 minutes to 1 hour 7 minutes. Any time improvements in the rubber press, which is the future state bottleneck, will translate into increased throughput. Data from current metrics indicates that press utilization is on average 60%. That is to say that the rubber press is only pressing parts 60% of the available time. The low utilization rates can be in part due to poor scheduling and human resource allocation. The future state map creates a controlled bottleneck at the press. Scheduling is mainly focused on the press to ensure that it is running at its maximum efficiency. First-in-first-out and supermarket inventory systems are placed in front of the rubber press to make sure that the press always has material to process and cross-training ensures that an operator is always available. Any lost time on the rubber press is lost throughput. By implementing these changes in the future state map, it is reasonable for the rubber press to obtain 80% efficiency, a 20% gain. Since the rubber press is the bottleneck, increased productivity at the press will directly translate to increased throughput. A 20% gain in rubber press productivity is a 20% gain in throughput. In conclusion, a 66% reduction on lead-times and a 20% throughput gain can be made by improvements suggested by the future state map.

Chapter V: Discussion

Introduction

The purpose of this study was to reduce lead-times and increase throughput of rubber modular screen panels through the use of value stream mapping. A current state map was created and analyzed for potential areas of improvement. Lean manufacturing techniques were used to create a future state map that would reduce lead-times and increase throughput. The future state map suggests that a 66% lead-time reduction could be achieved, mainly though eliminating large batch production and using cellular manufacturing. In addition, a 20% increase in throughput could be realized by focusing on the scheduling of the rubber press, a controlled bottleneck. Value stream mapping has proven to be an excellent tool to analyze a manufacturing process. The current state map helped identify areas of potential improvement while the future state map suggested ways to reduce lead-times and increase throughput.

Conclusions

The researcher concludes that value stream mapping is an effective tool to suggest ways to reduce lead-times and increase the throughput of a manufacturing process. The current state map laid out the manufacturing process while the timeline comparing value added and non-value added times clearly showed large amounts of wastes contributing to long lead-times. Many times process improvement efforts will focus on reducing set up times or increasing machine and operator efficiencies. The current state map shows that most of the waste in the process contributing to long lead-times is in the non-value added times while the product waits in queue. Large reductions in lead-times can be achieved just by reducing time that the product waits in queue. In the future state, no new machines were purchased nor were operators expected to work faster or harder; only procedures and layouts were changed to allow the product to flow more smoothly through the manufacturing process. Increased throughput was achieved through careful scheduling of a controlled bottleneck. Ensuring that the bottleneck is producing at its maximum realistic capacity ensures the highest throughput potentials of the manufacturing system.

Recommendations

The researcher recommends that results from this study be used as a guide in determining future process improvement actions. Value stream mapping is a tool to help pinpoint areas of potential improvement and suggest ways to better them. The maps created by value stream mapping only focused on one product line and do not take into account other product mixes. Consideration must be taken into account for other products that are produced in the plant requiring the same resources. Other product families that are produced that use the same resources include rubber liners, rubber ceramic liners, and other non-modular screens. These products are similar in the fact that they are produced using much of the same equipment and manufactured in a similar fashion. The main difference is that these products often require outsourcing services. These processes could benefit from value stream mapping. Dramatic lead-time reduction and increased throughput can be achieved similar to the results seen in the modular screens used in this study. Control over lead-time and throughput is more difficult when products require outsourcing. As many of the processes that are outsourced cannot be done ahead of the design of the product, the outsourcing must take place with the promised lead-times. The time required for a product to be processed by another manufacturer is often governed by that manufacturer. Value stream mapping can help identify which products that are outsourced may require the most attention. Also, the exceptions such as expediting activities and changes due to customer demand need to be considered when making improvement decisions. The researcher also recommends mapping other products lines to create a better model of the plant floor. In addition, the map should extend further out into the organization to include customer service and engineering. Customer service and engineering can account for up to two-thirds of the total lead-time promised to the customer. Further research should be conducted in addition to this study to gain a larger model of the company.

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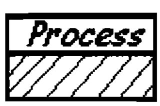
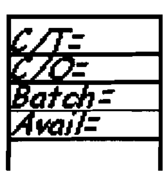
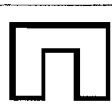
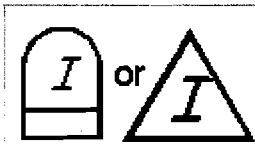
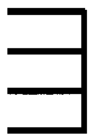
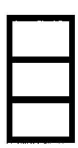
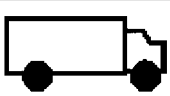
Appendix A:

VSM Process Symbols

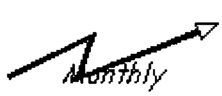
 **Customer/Supplier**	This icon represents the Supplier when in the upper left, the usual starting point for material flow. The customer is represented when placed in the upper right, the usual end point for material flow.
 **Dedicated Process**	This icon is a process, operation, machine or department, through which material flows. Typically, to avoid unwieldy mapping of every single processing step, it represents one department with a continuous, internal fixed flow path. In the case of assembly with several connected workstations, even if some WIP inventory accumulates between machines (or stations), the entire line would show as a single box. If there are separate operations, where one is disconnected from the next, inventory between and batch transfers, then use multiple boxes.
 **Shared Process**	This is a process operation, department or workcenter that other value stream families share. Estimate the number of operators required for the Value Stream being mapped, not the number of operators required for processing all products.
 **Data Box**	This icon goes under other icons that have significant information/data required for analyzing and observing the system. Typical information placed in a Data Box underneath FACTORY icons is the frequency of shipping during any shift, material handling information, transfer batch size, demand quantity per period, etc. Typical information in a Data Box underneath MANUFACTURING PROCESS icons: · C/T (Cycle Time) - time (in seconds) that elapses between one part coming off the process to the next part coming off, · C/O (Changeover Time) - time to switch from producing one product on the process to another · Uptime- percentage time that the machine is available for processing · EPE (a measure of production rate/s) - Acronym stands for "Every Part Every___". · Number of operators - use OPERATOR icon inside process boxes · Number of product variations · Available Capacity · Scrap rate · Transfer batch size (based on process batch size and material transfer rate)
 **Workcell**	This symbol indicates that multiple processes are integrated in a manufacturing workcell. such cells usually process a limited family of similar products or a single product. Product moves from process step to process step in small batches or single pieces.

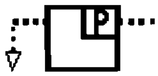
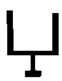
VSM Material Symbols

 **Inventory**	These icons show inventory between two processes. While mapping the current state, the amount of inventory can be approximated by a quick count, and that amount is noted beneath the triangle. If there is more than one inventory accumulation, use an icon for each. This icon also represents storage for raw materials and finished goods.

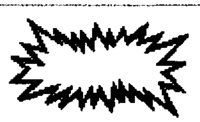
 **Shipments**	This icon represents movement of raw materials from suppliers to the Receiving dock/s of the factory. Or, the movement of finished goods from the Shipping dock/s of the factory to the customers
 **Push Arrow**	This icon represents the "pushing" of material from one process to the next process. Push means that a process produces something regardless of the immediate needs of the downstream process.
 **Supermarket**	This is an inventory "supermarket" (kanban stockpoint). Like a supermarket, a small inventory is available and one or more downstream customers come to the supermarket to pick out what they need. The upstream workcenter then replenishes stocks as required. When continuous flow is impractical, and the upstream process must operate in batch mode, a supermarket reduces over-production and limits total inventory.
 **Material Pull**	Supermarkets connect to downstream processes with this "Pull" icon that indicates physical removal.
 **FIFO Lane**	First-In-First-Out inventory. Use this icon when processes are connected with a FIFO system that limits input. An accumulating roller conveyor is an example. Record the maximum possible inventory.
 **Safety Stock**	This icon represents an inventory "hedge" (or safety stock) against problems such as downtime, to protect the system against sudden fluctuations in customer orders or system failures. Notice that the icon is closed on all sides. It is intended as a temporary, not a permanent storage of stock; thus; there should be a clearly-stated management policy on when such inventory should be used.
 **External Shipment**	Shipments from suppliers or to customers using external transport.

VSM Information Symbols

 **Production Control**	This box represents a central production scheduling or control department, person or operation.
 **Manual Info**	A straight, thin arrow shows general flow of information from memos, reports, or conversation. Frequency and other notes may be relevant.
	This wiggle arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs (local area network), WANs (wide area network). You may indicate the frequency of

Electronic Info	information/data interchange, the type of media used ex. fax, phone, etc. and the type of data exchanged.
 **Production Kanban**	This icon triggers production of a pre-defined number of parts. It signals a supplying process to provide parts to a downstream process.
 **Withdrawal Kanban**	This icon represents a card or device that instructs a material handler to transfer parts from a supermarket to the receiving process. The material handler (or operator) goes to the supermarket and withdraws the necessary items.
 **Signal Kanban**	This icon is used whenever the on-hand inventory levels in the supermarket between two processes drops to a trigger or minimum point. When a Triangle Kanban arrives at a supplying process, it signals a changeover and production of a predetermined batch size of the part noted on the Kanban. It is also referred as “one-per-batch” kanban.
 **Kanban Post**	A location where kanban signals reside for pickup. Often used with two-card systems to exchange withdrawal and production kanban.
 **Sequenced Pull**	This icon represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product, typically one unit, without using a supermarket.
 **Load Leveling**	This icon is a tool to batch kanbans in order to level the production volume and mix over a period of time
 **MRP/ERP**	Scheduling using MRP/ERP or other centralized systems.
 **Go See**	Gathering of information through visual means.
 **Verbal Information**	This icon represents verbal or personal information flow.

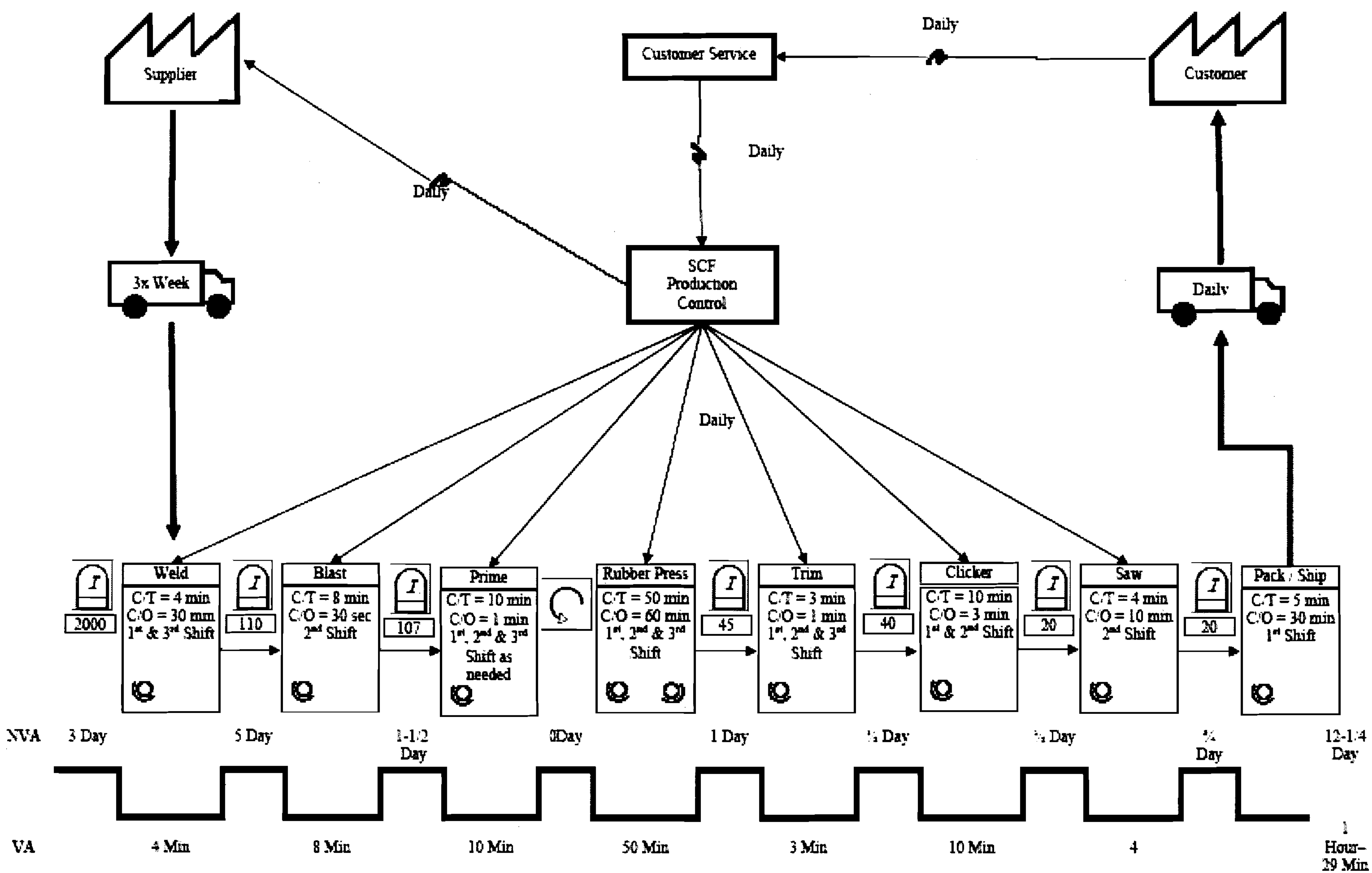
VSM General Symbols

 **Kaizen Burst**	These icons are used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the Future State Map of the value stream.

 **Operator**	This icon represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.
 **Other**	Other useful or potentially useful information.
 **Timeline**	The timeline shows value added times (Cycle Times) and non-value added (wait) times. Use this to calculate Lead-time and Total Cycle Time.

(Rother & Shook, 1999)

Current State Map



Future State Map