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Lean Manufacturing –A Multi Pronged Strategy for Enhancing the Performance of an Organisation– A Case Study

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ABSTRACT

Lean Manufacturing is a systematic approach for identifying and eliminating waste in the process of manufacturing. Lean thinking is to determine the value in terms of the customer and ensure that the value is created and given to the customer at the lowest possible cost. In this process, lean approaches analysis the value stream from the raw material stage to the point it reaches the customer. Many lean strategies are employed in the organization depending on the process and the product they manufacture. Some of them are Value Stream Mapping, Cellular Manufacturing, Continuous Improvement (Kaizen & 5S), JIT & Kanban and so on. Value stream mapping helps to identify the current product flows based on which the future flows are planned with the help of lean strategies to satisfy the expectation of the customer. Cellular manufacturing is one of the cornerstones when one wants to become lean. Continuous Improvement is another fundamental principal of lean manufacturing. JIT and Kanban help lean manufacturing systems to meet high throughput with very little inventory. The paper anlayses the implementation of lean manufacturing strategies in an organization as a multi pronged approach for enhancing the performance of it. A case study has been conducted in a rubber component manufacturing unit to show that a multi pronged approach was used in implementing lean manufacturing in the company to improve its performance.

Keywords: Lean Manufacturing, waste, Value Stream Mapping, Cellular Manufacturing, JIT.

1. INTRODUCTION

The economic scenario for the industries has been encouraging now with the increase in demand for their products after the economic downturn. The strong economic performance in the domestic front, higher disposal incomes and increased government spending on roads and infrastructure show a sign of growth for the industries in India. This growth also brings with it, intensified competition and hence numerous challenges are expected for the

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industries for survival. The greater expectation of customers, the fierce competitive market and the flow of materials to the market with shorter lead-times have forced many companies to focus more on their manufacturing strategies. In order to compete in today's global competitive market the industries are looking forward to more ways to gain a competitive edge. Major businesses have been trying to adopt new business initiatives in order to stay alive in the new competitive market place. Business organisations involved in manufacturing must be cognizant of current trends in manufacturing and take them in to account in their strategic planning. Hence Industrial innovators have constantly focused on improvement through a variety of different manufacturing strategies. Lean manufacturing is one of the current initiatives that focus on cost reduction by eliminating non-value added activities, which result in the improvement of the performance of the organisation. Tools including just in time, cellular manufacturing, total productive maintenance and single-minute exchange of dies have been widely used in implementing lean manufacturing.

2. CONCEPT OVERVIEW

LEAN: The term "lean" as Womack and his colleagues define it denotes a system that utilizes less, in terms of all inputs, to create the same outputs as those created by a traditional mass production system, while contributing increased varieties for the end customer (Panizzolo, 1998).

LEAN MANUFACTURING: "Lean Manufacturing"- The basic idea behind the system is eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective. The primary objective of lean manufacturing is to assist manufacturers who have a desire to improve their company's operations and become more competitive through the implementation of different lean manufacturing tools and techniques. From the customer's perspective, value is equivalent to anything that the customer is willing to pay for in a product or the service that follows. So the elimination of waste is the basic principle of lean manufacturing. Once companies pinpoint the major sources of waste, Lean Manufacturing Tools and Techniques such as Value Stream Mapping, Cellular Manufacturing, Continuous improvement, Just-in-time production and others will guide the companies through corrective actions so as to eliminate waste. In the following sections a brief description of such tools is given.

VALUE STREAM MAPPING: The lean manufacturing discipline is to work in every facet of the value stream by eliminating waste in order to reduce cost, generate capital, bring in more sales, and remain competitive in a growing global market. The value stream is defined as "the specific activities within a supply chain required to design, order and provide a specific product or value" (Hines and Taylor, 2000).

Value stream mapping is an enterprise improvement tool to assist in visualizing the entire production process, representing both material and information flow. The goal is to identify all types of waste in the value stream and to take steps to try and eliminate them (Rother and Shook, 1999). Taking the value stream viewpoint means working on the big picture and not individual processes, and improving the whole flow and not just optimizing the pieces. It creates a common language for production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald, Van Aken, and Rentes, 2002).

CELLULAR MANUFACTURING: Cellular Manufacturing is one of the cornerstones when a company wants to become lean. It is a concept that increases the mix of products with the minimum waste possible. A cell consists of equipments and workstations that are arranged in an order that maintains a smooth flow of materials and components through the process. It also assigns operators who are qualified and trained to work at that cell. Arranging people and equipment into cells has great advantage in terms of achieving lean goals.

CONTINUOUS IMPROVEMENT: Continuous improvement is another fundamental principle of lean manufacturing. Kaizen, is the Japanese word for a continuous endeavor for perfection. Kaizen is a systematic approach to gradual, orderly, continuous improvement. One of the most effective tools of continuous improvement is 5S, which is the basis for an effective lean company. 5S is a first, modular step toward serious waste reduction. 5S consists of the Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize). The underlying concept behind 5S is to look for waste and then to try to eliminate it. Waste could be in the form of scrap, defects, excess raw material, unneeded items, old broken tools, and obsolete jigs and fixtures (Monden, 1998).

JUST-IN-TIME: Closely associated with lean manufacturing is the principle of just-in-time. JIT is a management idea that attempts to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. This addresses waste such as work-in-process material, defects, and poor scheduling of parts delivered (Nahmias, 1997). Inventory and material flow systems are typically classified as either push or pull systems. Customer demand is the driving force behind both systems. However, the major difference is in how each system handles customer demand. Just-in-time is a tool that enables the internal process of a company to adapt to sudden changes in the demand pattern by producing the right product at the right time, and in the right quantities (Monden, 1998).

KANBAN CONTROL: A *lean* manufacturing system is one that meets high throughput or service demands with very little inventory. Kanban control uses the levels of buffer inventories in the system to regulate production. When a buffer reaches its preset maximum level, the upstream machine is told to stop producing that part type. This is often implemented by circulating cards, the *kanbans*, between a machine and the downstream buffer. This way, a demand for a unit of finished goods percolates up the supply chain.

STANDARDIZATION OF WORK: A very important principle of waste elimination is the standardization of worker actions. Standardized work basically ensures that each job is organized and is carried out in the most effective manner. No matter who is doing the job the same level of quality should be achieved.

TOTAL PRODUCTIVE MAINTENANCE: Machine breakdown is one of the most important issues that concern the people on the shop floor. The reliability of the equipment on the shop floor is very important since if one machine breaks down the entire production line could go down. An important tool that is necessary to account for sudden machine breakdowns is total productive maintenance. In almost any lean environment setting a total productive maintenance program is very important which helps in maintaining the machines in good working conditions.

OTHER WASTE REDUCTION TECHNIQUES: Some of the other waste reductions tools include zero defects, setup reduction, and line balancing. The goal of zero defects is to ensure that products are fault-free all the way, through continuous improvement of the manufacturing process (Karlsson et al., 1996). One of the tools that the zero-defect principle uses is pokayoke. Poka-yoke, which was developed by Shingo, is an autonomous defect control system that is put on a machine that inspects all parts to make sure that there are zero defects(Feld, 2000). Ohno at Toyota developed Single Minute Exchange of Die (SMED) in 1950. Ohno's idea was to develop a system that could exchange dies in a more speedy way. The basic idea of SMED is to reduce the set up time on a machine. Inventory can be reduced by producing small batches and more variety of product mix can be run. Line balancing is considered a great weapon against waste, especially the wasted time of workers. The idea is to make every workstation produce the right volume of work that is sent to upstream workstations without any stoppage. This will guarantee that each workstation is working in a synchronized manner, neither faster nor slower than other workstations.

From the discussions we understand that Lean Manufacturing is "a set of approaches utilized in an organisation to efficiently manage it to minimize the system wide cost and waste". Thus the emphasis centers on the integration of all the tools and techniques which are applied in the organisation to achieve of the objective of lean. In order to adapt lean manufacturing tools to the industry, one needs to thoroughly examine different characteristics of the same and develop a systematic approach to best utilize these techniques at the industry. There are a lot of companies that are implementing lean manufacturing. Those companies who understand the concept and master them are able to enjoy the benefits of lean.

3. COMPANY OVERVIEW

The company researched is a midsize manufacturer of rubber components. The products of the company are sold and used throughout the world. The company manufactures several lines of products producing hundreds of different parts, many of those being custom. The company has seen a dramatic increase in sales due to the increased worldwide demand for the products. The company has recorded growth in the demand in the past two years and is growing at a steady rate. Although the company is achieving higher sales, their profit margins are decreasing and product lead-times are increasing. Though the company is growing, by working harder it is making very less profit. Today, 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 rubber manufacturer produces to customer orders and hence very few products are stocked. Jobs on the factory floor are run in a batch mode, usually comprising the entire order. High levels of work in process (WIP) are created as pallets of products which move from one department to the next wait for processing. In addition, many processes are only manned on one shift and hence piles of product are queued in front of machines as pallets are dropped off from the other two shifts. Products move slowly through 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.

The focus of the study will concentrate on manufacture of rubber modular screen panels; a family of parts that comprise approximately 65% of all the rubber products produced by the selected company. The study will address the lead-times for manufacturing rubber modular screen panels. Analysis showed that, current lead-times are higher than in the past and may lead to lost market share and stunt planned growth.

4. METHODOLOGY

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 the selected company. Reduced leadtimes 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 (VSM) is used to help identify potential areas of improvement and suggest ways to fix problem areas.

By VSM 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. Information had been collected from the records of the company and also by observations made on the shop floor. This information had been used to construct a current state map that showed the flow of information and material for the rubber modular screen panel. The data was then analyzed to determine the areas that needed the most improvement. These areas were further analyzed and lean manufacturing techniques have been suggested to lower the lead-times and increase throughput. The suggestions were used to create a future state map that will provide a guideline for improvements that can be made for enhancing the performance of the selected company.

4.1 Data Collection

Value stream mapping was the tool used to map the processes. The method to obtain data for the mapping was accomplished by retrieving information from the company's record and by making observations on the plant floor. The first step was to determine what product to map. The researcher decided to choose the rubber module screen panels for the study as it accounted for 65% of the panels produced in the company. The next step was to map the current state of the rubber modular screen panels. Information was collected on cycle times, changeover times, number of operators, number of shifts, inspection points, and the quantity of work in process. A current state map was then created showing the flow of both information and material. The third step was to analyze the map and investigate lean manufacturing techniques to use for possible improvement in lead-times and throughput.

4.2 Data Analysis

A current state map was created using the information collected for rubber modular screen panels. The current state map reveals that the orders are taken daily by customer service and entered into the production planning system. The orders are then sent to production control department where planning and scheduling activities are performed by the plant supervisor, planner, and department leaders. Job direction is communicated to each person at every machine daily.

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 three days before processing begins. The average set up time in welding for a modular panel is 30 minutes. This must be done before each job is started. After the set up is complete, each frame only takes 4 minutes to weld. The welding operation utilizes one operator on each of two shifts.

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 10 pieces waiting for an average of 5 days. 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. The parts are left in queue until the rubber press is ready to utilize the frames. When a frame is needed in order to mould 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. Because an operator primes only the frames that are needed and only when needed, there are no parts in queue between priming and rubber. 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 mould along with a specified amount of raw natural rubber. The mould 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 mould and prime the next frame. The changeover time for a new mould is one hour. To avoid making unnecessary changeovers, entire batches are processed through the press before changing to another mould. 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 him to trim before the panels produced that day can be trimmed. Trimming on average takes 7 minutes with a one minute change over 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 and 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 in one shift. Panels from the first and third shifts are piled around the saw. 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 shown in the mapping 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 12-114 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 20 hours of production available during the day at the plant, only 7% of the time value added processing was taking place. That means that 93% of the time no value added activity is occurring.

The result of the current state value stream mapping of the manufacturing process of rubber modular screen panels 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 helped the researcher to identify areas of improvement and create a future state map. The future state map thus suggested would help the management to plan future process improvements to enhance the performance of the selected company for study.

4.3 Analysis of the Current State Map

Analyzing the timeline on the current state map, it has been identified that only 7% of the time value added processing was being done to the part while 93% of the time non-value activity was occurring. This is largely due to product being produced in a batch mode, resulting in poor product flow. Jobs are currently produced in a batch mode where the size of the order often determines the size of the batch. 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 priming process can be done by batch mode which is advantageous. 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 visualized that there is no non-value added time spent between the priming process and the pressing process. Hence there is no inventory or WIP between the processes. 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 inferred from the current state mapping that there is poor scheduling of human resources, which stops the work flow between many processes resulting in large WIP. 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 a need for better communication between the processes

of producing the rubber screen panels. 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 leaders spent time on scheduling and planning, frequent mistakes and over-sights are found in the mapping process. During scheduling we have to understand that some processes are performed at specific time periods which results in queuing of the WIP between processes.
In addition, some times, work is given to an operator in order keep that machine busy regardless of workload. Hence 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. If an unconformity was not detected earlier, the entire batch could receive many hours of processing before the mistake is identified. Current quality efforts are aimed at avoiding errors and not at minimizing the consequences of an error.

The inefficiencies identified by the current state mapping can be summarized as the following.

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

5. FUTURE STATE MAP

A future state map has been created to suggest solutions to the inefficiencies that have been identified in the current state mapping process. The future state map suggests a proposed solution. The future state map utilizes several lean manufacturing techniques during the production process to enhance the performance of the company. The first technique used is the idea of one piece flow and cellular manufacturing.

The future state map appears very different from the current state map and 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 rearranging the machines 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. First-in-first-out lanes 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 finishing cell has three processes, namely trimming, clickering, and sawing which are manned by one person. As the product arrive from the rubber press, the operator of the cell removes parts from the first-in-first-out lane. 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 that 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 for a total of 2 days in queue to complete trimming, clickering and sawing. In the future state map utilizing the finishing cell, the part would have been in queue for only 3 hours and processing gets completed within 22 minutes after the waiting period. 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. 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. Hence large lead-time reduction and improved flow can be made by one piece or small batch production.

Every manufacturing process will have at least one operation that is slower than other operations. This operation is referred to as a bottleneck operation. 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 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.(ie. first in first out basis).

Production control department schedules only the rubber presses. The metal fab department receives instruction from the rubber press leaders 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 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.

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 to manage so many jobs all at once leading to mistakes and oversights which results in the wrong jobs 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 the 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.

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 ensure 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.

5.1 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 * 2 0 hours available per day = 245 hours

4.125 days * 2 0 hours available per day = 82.5 hours

% reduction = 1 - (82.5 hours / 245 hours) * 100 = 66.32%

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 65%. That is to say that the rubber press is only pressing parts 65% 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-firstout 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 85% 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.

6. CONCLUSIONS

A multi pronged strategy of using various lean manufacturing techniques to create a future state map reduced lead-times and increased throughput of the compnay selected for study. The future state map suggests that a 66% lead-time reduction could be achieved, mainly though eliminating large batch production and using techniques like cellular manufacturing, JIT and assembly line balancing. 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 which helped to analyse the value added and non-value added times. The analysis clearly showed large amounts of wastes contributing to longer lead-times. The current state map helped to identify areas of potential improvement, while the future state map suggested ways to reduce lead-times and increase throughput. It is evident from the research that lean manufacturing is a powerful tool, when adopted can create superior financial and operational results. Managers, however, have been reluctant to adapt lean manufacturing tools due various reasons known to them. In order to adapt lean manufacturing tools to an industry, one needs to thoroughly examine different characteristics of the same and develop a systematic approach to best utilize these techniques suitable to their industry. The research was limited to the manufacturing process of rubber modular panels. The results of the study derived from a selected company and hence it should be generalized.

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