Design a One-Piece Flow System in a Casket Manufacturing Company

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Abstract *— The competition between Casket companies is increasing every day. Many casket companies are importing products from China and Mexico. The customers are greatly influenced by prices. To be competitive, the industry is seeking for tools to be used in order to reduce cost and improve manufacturing capacity without compromising the quality of the products. One methodology used to reduce manufacturing cost and increase process capacity is Lean Manufacturing. This methodology is used to reduce sources of muda or in other words, waste. Muda can be associated to downtime, waiting time, unnecessary movements among others things that do not create value to the customer. This article discusses the improvement of the manufacturing line capacity and layout of a Casket Manufacturing Company. The methodology used for the improvement was Lean Manufacturing using the DMAIC tool as a systematic approach.*

Key Terms *— DMAIC, Lean Manufacturing, Process Capacity, Process Flow.*

INTRODUCTION

Manufacturing is the production of merchandise for use or sale using labor and machines, tools, chemical and biological processing, or formulation. A manufacturing process is the industrial production, in which raw materials are transformed into finished goods on a large scale. The manufacturing world has gone through many changes throughout the years. Many new technologies have been invented to increase production and lower costs. But many of the machines tend to be extremely expensive. Therefore, many changes in the manufacturing process have taken place as well. Some of these changes are owed to the Toyota Production System. They were able to create and implement a system within the manufacturing process to reduce waste and, in turn, reduce costs, increase production, and many others things as well. This process is known as Lean Manufacturing.

The focus of this design project is the implementation of lean manufacturing in a casket manufacturing company in Puerto Rico, particularly in the welding and grinding departments. The company's name in which the project will take place is J. R. Quality Metal. This is a casket manufacturing company since 1994. Since the beginning, they have manufactured caskets in a batch style system. This creates a lot of unwanted inventory of unfinished product, which can cause many problems in the future. Problems because it will slow the production line, it will cause the unfinished product to rust due to the time that it is exposed to the environment without any product to prevent it (such as primer), etc. This project designs a one-piece flow system in these departments to prevent these problems to keep transpiring.

Research Description

This article describes the design of a one-piece flow manufacturing process to the welding and grinding departments of a casket manufacturing company. As opposed to how these departments function in reality, this is in batch production. Because the employees work in batches and independently, a lot of inventory of unfinished product is made. This causes for a lot of space dedicated for inventory. Since caskets, are such big and bulky products, making them by batches, means compromising the quality of the casket by setting them on the floor while the next employee in the line finally gets to it. This, in turn, slows the line and increases the production time of the casket and does not promote any teamwork whatsoever within the company. One-piece flow is the state that

exists when products move through a manufacturing process one unit at a time. One-piece flow allows for a more continuous manufacturing process and eliminates the need to produce in batches.

Research Objectives

This research is designed to analyze the current manufacturing process in order to identify opportunities to improve the manufacturing line capacity to produce more products per hour due to the increased demand. Design and implementation of a strategy to reduce product manufacturing cost in order to sell the product at a competitive price without compromising the quality of the product.

Research Contributions

There will be some direct positive contributions to the development and implementation of this research, and some indirect positive contributions. The main contribution that this research will provide is the implementation of the lean manufacturing style into the manufacturing company. This will start to create what some people call the "Lean Thinking", which basically is that the executives and employees of the company start looking at all of the process of manufacturing looking for ways to eliminate waste and apply the Lean system. In the departments themselves, it will reduce waste in the form of inventory, decrease the space needed for the manufacturing process, and reduce the production time of these departments. Some of the indirect contributions will be the start of applying teamwork within these departments, reduce costs due to the increase of production, and a more organized production line.

LITERATURE REVIEW

Lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS). Lean manufacturing is a systematic method for the elimination of waste within a manufacturing process. Waste is any activity that takes up time, resources, or space but does not add value to a production or service. Lean identifies seven key areas of waste. They are:

1. Overproduction – overproduction, as demonstrated in [1], occurs when operations continue after they should have stopped. The results of overproduction are
   a. Products being produced in excess quantities and,
   b. Products being made before the customer needs them
2. Waiting – this term refers to the periods of inactivity in a downstream process that occur because an upstream activity does not deliver on time.
3. Transport – this is the unnecessary movement of materials, such as work-in-progress (WIP) materials being transported from one operation to another.
4. Extras Processing – this term refers to extra operations, such as rework, reprocessing, handling, and storage, which occur because of defects, overproduction, and too much or too little inventory.
5. Inventory – this refers to any excess inventory that is not directly required for your current customer orders.
6. Motion – this term refers to the extra steps taken by employees and equipment to accommodate inefficient process layouts, defects, reprocessing, overproduction, and too little or too much inventory.
7. Defects – these are products or aspects of your service that do not conform to specifications or to your customers' expectations, thus causing customer dissatisfaction.

To be able to eliminate these wastes and achieve the goals and objectives of this project, there are some tools that can be used. For this particular project and to be able to achieve and complete the objectives stated, the following tools will be used:

1. Value Stream Mapping – this tool is used as an illustration that uses simple graphics or icons to show the sequence and movement of

information, materials, and actions in a company's value stream. This tool helps to expose waste in the current process.

2. 5S (Sort, Shine, Set in Order, Standardize, and Sustain) – A method of creating a clean and orderly workplace that exposes waste and errors.
3. Takt Time – Takt time sets the pace of production to match the rate of customer demand. Calculated as Planned Production Time divided by Customer Demand. This tool helps to provide an efficiency goal for the plant floor (Actual Pieces / Target Pieces).
4. Cellular Manufacturing (One-Piece Flow) [2] – One-piece flow is the movement of products through the manufacturing process one unit at a time. This tool helps to create a cellular manufacturing layout. Cellular manufacturing is when equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay.
5. Standardized Work [1] – Reliable instructions that describe the correct and most effective way to get a work process done (including the time to complete each task).
6. Total Productive Maintenance (TPM) [1] – A series of methods that ensures every piece of equipment in a production process is always able to perform its required tasks so that production is never interrupted. This tool helps to create a shared responsibility for equipment that encourages greater involvement by plant floor workers.

Lean Manufacturing

The Lean Manufacturing methodology has the objective of eliminating and/or reducing muda (waste) to a process to reduce costs and improve efficiency. Muda can be classified as Muda Type One or Muda Type Two. Muda Type One is the waste that does not add value to the customer but cannot be eliminated because it is necessary to the process. On the other hand, Muda Type Two is the activity that does not add value to the customer and can be eliminated immediately. Figure 1 shows the five (5) principles of the Lean Manufacturing methodology.

1. Value – the customer can only define the value of a process. Companies need to improve the process considering the Voice of Customer (VOC). In this principle, the company needs to understand the customers and their requirements. In others word, the companies need to understand what the customer wants for a specific product.

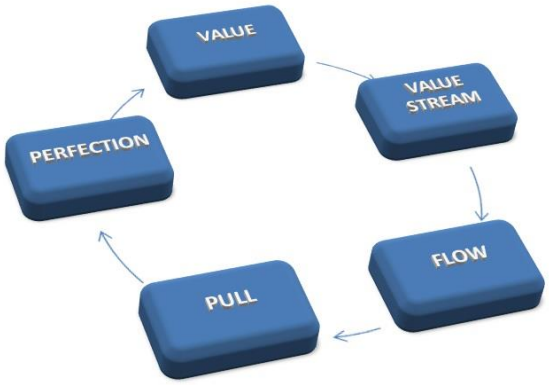

Figure 1
Lean Principles

2. Value Stream – The value stream is the activities required to produce a product or service required by the customers. This principle has the objective to create a process map (Value Stream Mapping) of the activities required to produce a product or service in order to determine which activities create value or do not create value from the customer perspective.
3. Flow – This principle is used to eliminate waiting times or obstacles that do not allow the process to be performed without interruptions or continuous flow.
4. Pull – This principle allows the customer to pull the product from the manufacturing facilities as needed instead of pushing the product to the customer. In other words, manufacturing facilities will produce their products only if the customer requires them.
5. Perfection – The perfection principle is not the end of the process. On the other hand,

perfection refers to repeating the Lean cycle to continue with the improvement process to offer the product that the customer wants.

METHODOLOGY

A systematic approach needs to be used as a methodology to achieve the goals of the project. Since the purpose of the project is to improve the manufacturing line capacity on a casket manufacturing company, the Lean Manufacturing methodology was selected. The Lean Manufacturing methodology is used to eliminate the muda (waste) and non-value activities of any process. The project will be divided into five phases (Figure 2) following the DMAIC tool (Define, Measure, Analyze, Improve and Control). Each phase will be reviewed before continuing to the next phase.

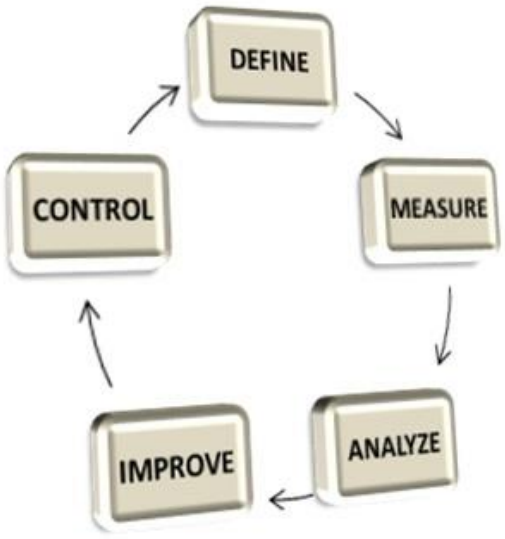

Figure 2
DMAIC Process Steps

Define Phase

In the define phase, the problem will be defined along with the objectives that will be accomplished when it is finished.

Measure Phase

In the Measure Phase the baseline data will be established. This will help to determine if there was an improvement after the implementation of the one-piece flow. This can be done using the same type of data so that it can be evident to anyone who sees this project. Once the data baseline has been established, the next step within the Measure phase is to establish how will this data baseline be measured. This is extremely important, because this data baseline will be crucial to determining if the objectives were established or not. If the wrong data is measured, it could lead to inconclusive results and jeopardize the project as a whole.

Analyze Phase

The Analyze Phase is used to identify the data that was measured. This will give room to find defects and opportunities for improvement. This section will help identify gaps between current performance and the desired performance that is desired. When multiple opportunities for improvement arise, then these opportunities have to be prioritized.

Improve Phase

The Improve Phase has the objective of identifying, testing and implementing a solution to the problem. The Improve phase focuses on fully understanding the top causes identified in the Analyze phase, with the intent of either controlling or eliminating those causes to achieve breakthrough performance.

Control Phase

In the Control Phase the main objective is to sustain the improvements made in the Analyze phase to guarantee lasting results and not go back to the "old ways". This generally requires the development, documentation and implementation of a control plan.

RESULTS AND DISCUSSION

The results obtained during the project execution are discussed in this section following the systematic approach of DMAIC.

Define Phase

The objective of this project is to design a one-piece flow manufacturing process to the welding and grinding departments of a casket manufacturing company. This research is designed to analyze the current manufacturing process in order to identify opportunities to improve the manufacturing line capacity to produce more products per hour due to the increased demand. Design and implementation of a strategy to reduce product manufacturing cost in order to sell the product at a competitive price without compromising the quality of the product.

Measure Phase

There will be two main data baselines that will be used to determine the magnitude of the improvements that were made. The first is the cycle time, and the second is the layout itself. The cycle time is important because it will prove that the new process and the implementations that were done to the production line worked. It will tell the time that it takes to complete a job within the production line. As demonstrated in [3], the layout itself will also be a very important factor because it will help to reduce walking time and save space in the manufacturing floor. This would in turn reduce the probability of defects being developed from workstation to workstation. The layout that was used before the improvements was scattered and disorganized (see Figure 3).

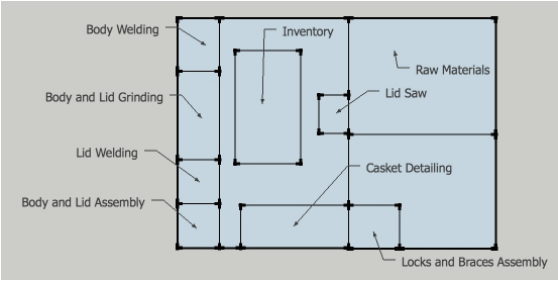

Figure 3
Factory's Old Layout

The way the manufacturing floor used to work was with this layout. There were 8 employees in this area:

- One in body welding,
- One in body and lid grinding,
- One in lid welding,
- One in body and lid assembly,
- Three in casket detailing, and
- One in locks and braces assembly.

The process would start with the body welder and lid welder having to go to the raw materials area, in the next room, to grab the materials, which they would be using throughout the day. Then, the body welder would begin welding the casket bodies. Meanwhile, the lid welder would go to the lid saw and start cutting the lids in half. After being finished, he would then start to weld the casket lids. As both welders would begin finishing welding, they would pass their finished product over to the grinder. The grinder would apply z-grip, a filler to reduce the time spent welding the lids. While the filler would dry, the grinder then starts grinding the casket body. After finished grinding the casket body, he would then go to grind the lids. After he would finish grinding, he would set them in a corner for the body and lid assembly welder to pick the up and bring them to his workstation. There, he would then start to weld the body and lid together with four hinges. After welding the body and lid together, he would put this casket in the inventory section, where the detailing group would start picking them up to do the detailing on the casket. After they would be done, the casket passed to the locks and braces assembly workstation. When the casket is done, it would pass to the painting department.

This layout made the employees walk a lot from station to station to pick up their working materials and to drop them off to the next workstation. This would result in long times of walking and picking up and putting down the casket many times, greatly increasing the chances of defects, dents and scratches from forming in the casket and having to fix them in the detailing department.

The average time each workstation would take is as follows (see Table 1):

Table 1
Average Cycle Time in Old Layout

Workstation	Average Cycle Time
Body Welding*	8:15
Body and Lid Grinding	12:26
Lid Welding*	6:32
Body and Lid Assembly	7:40
Casket Detailing	25:56
Locks and Braces Assembly	5:12

*It has to be noted that the time for the body welder and lid welder do not include the pre-work time of having to pick their materials from the raw materials room.

Analyze Phase

After analyzing the data and layout of the factory, various opportunities for improvement came up. The layout is not right. It needs to change in order to be able to implement a successful one-piece flow. The other area that needs to be addressed are the workstations. They need to be balanced in order for the one-piece flow system to work and avoid any inventories and bottlenecks from occurring on the manufacturing floor and avoiding defects from befalling on the caskets.

After studying different alternatives to implement, the following was chosen and established. A new piece of equipment (a bender) would be bought to reduce the space that the raw materials take. A new employee would be hired to use this machine and help to eliminate the pre-work from the body welder and lid welder. The layout would change to a cellular manufacturing layout. Also, the lids and the bodies of the casket would be worked separately until the very end. This will help to speed up each station and balance them. Also, it would help for each employee to better handle a body or a lid, instead of a whole casket, which would make it a lot heavier and more difficult to handle. This will avoid the need of putting the casket part on the floor.

The problem with the actual shop floor is the space that it requires. It takes way too much space for the workstations. Increasing the square footage needed to operate. This includes the raw materials and the last workstation, which are in a different room. This means that the welders need to go back and forth when they need raw materials. Although these welders try to get all of their production worth of materials in the morning and in one trip, situations arise when a specific style of casket has to be made at the last minute. This would mean for the welders to go back to the raw materials room and return to its area. This consumes too much time for them in the long run, aside from the fact that it will greatly tire them more because of the excessive walking. Also, the casket detailers have to walk from one room to another to be able to pass on their finished product to the next workstation, wasting valuable production time in walking from one room to another because the last workstation could not fit in the previous room. This issue will be addressed.

Improve Phase

After analyzing the data, the changes that were discussed in the Analyze Phase were implemented. A new layout was designed, following the cellular manufacturing techniques (see Figure 4).

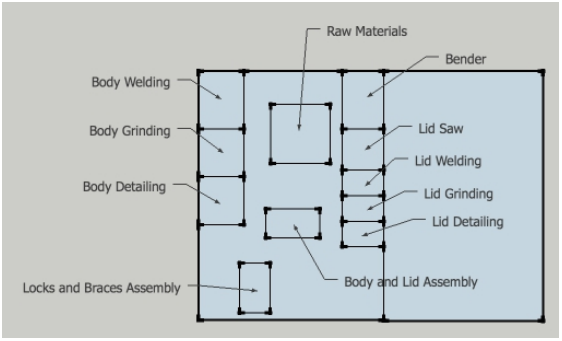

Figure 4
Factory's New Layout

As it can be seen in the new layout, there is no space needed for the inventory. This is because the one-piece flow system is implemented and the need for inventory disappeared.

The way the manufacturing floor would work now with this layout follows. There would be 9 employees in this area:

- One in body welding,
- One in body grinding,
- One in body detailing,
- One in the bender and lid saw,
- One in lid welding,
- One in lid grinding,
- One in lid detailing,
- On in lid and body assembly, and
- One in locks and braces assembly.

This new layout helps the workstations to flow better and to avoid any unnecessary walking between the workstations. This also helps for the employees not having to put anything on the floor.

The way this new layout would work would be as follows. First one employee is constantly bending materials and cutting lids for the welders. This eliminates the pre-work for the body welder and the lid welder. The body welder gets his materials from the raw material section right in front of him and starts welding. As soon as he is done, he passes the welded casket body over to the body grinder, who will then start to work on the casket body. As soon as that casket body is grinded away the excess welding and markings, he then passes the casket body over to the casket body detailer. The casket body detailer will erase any markings left on the casket body done by the grinder and fix any defects that could be in the casket body. Although, with this new system, the defects on the caskets have almost disappeared.

Meanwhile, the lid welder is welding the casket lid. As soon as he is done, he passes the welded lids over to the lid grinder. The lid grinder eliminates any excess welding done by the welder. When done, the lid grinder passes the lids over to the lid detailer. The lid detailer will remove the markings done by the lid grinder and fix any defects that the lid may have. As soon as the lid detailer and body detailer are done, they pass their respective parts over to the lid and body assembler. The lid and body assembler will weld four hinges to the casket body and lid to make it a unit. As soon as he is done, the lid and body assembler will pass the casket over to the locks and braces assembler, who will install the lock mechanisms of the casket, as well, as the braces for the lids to help maintain the lid open for viewing.

In terms of the cycle times, they were balanced so that each workstation was similar in cycle times and help the flow of the one-piece flow system.

Table 2
Average Cycle Time in New Layout

Workstation	Average Cycle Time
Body Welding	6:23
Body Grinding	6:30
Body Detailing	6:27
Lid Welding	6:32
Lid Grinding	6:20
Lid Detailing	6:50
Lid and Body Assembler	6:42
Locks and Braces Assembler	5:58

These new times have been balanced, which help the employees to better transition the casket parts from one workstation to the other. This eliminates for any bottlenecks, any unwanted parts on the floor, and any employee standing around and waiting for their work to come to them.

Control Phase

The control phase includes an SOP, which would eliminate the need to change the layout to the old one. The SOP, as demonstrated in [4], will help create a more standardized work, which will help the employee to better perform their respective job. Another method of control that could be established is time monitoring. This will help to maintain the workstations balanced at all times. If

there seems to be a problem at some point, the time monitoring will be a quick flag that would arise and warn that there is something wrong.

A great tool to be used to maintain the factory clean, in order and organized is the 5S tool. This tool will help in making the factory floor look much nicer, organized and clean. While at the same time, that same order will help the employees be more efficient in their workstations and increase productivity in the long run. Along with the 5S tool, another important tool to use and maintain is the Total Productive Maintenance (TPM). Total Productive Maintenance is a series of methods that ensures every piece of equipment in a production process is always able to perform its required tasks so that production is never interrupted. This tool helps the employees to keep their tools and equipment in optimized conditions. The perfect way to establish this is when there is a little bit a free time from a workstation waiting for the casket to come from the previous workstation. This is the perfect time to do a little maintenance on their equipment. This will prevent the production line to have to stop because of equipment malfunction and keep the productivity up at all times.

CONCLUSION

Once the implementations that were suggested on this project were done, a few things came up. Production ran a lot more smoothly, quality was higher, and the cycle time of each workstation was reduced. This means that the cycle time of a casket was reduced as well. A more organized production floor was seen and it was much cleaner as well.

The objectives that were established for this project were accomplished. Since the change in layout, the production line was greatly improved and the manufacturing line capacity increased as well. This allowed for a daily production increase of 50% and it only required one more employee to be hired and the change in the manufacturing layout. This change will greatly help the increased demand that the company is facing right now.

The floor layout also helped to reduce the product manufacturing cost, because with, pretty much the same workforce, production was increased and the quality of the product was increased as well. This is due to the fact that the detailers did not have to spend as much time fixing dents and defects of the caskets as they used to.

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