Increase of Packaging Line Capacity using Lean Manufacturing

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Abstract *— The main purpose of this project is to implement Lean Manufacturing practices and techniques in the packaging area at a Manufacturing Plant. Concepts like Kaizen ideas (continuous improvement), SMED and process excellence are the new foundation of the company. To be able to keep up with the constant increase in food costs, it is critical to evaluate which areas will benefit from using Lean techniques. The best way to reduce or eliminate the manufacturing cost is using Lean Manufacturing. This methodology will be used to identify the sources of waste or muda. Waste usually is associated with downtime, unnecessary steps and waiting. This article discusses the improvement of a packaging line capacity at a Manufacturing Plant. The Lean measures were implemented using the DMAIC tool as a systematic approach.*

Key Terms *— Capacity, DMAIC, Lean Manufacturing, Muda, SIPOC Diagram, Pareto Chart, Process Flow.*

INTRODUCTION

Pasta Manufacturing plants in the USA and foreign countries are competing against each other to obtain long-term contracts. To be more attractive and competitive, the companies are recurring to methods that decrease the manufacturing cost and at the same time, enhance the manufacturing capabilities of the production line in order to satisfy the demand from the customers. Thus, many Pasta companies are recurring to use Lean Manufacturing and Six Sigma to be able to achieve the desirable goals.

Research Description

A Pasta company won a long-term contract for its products which implies that the packaging demand will increase from 1.627 million of units to 6.527 million of units per year. On the other hand, the company has an incubation period to demonstrate the capacity to commit and comply with the customer requirements. Not only does it need to demonstrate that it has the capacity to increase the packaging output, but also reduce the packaging cost to be more profitable.

Research Objectives

This research is designed to analyze the current packaging process to identify areas of improvement and further enhance the packaging line capacity to process more boxes per hour. The goal is to reduce the packaging cost in order to be more profitable and sell the product in the market with an aggressive or competitive price, without compromising the quality of the product.

Research Contributions

The research discussed in this article will contribute to the betterment of a Pasta company that wants to increase its packaging capacity. Furthermore, the research will contribute to reducing costs related to the packaging process without compromising the quality of the product or finished good. From a consumer's perspective, the consumer will get a higher quality product at a lower retail price. The Pasta company will increase its capacity to achieve the customer's requirements/demands regarding the finished good.

LITERATURE REVIEW

To gain an edge in efficiency and competitiveness, Pasta companies are implementing Lean Manufacturing methodologies in an effort to lower manufacturing costs by eliminating the muda in its process. Muda is a Japanese word that means waste.

Lean Manufacturing methodology is used by many companies as a systematic approach to be able

to eliminate the waste in processes. In practice, its use translates to a reduction of manufacturing costs, processing time, and avoidance of excess inventory at the end of the month. In the Lean philosophy, the muda or waste is related with non-value activities in the processes. Taiichi Ohno (1912-1990), the Toyota executive identified the first seven types of muda [1]. The types of waste that are be found in a manufacturing process are:

- Defects – components or products that do not meet the specification.
- Over-Production – produce more than or sooner than is required by internal or external customers.
- Waiting – Time not being used effectively is a waste. There are related to human, machine or material.
- Transportation – transport or double handling of materials or products.
- Inventory – additional raw material, sub-assemblies, work in progress (WIP) or finished good at any point.
- Motion – physical motion of people or machinery that do not add value.
- Extra Processing – to do more than the customer requires, activities that are transparent to the customer.

Lean Manufacturing methodology is also used as a tool for companies to increase their production capacity. Per the article written by M. Subburajan [2], the following three strategies can be used to increase the capacity: add new facility or machine, increase, machine availability and debottleneck process/duplication. The expansion of facility or addition of machines to increase the capacity of production at a manufacturing plant is extreme and costly since it involves construction of new facilities, acquiring new equipment, and the installation and qualification of the equipment. Before attempting this approach, many companies try to enhance the current process and perform Return of Investment [3] (ROI) analysis to determine if this option is cost effective. The next alternative to increasing the capacity is to expand the machine availability. This approach can be achieved by improving change over time that contributes to creating downtime in the equipment. Lastly, the third strategy that will be utilized to increase the capacity of machine is the debottleneck process. A bottleneck in a manufacturing process is when a machine or equipment has large processing time compared to others equipment in the same manufacturing area and the product is accumulated in the slower station waiting to be processing. A bottleneck limits the capacity of the process and impacts the output directly. This phenomenon is associated with the changeovers, mechanical issues, and equipment yield.

Lean Manufacturing

Lean Manufacturing methodology has the purpose of eliminating or reducing the waste in a process. This improvement will be reflected in a reduction on costs and an improvement in the yield or efficiency. Muda will be classified as Muda Type I or Muda Type II. The first one is the waste that does not add value to the customer but cannot be eliminated because it is necessary to the process and current technology cannot be used to eliminate it. Then, the Muda Type II is the activity that does not adds value to the customer and will be eliminated immediately. Below are the five (5) principles [4] (Figure1) of Lean methodology.

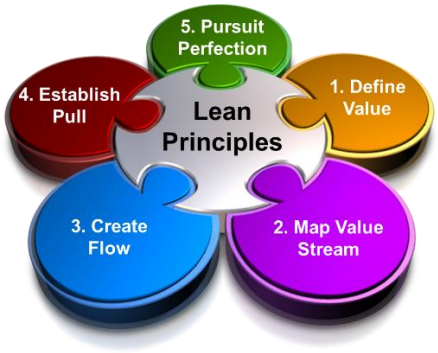

Figure 1
Lean Principles

1. Value – Value is always defined by the customer's needs. For example, what is the time to complete the Step C to be able to start Step D.

2. Value Stream – This tool helps to create a Value Stream Mapping of the required activities to produce a product or service. This diagram identifies every step that does not create value from the customer perspective and finally finds ways to eliminate those wasteful steps.
3. Flow – This principle is used to eliminate waiting times or impediments that do not allow the process to be completed without interruptions.
4. Pull – This principle allows the customer to pull the product from the manufacturing facilities as needed instead of pushing the product (Push System) to the customer.
5. Perfection – The perfection principle is not the end of the process. Therefore, perfection refers to repeating the Lean cycle to continue with the continuous improvements.

METHODOLOGY

Lean Manufacturing methodology is used to eliminate the muda and non-value activities. Lean practices are often implemented using DMAIC. The DMAIC tool (Figure 2) uses five phases to achieve a transformation, it is also defined as Define, Measure, Analyze, Improve and Control.

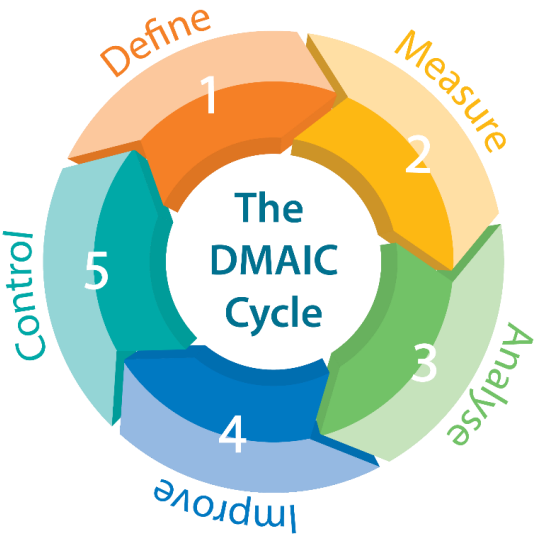

Figure 2
DMAIC Cycle

Define Phase

The Define phase aim is to determine the problem, project's objective, scope, background on both the process and the customer. During this phase, it is critical to settling an agreement with the customer, team members and the champion of the project. Before moving forward to the next phase, the following activities are to be completed: Project Charter, SIPOC Diagram, Voice of the Customer and CTQ Diagram.

- **Project Charter** – The project charter serves as the pivotal element for initiating, planning and performing the project. This document defines the project objectives, goals, and team members, it also contains the agreement between the project team and the sponsor.
- **SIPOC Diagram** – The SIPOC diagram is a high-level view of a process. The SIPOC diagram consolidates the suppliers and customers' information, as well as, the process inputs and output variables. The SIPOC, which derives as Suppliers Inputs Process Outputs Costumers, provides a large perspective of the whole system. Although it is not the first step in the acronym, it is ideal to begin by filling in the process, so the scope can be clear.

Measure Phase

During the Measure phase is where the data gathering occurs. This phase helps to understand the current status of the process. The main goal is to establish a process baseline using the data gathered to identify the anomaly or problem. These three fundamental goals are found in this phase: data collection that leads to problem location or occurrence, comprehensive baseline data, and a detailed and focused problem statement.

Analyze Phase

The Analyze phase identifies the causes that impact the current process using the data gathered during the previous phase, and all the potential causes of the problem are documented. Additionally, a root cause is identified to be able to improve the process and increase the productivity.

Improve Phase

The goal during the Improve phase is to implement changes to the process in order to eliminate the problem's root cause found during the previous phase.

Control Phase

During this phase, new updated documents are added to the current procedures that are in place. The operators are trained on the new procedures and metrics are established to monitor the process. These four fundamental goals will be found on this phase: use data to evaluate both the solutions and the plans, validate that all changes adhere to all the operating company change control, GMP, and compliance requirements, maintain the gains by standardizing processes, and outline next steps for on-going improvement.

Results and Discussion

The results gained during the project execution using DMAIC will be discussed in the sections that follow.

Define Phase

Following the DMAIC's phases, a project charter was performed with the purpose of defining the objective, scope, goals, business impact, and project statement, Figure 3 presents the project charter that was developed and approved.

PROJECT CHARTER	
Project Title	Increase the Packaging Line Capacity
Project Leader	Pedro Rosado
Champion/ Sponsor	Manager of Manufacturing Business Unit
Start Date	11/28/2016
Target Close Date	1/13/2017
Problem Statement	The company won a new contract worth 45 million dollars. The packaging line handles 1.627 million of units per year. The new contract represents 4.9 million units more per year.
Project Goal	Increase the output of the packaing line to improve the current effeciency of 80%. Reduce the packaging cost by at least $30,000 per year.
Team Members	Pedro Rosado - Project Leader Manufacturing Deparment Quality Deparment Operators Technicians
Business Impact	Increase the actual yield and reduce the cost of the packaging area.

Figure 3
Project Charter

Next, a SIPOC diagram was developed to identify the suppliers, input, output and customers of the manufacturing process related to the project. Figure 4 shows the SIPOC diagram of the current process.

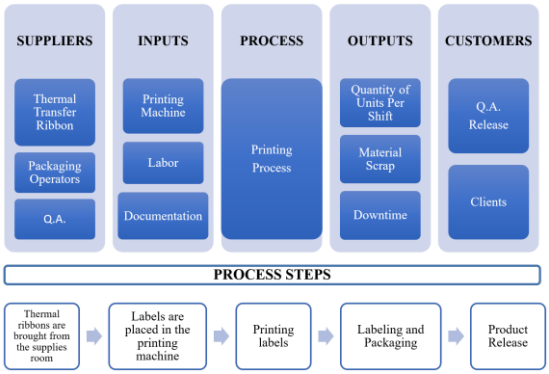

Figure 4
Printing Process SIPOC

Measure Phase

The existing process is outlined to have a better understanding. The flowchart on Figure 5 shows the current process.

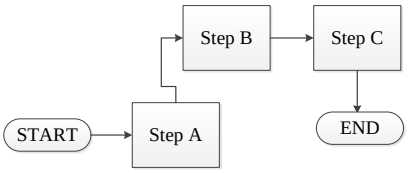

Figure 5
Process Flowchart of Current Packaging Process

The scope of the project is to increase the output of the packaging line, the cycle time of each step of the process was measured to determine the processing time of each step (Table 1).

Table 1
Processing Time per each Packaging Step

Packaging Line	Processing Time per Product (Seconds)	Preceding Step	Comment
A	30	-	1 Product
B	300	A	1 Product
C	3	B	1 Product
		-	1 Product
Total	**333 Seconds**		

The packaging line was monitored for four weeks to determine which process or step contributes more to the downtime. Table 2 shows the results.

Table 2
Packaging Downtime per Process Step

Packaging Line Step	Downtime (Minutes)			
	Week 1	**Week 2**	**Week 3**	**Week 4**
A	6	4	10	0
B	25	10	50	5
C	15	20	9	14

Furthermore, the packaging line output of product per hour was monitored during four weeks (Table 3).

Table 3
Average Boxes Output per Hour

Monitored Week	**Shift 1**	**Shift 2**
Week 1	190	180
Week 2	230	245
Week 3	160	181
Week 4	260	270
Average	**210**	**219**

Analyze Phase

The Pareto Chart (Figure 6) below indicates which packaging step causes the greatest downtime.

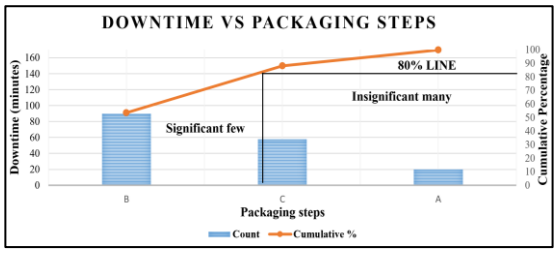

Figure 6
Packaging Steps Downtime

The analysis of downtime shows that step B is the major offender. This step consists in printing the box labels using two Xi Series printer or ZEBRA printer. Furthermore, step C is the second greatest offender. This step consists of placing the labels onto the boxes by hand.

1. Packaging Step B - A fishbone was developed by the Packaging Team, to find the root cause why step B is causing such downtime during the packaging process. Thus, it was found that both printers need new heads and platen rollers to print correctly. Also, an issue was found between the printing software (LABELVIEW 2015) and the ZEBRA printer. Finally, the Thermal Ribbon is causing issues during the impression process.
2. Packaging Step C- Due to the nature of this process, the SOP and the Validation of this step were verified and it was found that the downtime found is acceptable.

Improve Phase

During the improve phase, the Packaging Team decided to automate Steps B and C. To achieve it, a Markoprint XJET system was installed and implemented in the packaging line. Figure 7 shows the print head that makes the impressions to the boxes. Figure 8 shows the Markoprint XJET unit.

Figure 7
Print Head in the Packaging Line

Figure 8
Markoprint XJET Unit

This change represents a cost saving of $25,000 per year on Thermal Ribbon buying. Additionally, with the new equipment and process, the new yield of the packaging line is 97 %. The cost of ink for the new system is $ 6,720 per year.

During the implementation and validation phase, the output of the packaging line was monitored to compare the initial output with the new output after the improvement. The new output of the packaging line is displayed in Table 4.

Table 4
New Average Boxes Output per Hour

Monitored Week	Shift 1	Shift 2
Week 1	350	325
Week 2	340	400
Week 3	360	375
Week 4	370	390
Average	**355**	**373**

Control Phase

The Standard Operating Procedures (SOPs) for this area were updated. The operators were trained with the new SOPs to use the new equipment and software to avoid in the future a misinterpretation of some step and prevent a deviation of the process. A critical part of this phase is to take metrics of the output to verify that the new process is in control. The new target of the packaging area is 373 boxes per hour.

CONCLUSION

The Packaging Line was improved using Lean tools, using DMAIC as the systematic approach. Using this approach, the muda or waste in the process was identified and a Fishbone was created to understand the root causes of the problem. During this analysis, it was found that printer software had issues with the ZEBRA printer and the printer needs new parts to print appropriately. The goals of the project were achieved through the improvements.

The first goal of the project was to increase the output of the packaging line to improve the yield. The results show that the goal was achieved since the capacity increased from 219 boxes to 373 boxes per hour. With this improvement, the packaging line will manage 4.9 million of units more for the new customer. That means the efficiency or yield increase was from 80% to 97%.

The second goal of the project was focused on decreasing the packaging costs by at least $30,000 per year. To achieve this goal, the company automated the packaging line. This investment will be recovered in 10 months. The new equipment and process represent a cost saving of $60,000 dollars per year in overtime, maintenance, and downtimes.

REFERENCES

[1] J. P. Womack, et al., “Lean Thinking: Banish Waste and Create Wealth in your Corporation”, 2003, pp. 12-26.

[2] M. Subburajan, et al., “Enhancing the Production Capacity of 300 Ton Press by Applying Lean Principles”, *SasTech Journal*, Volume 10, Issue 1, May 2011, pp. 76-82.

[3] J. Knight. (2015, April 9). *The Most Common Mistake People Make in Calculating ROI* [Online]. Available: https://hbr.org/2015/04/the-most-common-mistake-people-make-in-calculating-roi

[4] M. Crawford. (2016, March 6). *5 Lean Principles Every Engineer Should Know* [Online]. Available: https://www.asme.org/engineering-topics/articles/manufacturing-design/5-lean-principles-every-should-know.