Production Improvement for Manufacturing Furniture Company

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***Abstract* —** *This project was based on the laminating production improvement for a manufacturing furniture company. Basically, the process consists of the laminated production of wood materials. The lead time and ship dates of the product play an important paper to satisfy the customer's needs. Also, every order has to be inspected at the end of the packing process, but the focus of this project is to improve the production of laminating production. The DMAIC methodology was used to improve the efficiency and laminate of wood production. DMAIC is an acronym for a series of steps used to measure defects in a company and improve the efficiency. These steps are: Define, Measures, Analyze, Improve and Control. The focus of the project is to reduce waste time (to improve the efficiency), lead time and increase the capacity of orders according to the customer's needs using the DMAIC methodology and SMED system. The company seeks to comply with the demand expected yearly. The DMAIC methodology brings a structure and the tool to improve a process by optimizing and stabilizing it. In this case the laminates production will be applied to help and improve the efficiency and capacity for the furniture production.*

Key Terms *— DMAIC Methodology, Lead Time, SMED System, Waste Time.*

INTRODUCTION

The furniture manufacturing company has as a challenge, to comply with order demand every year. The company is focused to bring a high quality product quick. The ship time for the customer is the challenge for the furniture company because every order came from around different countries and place with a delivery time and prioritized. The company bring products for companies, dealers, and commercial sectors. Every order submitted is processed by priorities and expected time. The company is focused to bring this product with the customers' requirements and expected time required.

Problem Statement

The laminates production had been growing rapidly from the past years to now. Also, the customers complain about shipping date which has been increasing. Every year the company seeks to satisfy the customer's needs for the delivery time and the capacity of product per orders. The company receives an average of 6% to 8% delayed orders per week. This means that from every 100 orders processed, 6 to 8 have a customer complain about due delays. This means the demand of capacity and product have been growing rapidly. The goal is increasing the production capacity and improving the lead time for every order using the DMAIC methodology as tool.

Research Description

The project is focused on increasing the production capacity and improving the lead time. The most important reason for customer's complains is the delivery time of order. The lead time plays an important role into the capacity and laminating process.

Research Objectives

The project seeks to reduce the delayed product at least from 8% to 2% per week. Decreasing the waste time seeks to increase the productivity 10% to 15% per month. In this manner the company will be

able to increase the production and accomplish the demand annually.

Research Contributions

The project seeks to increase the capacity to satisfy the customers demand annually. This allows the company to pull more orders from the customer and increase capacity of laminate products. This increase represents approximately $50,000 of laminates product per year. Using the DMAIC solution the company will be able to reach this goal.

General Concepts of DMAIC Methodology

DMAIC is an abbreviation of five improvements steps: Define, Measure, Analyze, Improve and Control. These improvement steps refer to a data driven improvement cycle used for improving, optimizing and stabilizing business processes and designs [1]. The DMAIC cycle is the core tool that is used to manage Six Sigma projects. All of the DMAIC process steps are required, and always proceed in the given order. DMAIC can be used for any improvement project or application. See Figure 1.

- Define: Define who the customer is, what the requirements for the product or the service are and what their expectations are. In this phase, the project boundaries are defined, and the process is mapped to understand the flow.
- Measure: Create and develop a data collection plan for the process, data is collected from many sources to determine types of defects and metrics.
- Analyze: The data is collected to be analyzed and to determine root causes of defects and opportunities for improvement. In this Phase, gaps are identified between current performance and goal performance, also to help identify the sources of variation and prioritize opportunities to improve.
- Improve: The target is processed by designing creative solutions to fix the problem and prevent future occurrences. In the Improve phase, innovate solutions are created to develop and deploy the implementation plan.
- Control: The phase of Control helps to maintain and improve the new process implemented. This helps to prevent reverting back to the “old way”. This phase requires the development, documentation and implementation of an ongoing monitoring plan.

PROJECT METHODOLOGY

An improvement methodology needs to be used to carry out a project successfully. In this case the DMAIC methodology was selected as tools to achieve the goals of increasing the productivity and the efficiency of the company as specified in the objective. Figure 1 explains the acronyms of DMAIC methodology [2].

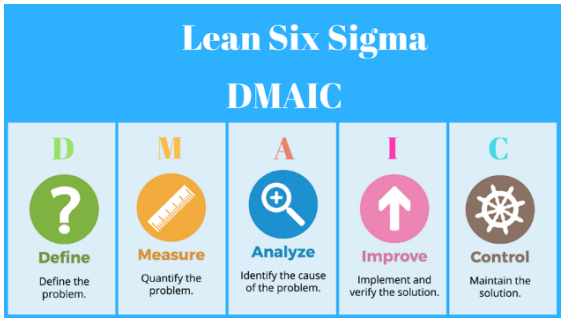

Figure 1
DMAIC [3]

The tool at Define step was the Project Charter:

- Project Charter is a statement of the scope, objectives, and participants in a project.
- Provides a preliminary delineation of roles and responsibilities, outlines the project objectives, identifies the main stakeholders, and defines the authority of the project manager.
- Serves as a reference of authority for the future of the project.

At the Measure steps the following tools will be used:

- The SIPOC diagram - A tool that summarizes the inputs and outputs of one or more processes. The acronym SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customers. The SIPOC diagram helps us to understand the relationship between the supplier and customer,

in other words, the input and output variables of the process, and finally the process steps.

- Voice of the Customer - A technique that helps to understand in detail the customer needs organized and prioritized. This is showed in hierarchical structure arranged by customer comment, customer needs and customer requirements.

For the following steps (Analyze, Improvements and Control) tools to be used will be determined during the project process according to the previous steps results [3].

RESULTS AND DISCUSSION

The results obtained through the five phases of the DMAIC methodology follows.

Define – As part of the define phase the Project Charter tool was performed in order to determine the problem statement, the goal of the project and the metrics that will be defined. The Project Charter can be seen in Table 1.

Another tool that was used for the Define stage is the Thought Process Map (TMAP). It is a visual representation of a Black Belt's, team leader's or an entire team's thoughts, ideas, and questions relative to accomplishing the project goal. It should be one of the first tools employed when starting any Six Sigma or process improvement project. A TMAP presents a structure of information and helps a team progress through the DMAIC process. It is a living document that will change throughout the project and has no set format. A TMAP (see Figure 2) can be used to drive specific actions and select the Six Sigma tools that should be employed.

The TMAP helps to understand the role clearly through several question. Also, this tool helps to show the priorities to the team members and ensure that nothing is missed. The idea is to start showing how to reach the goals clearly. Table 2 describes the Action Log.

Table 1
Project Charter [2]

Project Charter: Laminates Production	
Problem Statement	
The company receive around 6%-8% average of orders per week are delayed. This mean that every 100 of orders processed 6-8 have a customer complains due delays. The production demand have increasing radidly through the year.	
Goal Statement	
This project seeks to reduce the delayed product from 8% to 2% per week at least. Decreasing the waste time this project seeks increase the productivity 10% to 15% per month. In this manner the company will be capable to increase the production and accomplish the demand annually.	
Business Case & Benefits	
Cycle time improvement of laminates production would result of economic impact and would allow increase the laminates production and would decrease the number of emplyee. Also, this would eliminate the unnecessary waste in this manner would improve the flow of production. This would maximize the laminate production and would meet with the goals of the company and customer satisfaction.	
Scope - First/Last and In/Out	
1st Process Step:	The operator prepare the order and material to process.
Last Process Step:	Materials laminated pending to be cut.
In Scope:	Material localization, Material preparation, Documentation, Process step, Confirm ID number.
Out of Scope:	Cut HPL order, Edgeband process, Ship the order on time, QC if required.

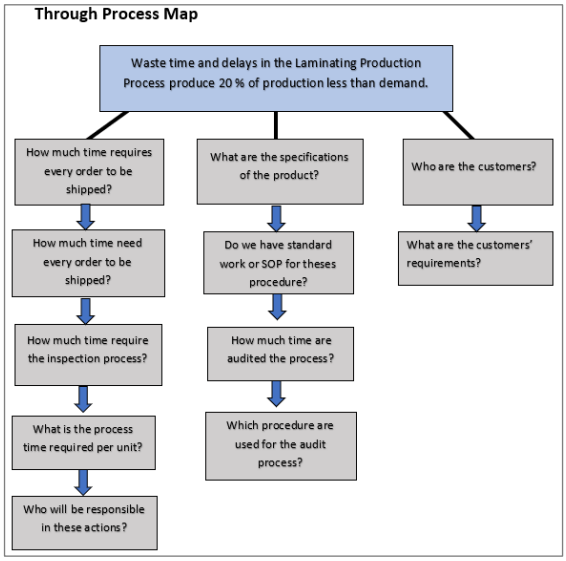

Figure 2
TMAP

Table 2
Action Log

Action	Description	Completion Date
How much time requires every order to be shipped?	Re-make a time study to identify VA and NVA.	2/2/2020
How much time need every order to be shipped?	Review the process and re-define what is the lead time required.	2/2/2020
How much time require the inspection process?	Review the laminates process and the standard works procedures.	2/2/2020
What is the time required of the laminates process per unit?	Review the manufacturing demand and identify customer's needs.	2/2/2020
What are the specifications of the product?	Review the Voice of the Customer and identify the customers' requirements.	2/2/2020
How much time are audited the process?	Review the SOP or standard works audited.	2/2/2020
Which procedure are used for the audit process?	Review the SOP or standard works audited	2/2/2020

The most important variables in the project can be identified through the TMAP through question and answers that help to prioritize roles of the team members. The main idea is identifying what are the most important requirements needed to follow the process and what are the customers' requirements to improve and accomplish the objectives at the end.

Measure

As part of this phase a Data Collection Plan is performed to identify the operational definition, type of data and how it would be measured as shown in Table 1. The continuous data are the all fixed value or measurement. The discrete data is one that can be changed by different reasons. Also, a SIPOC diagram was performed as part of the Measure phase.

SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customers which form the columns of the diagram [4]. SIPOC diagram visually documents a business process from beginning to end. The SIPOC diagram helps to show how the process affects to the customer. Every process was validated and audited before being implemented. The documentation is very important as evidence for results of every process at the company. The result of the Data Collection Plan and SIPOC diagram is shown in Figure 3.

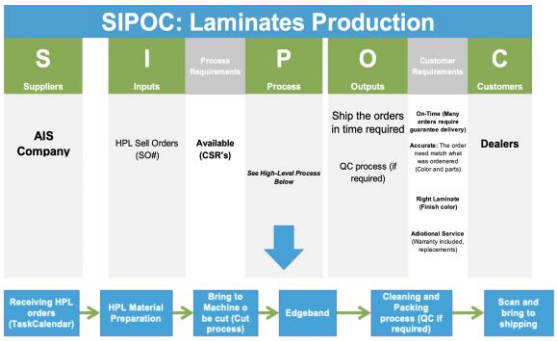

Figure 3
SIPOC Diagram

The SIPOC analysis helped to identify the relationship of the process from the suppliers to the customers [4]. The process plays an important role between the suppliers and materials until the customer. The customer wants to improve the delivery time of the product, product quality and lead time. The satisfaction of the customer and the lead time of every product has been challenging for the company to improve. The following analysis would be the key to reach the solution and reach the objective of the project (see Table 3).

The Data Collection Plan consist of identifying the Operational Definition of the process and how it will be measured. Through the Data Collection Plan, the operational definition of process can be understood. In this phase the process was separated in three elements: preparation time, changeover time and transportation time. The preparation time consist of the set-up of the material to start the laminate process. This step starts where the product is prepared by the operator. The changeover time is defined as the change of the setup machine. This part plays a crucial role to improve the time and increase the capacity of the product. The operator needs to change the material and setup of the machine according the order requirement and specifications. The transportation time consist of the traveling the operator has to do every setup through the process. Through the final process the operator needs to bring the materials from one point to another.

Table 3
Data Collection Plan [4]

Data Collection Plan					
Measure	**Data Type**	**Operational Definition**	**Stratification Factors**	**Sampling Notes**	**Who and How**
Preparation Time	Minutes-Discretes	Time (in minutes) from the operator take the paperwork and verify what material and how many needs to the order.	none	Every table jobs the operator take 2-3 minutes to check what material and how many need to do it.	Analysis by study time video recorded
Changeover time	Minutes-Continous	The time (in minutes) of the operator take to change the set up of the laminate machine.	none	Every changeover of the material take between 8-25 minutes according of the material.	Analysis by study time video recorded
Transportation time	Minutes - Discrete	The time (in minutes) of the operator take to pull in/out the material.	none	At the beginning and end of the process the operator takes about 3-8 minutes to remove and set up the material.	Analysis by study time video recorded

These three elements of the process are defined as the operational definition of the process. The changeover steps play the most important step in the process. Therefore, the focus was around the changeover or setup steps. Then, the process needs to be validated and audited as part of the quality process inspection to make sure that it complies with all specifications.

Analyze Phase

As part of analyze phase a Pareto Chart was created to analyze frequency of defects through the laminates process. This Chart helped identify the requirements that are causing conflict through the process in order and helped to identify what activities were needed to do first to achieve the best yield and objective successfully.

The analysis was performed by a manufacturing engineering in charge to realize the analysis phases in this project. The activities that are causing most problems through the process were identified through the Pareto Chart. In Figure 4 can be observed the first three activities that are causing problems with more frequency. They were; missing materials in stock in every order, delays due to change of orders and down time by different reasons. This information was collected for 6 month from January thru July on 2019. Those activities have been causing the same problem during many years and have been affecting the capacity and causing that the product has not been delivered on time making a poor lead time.

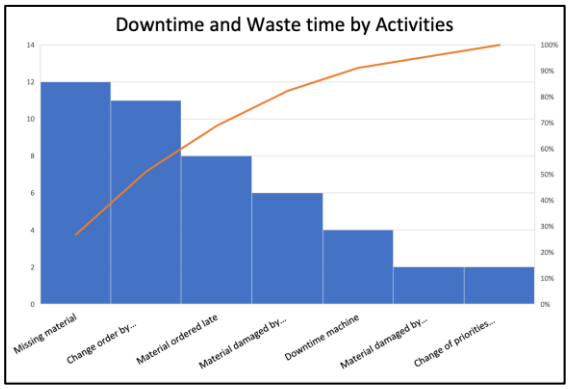

Figure 4
Downtime and Waste Time by Activities

The focus of the analysis was to identify the points that are affecting the efficiency and yield of the process and what activities or steps are causing those problems through the process [4]. Therefore, a Value-Added Flow Analysis was performed to identify what activities are Value Added (VA), No Value Added (NVA) and Enable Added Value (NVA-r). The analysis consisted of breaking down the process by element and identifying what steps are add value to the product directly and what steps don't add any value to the product. Also the steps that are necessary to do such as documentation and cleaning area called Value Added Allowed (NVA-r). Table 4 and Table 5 show the results of Value - Added Flow Analysis and the Time Study Analysis as part of Analysis phase [1].

Table 4
Value – Added Flow Analysis

Value-Added Flow Analysis

Name: James
Date: 3/10/19
Process Name: Laminating Process
Time Measured In: Minutes Hours Days (select units)

#	Process Step	Step Label (VA, NVA, NVAr)	Value Added Process Time	NVA & NVA-Required Process Time	NVA - Wait Time
1	Kitting boards per order using vacuum lift.	NVA			1.44
2	Kitting boards using Folklift.	NVA			2.12
3	Enter and remove sheets table of orders.	NVA			1.9
4	Enter and remove materials for laminates (PB, MDF).	NVA			3.62
5	Remove materials Laminated (WKS, DESK,CG).	NVA			2.7
6	Remove materials Laminated (Woodshop Tiles).	NVA			5.08
7	Kitting backers for every table.	NVA			5.24
8	Documentations (Laminates Report).	NVA-r		2.22	
9	Clean and prepare laminating machine.	NVA-r		29.96	
10	Laminating process (Glue + Laminate + Press + Weight)	VA	1.316		

	Time	% of total
Total Value-Added Process Time	1.316	18.20%
Total Non-Value-Added or NVA-r Process Time	32.18	57.88%
NVA - Wait Time	22.1	36.30%
Total Lead Time	55.596	100.00%

Table 5
Time Study Analysis Versus Values Added Flow Analysis

Time Study Analysis					
#Task	Aveg (Min)	Value	Cycle #	Total Time	Percent
1	1.44	Non-Value- Added	18	25.92	5.40%
2	2.12	Non-Value- Added	9	19.08	3.90%
3	1.9	Non-Value- Added	7	13.3	2.70%
4	3.62	Non-Value- Added	12	43.44	9.00%
5	2.7	Non-Value- Added	12	32.4	6.70%
6	5.08	Non-Value- Added	6	30.48	6.30%
7	5.24	Non-Value- Added	7	36.68	7.60%
8	2.22	Value-Enabled	13	28.86	6.00%
9	29.96	Value-Enabled	2	59.92	12.20%
10	1.3	*Value-Added*	132	173.712	36.00%
			NVA	46.10%	
			VA	18.20%	
			NVA-r	36.40%	

It was observed that around 46% of the process step is Non-Value-Added steps (NVA). The operator has to be waiting a lot of time while the process continues. The average of total Value Added was only 18% in total. An inefficiency that is causing delays in the product and a poor lead time in the process can be clearly seen. This is one of the reasons that are causing dissatisfaction of the customers and where the focus was to reduce the lead time and the waste time to increase the efficiency of the product as well. The process has enabled Non-Value Added that are accepted in the process such as documentation, cleaning and maintenance as well. Then, a Spaghetti Diagram was made to better understand the waste time caused into the process as part of visual analysis (see Figure 5).

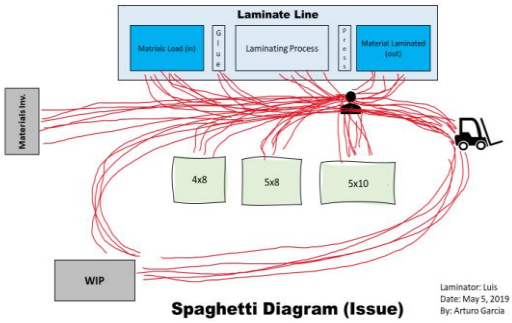

Figure 5
Spaghetti Diagram

Through the Spaghetti Diagram it can be better appreciated how the operator is getting out of the workplace to setup the material and how the process is going to be down. It can be seen how there are a lot of unnecessary movements through the process where flexibility is not allowed causing a lot of downtime through the process. Each operator had to move out to set up the materials every time with the

forklift and walking losing 30% and sometimes 40% of waste of time.

Improve Phase

Through this phase the improvement to make possible a problem solution was implemented, and the objective of the project achieved. SMED system was used as part of the improvement phase.

The SMED methodology is an abbreviation for Single-Minute Exchange of Dies. The goal of this methodology is reducing the changeover time to the "single" digits (less than 10 minutes).

The SMED system seeks achievement with the following benefits:

- Lower manufacturing cost
- Smaller lot sizes
- Improved responsiveness to customer demand
- Lower inventory levels
- Smoother startups

The essence of SMED system is to convert to "external" as many changeover steps as possible (the steps performed while the equipment is running) and to simplify the remaining steps through the process. Figure 6 shows the SMED system has three major phases [5].

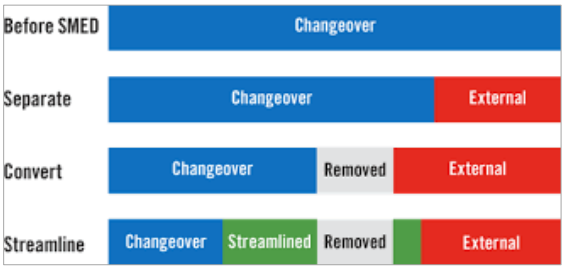

Figure 6
The SMED System Three Major Phases

The process focuses on making external as many elements as possible, simplifying and streamlining all elements [5]. These phases are performed in sequence and the entire sequence can be repeated. The system consists of separating the internal external steps. The internals activities are the activities that are performed while the machine is stopped. The external activities are the activities that are performed while the machine is running. The idea of this system is converting all internal activities to external. In other words, convert all activities that are performed while the machine is down and try to convert those activities while the machine is running. Figure 7 shows the result of SMED system implemented in the laminating process of this project.

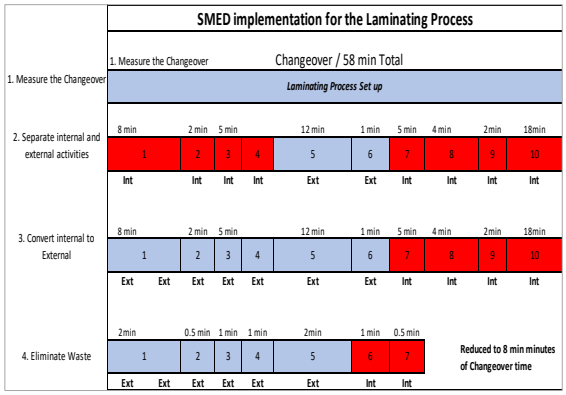

Figure 7
SMED System Implementation

The process flow was modified with two conveyors to make this system happen. Usually it is hard to convert internal tasks to external or while the machine is running. In this case it was possible implementing two conveyors at the beginning and the end of the process. The system allowed to reduce the lead time process to 8 min approximately. This improvement gives the opportunity to increase the capacity and efficiency process. With the conversion of internal to external it was possible, thanks to the change in the process flow, to reduce unnecessary movements through the process. A lot of times the process is going to be affected due to unnecessary movements and won't pay attention where the machine is down. The SMED system helps to identify those tasks where the process can work while the machine is running. The Spaghetti Diagram was modified to visualize the process improvement. Figure 8 represents the result of the SMED system implemented into the laminating process and how it was possible to reduce from 58 min to 8 to 10 minutes of set up. The internal tasks were changed implementing two conveyors to keep the process while the machine is running. The movements of each operator were improved through this system.

Control Phase

A document was created to track and audit the process every month. A standard work was created as part of the process (see Table 6). The quality control agents are responsible to run a report monthly to make sure that the process comply with the parameters and the operator keeps doing the process per standard work. This is one of the most important phases of the project because is where the project should be sustained. Many projects look very good at the beginning, but they fall at the end because attention is not paid to this phase. The sustain and control of a project is very important to give value to the project.

The template was created as a standard document for quality control. The quality agent has to fill it up every month to audit the process and make sure that the operators are following the process by standards that work correctly.

Table 6
Standard Work to Audit the Laminate Process

Line		Required Setup tools		Standard setup time	
Machine					
Operators					

Nº	Task / Operation	Actual time		Improvement	Target time		Necessary activities
		Internal	External		Internal	External	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

CONCLUSION

Through the project productivity was increased 20%. The goals at the beginning were 10% - 15% to accomplish with the demand. The change of the process was amazing, and it can be seen how the discipline and the lean system methodology works. In addition, one operator was reduced in the process, an equivalent of $30,000 of additional saving for the company. The capacity increased around 5M to 10M more to fulfill more than the demand expected. The project was a great success and an example for other companies to use this discipline and methodology.

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