Lean Manufacturing Implementation to Improve Process Capability and Performance

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Abstract *— Industries has been continuously evolving with the change in tendencies and market growth of products. To be capable of maintaining the organization competitiveness, in front of an aggressive market, production capability and cost reduction is desired. Company X is dedicated to the design and manufacturing of customizable packaging and promotional merchandise. It was identified some factors affecting the deliverables of the production floor, such as inefficient layout design. Lean manufacturing is a tool widely used by many industries to reduce waste in processes. Applying this tool into production processes, allows to reduce wastes in process and to reduce production costs and defect ratio. DMAIC (Define, Measure, Analysis, Improve and Control) was the methodology used to improve the outputs of the production floor of Company X. At the end of the project an improvement of 15% on the productivity was observed; in addition, the defect rate was reduced by 33%.*

Key Terms*: 5'S, DMAIC, Lean Manufacturing, Waste Reduction.*

INTRODUCTION

Company X mission and vision are to provide a high-quality product that meet customer expectancies, delivering it on time. After COVID-19, the demand of products, specifically packaging products, has a rapid increase. For industries, it is important to maintaining competitive because of the existence of companies offering similar products. In Company X it was identified a need to operate in an efficient way, to meet customer's requirements. Production deliverables were often delayed by inaccurate planning in the production department, affecting customer satisfaction. There exist some losses of time because of an excess of movement and a lack of organized area; making difficult for operator to find the correct tools or materials to be worked on. This overwhelmed area and lack of organization affects productivity and increase the defect rate, not only for waste in time finding tools or materials, but also affects the work environment and the morale of employees. Lean manufacturing was implemented with the purpose to identify the weakness of the process to improve it and obtain better results. Using the capabilities of the tool to reduce the waste that was generated in the process.

Research Description

This research is being performed to understand and correct some issues of capability and productivity in an organization. It is important to fully understand all the techniques and tools that can be used to have an efficient and effective workflow. An important aspect on this research is to find the correct and applicable techniques and tools that are within the company reach.

Research Objectives

The objective of the research is to select the correct and applicable tools to optimize the deliverables and the production department for Company X. After the completion of this research, it is expected to get implemented those tools and techniques identified to solve principal issues affecting the organization performance, by reducing wastes such as: motion, inventory, transportation, waiting, but the most important one: defects. The goal of this research is to reduce by at least 40% the rate of defects and re-work and increase productivity by at least 15%.

Research Contributions

At the end of this research, the main contribution will be at the customer level, by meeting their expectancies and due dates with no delays and quality problems. In terms of the organization internally, this research will be beneficial to employees, allowing them to have a balanced workload and organized work area, which will require less effort to do those tasks that adds value to the product. All those effects will allow the company to reduce production costs, such as employees overtime, re-work, etc. and therefore, it will increase the organization's revenue.

LITERATURE REVIEW

Lean manufacturing philosophy dates to the late 1940's, when Sakichi Toyoda, Kiichiro Toyoda, and Taiichi Ohno creates a production system for the Toyota corporation. The intention was to improve its processes by reducing wastes and increasing productivity to be competitive with American production lines [1]. Lean Manufacturing can be defined as a set of tools and techniques to be implemented to reduce wastes in process, as well as increase productivity and efficiency, resulting in cost reduction. In Lean Manufacturing there exists 3 different types of barriers affecting an organization performance; often described as 3M rule: muda, muri, mura [2].

Muda are those wastes classified in 7 types. Waste in lean manufacturing philosophy are those steps which does not adds value to the final product. Looking that from a process perspective, waste are steps which does not moves the process itself to being closer to the final product. In Lean Manufacturing, there exists seven types of wastes: (1) overproduction: manufacturing more than needed or before required; (2) inventory: excess of inventory makes difficult to identify failures, also, excess of inventory requires more space than needed, increasing as a consequence the lead time; (3) waiting: occurs when product is waiting for next operation; (4) transportation: moving the material to one place to another, this can cause damage and compromises the quality of the product; (5) motion: moving, product, employees or equipment; this excess of movement can produce damage, fatigue and also safety issues; (6) over-processing: when used more expensive resources than needed, it could be materials or accessories not required by the client; (7) defects: this waste results in re-work or scrap, it involves more planning, schedule and inspections that does not adds value to the final product [2].

Muri is the overburden, caused when equipment's or operators are running more than 100%. This can produce equipment failures and breakdowns when the overburden is on the machines. On the other hand, when the overburden is over operators it can produce absenteeism due to stress because of an excess on demand or lack of training [2].

Mura is unevenness or non-uniformity, it could be on product demand, performance of different operators or process time per product. When Mura is not under control it can produce muri. In other words, it refers to the cycle of work that are busier than another [2].

Lean Manufacturing are based on three main pillars: Standardization, JIDOKA, and JIT (Just in Time). In the baseline of the pillars, there is standardization, with the implementation of tools such as: 5's, Kanban, SOP, TPM, etc. The results obtained are tangible in small period. This can be the starting point for Lean Manufacturing implementation [3].

JIT (Just in Time) implementation guarantee cost reduction for organizations, and meeting customers' demands. JIT can be defined as the concept of deliver raw material when needed and producing products only when needed, avoiding storage for product produced before needed. The focus of JIT is the reduction of raw material in the floor, reduction of work in process (WIP) and finished production inventories [4].

JIDOKA, on the other hand, refers to the process executed to identify abnormalities as they occur, to be fixed now. Once the abnormality is fixed, JIDOKA requires to find the root cause of the abnormality, to avoid recurrent abnormalities. Implementing JIDOKA helps an organization to identify any issue with the production before it is finished or before a re-work is needed [3].

At the end of the Lean Manufacturing pillars the focus is the customer satisfaction for the success of the organization. To be successful implementing Lean Manufacturing, the human capital plays an important and critical role. It is important for Managers to promote team building, empowerment of employees, cross-training, etc. [3].

Six sigma, on the other hand is a methodology which is focused on the reduction of the variation in processes. In combination, Lean Six Sigma combines tools from both methodologies, lean emphasizes in manufacturing cost reduction and six sigma emphasized in defect reduction; in contrast those two methodologies work in the improvement of processes, including an increase in productivity and quality [5].

According to Feld "The Five Primary Elements for lean manufacturing are (1) Manufacturing Flow, (2) Organization, (3) Process Control, (4) Metrics, and (5) Logistics" [6]. All those elements are related to each other covering standards to be followed, employee's roles, process improvement, performance measurements and mechanisms for planning and material flow. Even when these elements are focused on specific areas, they are complemented by each other to achieve lean manufacturing implementation. According to Feld, good environment work area could be achieved if employees start to see movement in the shop floor, or production area; for example: machines movement, cleaning, and painting areas. In addition, Feld also mentions that invisible changes such as organizational roles or trainings also improve the work area and employee's attitude and mood.

Some organizations get implemented Lean Manufacturing methodologies to increase profitability resulting from an increase in capability, productivity, and employee's engagement. Capacity increase can by achieved in some ways: (1) increasing the machine availability, by eliminating wastes from the process; (2) eliminating bottle neck processes and (3) making an investment to have new equipment and space [7].

To identify wastes and therefore works eliminating or reducing them, some strategies can be applied such as DMAIC and 5's. DMAIC methodology consists in a 5-step process. Define, Measure, Analyze, Improve and Control.

Figure 1

DMAIC cycle [5]

To have a productive and easy-to-follow work environment, 5's practice becomes important and relevant. This is a Japanese method to organize the work area. As shown in the Figure below, 5's method consists in: (1) Sort, (2) set in order, (3) shine, (4) standardize and (5) sustain. This method, could be seen as a simple one, however is becomes useful and relevant as it helps to identify and eliminate wastes in the processes, making those process to be improved. 5's also helps employees to work in a harmonic work environment, improving therefore the productivity and quality [8].

Figure 2

5's Method [6]

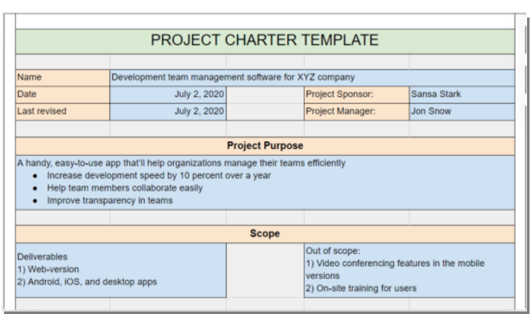
METHODOLOGY

To reduce non-value adding activities as well as wastes, often known as muda, lean six sigma methodologies results convenient for any organization. Lean manufacturing methodologies helps organizations to streamline manufacturing processes for its improvement. DMAIC approach is an abbreviation used to describe the five-step strategy which includes: Define, Measure, Analysis, Improve and Control phase. There is important to understand that this 5 Step strategy is a cycle for continuous improvement.

Define Phase

In the define phase the project goal needs to be established. At this point, the process of interest as well as the problem statement must be defined. To get this phase done, tools such as: Process workflow, Project Charter, and Voice of Customer (VOC) are some of the tools to be used.

For this project, a Project Charter will be developed to define the problem statement, as well as the scope of the project with the desired deliverables. Main advantage of Project Charter is to clarify from the beginning of the project the objectives and the scope of the project. Project Charter also authorizes the program manager to start working on the project and it also maintains continuity in case that the personnel involved in the project change during the project execution.



PROJECT CHARTER TEMPLATE

Name	Development team management software for XYZ company			
Date	July 2, 2020		Project Sponsor:	Sansa Stark
Last revised	July 2, 2020		Project Manager:	Jon Snow

Project Purpose

A handy, easy-to-use app that'll help organizations manage their teams efficiently
- Increase development speed by 10 percent over a year
- Help team members collaborate easily
- Improve transparency in teams

Scope

Deliverables 1) Web-version 2) Android, iOS, and desktop apps	Out of scope: 1) Video conferencing features in the mobile versions 2) On-site training for users

Figure 3

Example of Project Charter Template [9]

Measure Phase

In the second phase, the process actual performance needs to be measured. This phase helps to understand the current outputs for the process regardless of what the results are. The principal objective of the second phase of the DMAIC cycle is to establish a process baseline, which further will help to identify problems or process abnormalities.

In this phase, Pareto Chart will be implemented to illustrate the initial performance. This graphical tool helps to identify the main causes of problem and the degree of impact and significance.

Figure 4

Pareto Chart Example [10]

Analysis Phase

On the third phase, all the results obtained from previous phases must be analyzed. In this phase the root-cause of the problem needs to be identified for further improvement. Tools such as: cause and effect/fishbone diagram and 5Whys can be used to identify the root-cause.

In this phase, root cause analysis will be implemented. Advantages of this analysis are the identification of the main causes of the problem. It is a depth study which will give the root cause and the solution can be permanent and it will avoid future defects or reduce the re-occurrence.

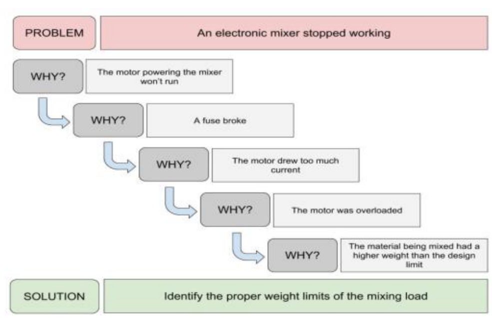


Figure 5

Root Cause Analysis Example [11]

Improve Phase

The objective of this phase is to get implemented some changes in the process to eliminate the wastes identified and therefore, get an improvement in the process. Brainstorming is one of the tools to be used in this phase. In addition, approaches such as 5's must be implemented for process improvement.

Control Phase

In this phase any change in process need to be added to the corresponding procedures, in addition trainings to employees who works directly with those process changes needs to be conducted. Process capabilities and metrics needs to be determined and defined in this phase. Internal audits need to be performed during this phase to identify and correct any irregularity that could affect the process performance.

In control phase a Statistical Process Control will be performed to compare initial outputs and final outputs after improvement of processes.

Results and Discussion

With the intention to improve capability of the production floor of company X, DMAIC approach was conducted. The first step was the Define phase, in this phase a Project Charter was developed to define the problem statement, the goals and scope of the project and the identification of team members who were working on that project. One of the most essential points when defining a project is to do it in a clearly and understandable way, to have all the team members aligned with the desired deliverables of the project. Also, it is critical for the success of the project to identify and define what the problem and the goal is. In the Project Charter illustrated bellow, it is easy to observe what is the project in general sense, and all the relevant and critical information will be compiled on the same document for further reference. Project Charter includes the timeline of the project that started on November 15, 2021 and was expected to be completed on April 01, 2022.

Table 1
Project Charter

Project Charter				
Name:	Internal Project: Production Floor Capacity Improvement			
Release Date	Nov 15, 2021		Project Approval	VP
Estimated time of Completion	April 01, 2022		Project Manager	Yanairy Orama
Project Purpose				
• Increase in capacity of production • Reduce by at least 40% defect and re-work rate • Improve by at least 15% the productivity of production floor				
Scope				
All the processes within production departments, including warehouse department				
Out of Scope				
Other administrative departments and design and customer service departments				
Deliverables	Reduction of production lead time, less rate of re-work, production costs reduction.			

To understand the current state of the process a Value Stream Map (VSM) was created for the entire operation from receiving the order to delivering it to the customer. The figure bellow illustrates the value stream map for production floor of Company X, representing the current state map of the process. In this figure it can observed the wastes occurring between each one of the operations.

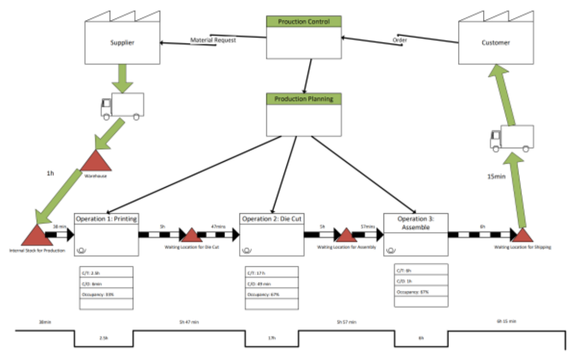


Figure 6

Value Stream Map of the Initial State

Another tool used to measure the current state the pareto chart. Here it can be easily identified that there are many issues that affect the production process. The team was involved in a brainstorming activity to identify the wastes of time in the process. It was noticed that production process was overwhelmed with issues of location of material and jobs between operations. Space limitation results one of the most common issues affecting the performance and productivity of the production department.

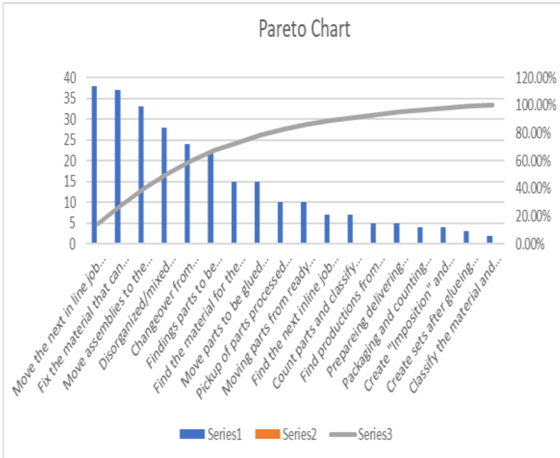


Figure 7

Pareto Chart for the Initial State

After performed the Pareto Chart, a Root-Cause Analysis was performed to identify the root cause of each one of the most significant problems. The figure below, shows the results obtained from this analysis. Same analysis was performed for each one of the possible causes identified.

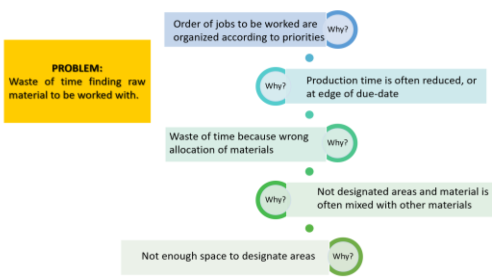


Figure 8

Root-Cause Analysis (5-Whys?)

A root-cause analysis was performed for all the possible causes of the main problems affecting production capacity, due to a lack of productivity. There was a common denominator identified: small space for allocation of material and unfinished jobs. Because of this space limitations, operators need to move long distances and move too often to find the materials or tools to be used; also, to move material to the next step in the production line. In the figure below, the initial state of equipment and utility's location was layout. The areas of MFG 1 (Printing) were the farthest area from warehouse. Since the use of raw material is initiated in this step of the production line and there was not enough space to have the material to be used near to the machine, operators need to walk to the warehouse to look for the material for the next job in line. To easy understand the initial state of the production flow, this layout was developed with a spaghetti diagram to illustrate all the distance and steps to finish an order.

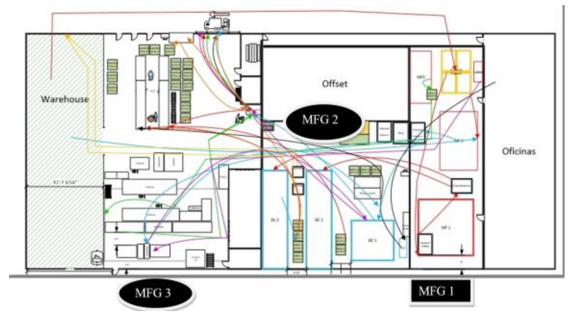


Figure 9

Initial State Layout

Another issue identified was the defects and rework ratio due to bad management of unfinished jobs and losing items from a job. This was identified by visual inspection as shown in the figure below where different jobs were mixed in the same pallet. Some different order has pieces which are similar, so after being mixed is difficult to find them. Most of the time when different parts of orders are mixed in the same pallet and the operators from MFG 3 are trying to find pieces to mount an assembly, not all the items are founded, and it is required to run again the missing items through the operation. At the end, there is a significant number of leftovers for the order that cannot be used, and it is discarded.

Figure 10

Initial State Allocation of Jobs Processed in Mfg. 2

After identifying all the areas having opportunities for improvement within the production floor, the next phase was executed. For this, an extensive planning was made, since this improvement includes not only the relocation of all areas to have better workflow, but also the acquisition of new equipment and a new facility for warehouse. The first step was the allocation design for the warehouse in the new facility adjacent the production plant. The design of material allocation in the warehouse is shown in the Figure 11. This new warehouse space is 4 times bigger than the space initial state. Figures 12, 13, and 14 makes a direct comparison between initial warehouse and final warehouse facilities allocation.

Figure 11

Final State Layout of Warehouse (New facility)

Figure 12

Initial State Warehouse Allocation

Figure 13

Final State Warehouse Allocation (Color code for materials)

Figure 14

Final State Warehouse Allocation

After the transition of the warehouse to the new facility, the machines and equipment movement phase started. The new layout for production plant was designed considering the space needed for reduce the wastes associated with inventory, movement, transportation, and defects. The new layout is shown in the figure below with a spaghetti diagram to compare the flow of jobs and operators.

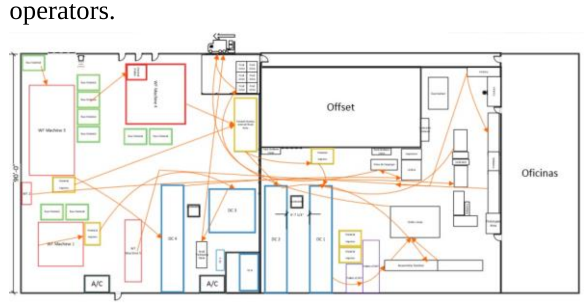


Figure 15

Final State Layout for production floor (Spaghetti Diagram)

Once the installation of new equipment and the movement of existing equipment according to the new layout designed. A 5's process was made for the organization and identification of the corresponding areas. Different areas were designated to allocate raw material, according to the machine allocation, to reduce movement waste. Also, areas were labeled, including bins of assembly accessories, as shown in figures below. Figure 16 illustrates the initial state of accessories, which were mixed, making difficult to organize them before starts the assembling. The next Figure 17 shows the final state of accessories bins, labeled according to a color code established in a catalogue for easy identification when needed from warehouse. The new bins to accommodate accessories was selected to be clear to identify whether an abnormality, such as mixed items occur.

Figure 16

Initial State of accessories allocation

Figure 17

Final accessories allocation

On the other departments, areas were also designated to guarantee a clean space for easy movement of pallets. Also, space to allocate specific jobs on pallets was established, to avoid having mixed orders. Figures below shows the difference between the same area before and after the allocation.

Figure 18

Final State of Production Department

On the other hand, Figures 19 and 20 shows a pallet with a specific job, this method reduce waste of time by identification items and moving them, as the operator can now move the entire pallet, instead of moving piece by piece.

Figure 19

Correct Accommodation of Jobs After Being Processed in Mfg.2

Figure 20

Correct Accommodation of Jobs After Being Processed in Mfg.2

This Project implementation was completed on April 01, which means that not enough data are being collected after the completion of the project. However, to perform a statistical analysis to prove if the objectives of the project were achieved, data collected from January to April was analyzed since one or more steps of the improvement phase were already on place. The objectives of the project where level of improvement to increase productivity by at least 15% and reduce defects by at least 40%. Looking for the first objective, a hypothesis test was performed. Time of all the activities carried out to complete a job will be compared to see if the time was reduced by at least 15%. The data used for that comparison was measured during January to April 2022 and compare with the same period in 2021. The null hypothesis for the t-test performed established as a null hypothesis that the difference of the two set of data was less to 15%, while the alternative hypothesis says that the difference will be more than 15%. The result of the test performed using Minitab software are summarized below.

Two-Sample T-Test and CI: Original; New

```
Two-sample T for Original vs New

           N     Mean  StDev  SE Mean
Original  30  2840.50   5.24     0.96
New       30   1868.7   10.4      1.9


Difference = µ (Original) - µ.(New)
Estimate for difference:  971.83
95% lower bound for difference:  968.26
T-Test of difference = 372 (vs >): T-Value = 281.21  P-Value = 0.000  DF = 58
Both use Pooled StDev = 8.2611
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Looking the results, the p-value obtained was 0, which means that the null hypothesis was rejected. With this statistical analysis it can be concluded that the difference between those two sets of data is more than 15%, meaning that the productivity was improved as expected. On the other hand, data of defects was collected and compared between January- April 2021 vs January- April 2022. During 2021 the number of defects reported was: 178, while the number of defects during the same period in 2022 was 119. This represents a reduction of 33%. That percent is less than the percent of reduction expected. However, those numbers were not measured with the implementation completed.

CONCLUSIONS

In summary, the production operations in Company X were not performing in optimal conditions. Each of the operations was affected by wastes that causes errors and issues in the products generated. This waste also resulted in monetary loses to the company between material waste and employees labor hours. The production floor space was limited so there was not enough space to maintain unfinished jobs in good conditions and easy to find. To understand the status of the production floor and the direct variables that are impacting the performance, an DMAIC analysis was performed. The project was defined and studied by using the value stream map and pareto chart. The use of those tools highlighted the areas that needed strengthening. Removing the warehouse from the previous area an located it on another facility, awards space for placing the current equipment, material, and unfinished jobs in optimal positions. Moving the warehouse also allows to add more equipment to increase the production volume capacity by reducing bottleneck. After allocating the operations in the new layout designed and applying 5's method to allocate the materials and miscellaneous, the operation process presents an improvement of 33% of reduction of defects and 15% increase in productivity. The productivity objective was accomplished as expected; however, the defect reduction objective was not achieved the percentage expected. One of the possible factors for not achieves the expected reduction on defects could be because when collecting data of defects reports the implementation was not completed. For future work it is important to measure defects again and compare them with the older data to see if the reduction desired was achieved with the implementation of this project.

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