Feasibility Study of Proposed Manufacturing Layout Re-design to Improve Process Capacity and Reduce Cycle Time of a Downstream Operation of Product A

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Abstract *—Lean Six Sigma tools and methodologies are widely used in today's work environments. The use of a Lean Six Sigma approach provides organizations more flexibility and efficiency to improve their competitiveness. At the present time, with the high market changes environment, is crucial for industries to improve their processes to fulfill their customers' needs. One key area for Manufacturing Operations is their production layout design. This article will discuss the use of DMADV (Define, Measure, Analyze, Design, & Verify) methodology to complete, and evaluate a feasibility study of a manufacturing layout re-design proposal. The project concluded that the proposed manufacturing layout re-design will represent a reduction of approximately 29-36% of the current process cycle time and represent a potential increase in production capacity of approximately 15-25%. These benefits identified during the feasibility study activities can lead to improve the company's competitiveness and obtain financial benefits.*

Key Terms *— Cycle time, DMADV, Lean, Process Capacity.*

INTRODUCTION

Manufacturing industries and operations are facing more challenges to adapt to the constantly changing market requirements, customer demands and needs. Organizations must evaluate and apply different quality concepts, tools, and methodologies to maintain their competitiveness, provide quality products to their customer, and earn profits. Lean Six Sigma is one of those operational excellence approaches used in the work environments to adapt and improve organizations, processes, and quality systems. Some of the benefits for the implementation of the tools and methodologies are the development of a continuous improvement culture and financial benefits.

Research Description

This design project will focus on the analysis of a manufacturing layout re-design to identify opportunities to improve the actual process capacity and reduce cycle time of a Downstream Operation of Product A.

This research will provide useful information to make improvements in the manufacturing layout of the current operation and help the organization to improve their competitiveness.

Research Objectives

This design project will focus on the following main objectives:

- Complete a feasibility study of a manufacturing layout re-design.
- Evaluate cycle time reduction and increase process capacity.

Research Contributions

Application of the Lean Six Sigma methodology (DMADV) to the manufacturing layout design will allow the identification of improvements to gain efficiencies and productivity. The feasibility study provide data to understand, identify, and recommend changes to the actual manufacturing layout where we can be able to reduce cycle time of the process and increase the plant capacity.

Improvements in the manufacturing operation layout will provide more flexibility for the operation and increase process capacity to fulfill future demand of company products, more weeks or manufacturing windows to implement projects, opportunity for new product introduction, and improve the company operations competitiveness.

LITERATURE REVIEW

At the present time, Manufacturing Operations are facing more challenges to adapt to the constantly changing market requirements, customer demands, and needs. Organizations must evaluate and apply different quality concepts, tools, and methodologies to maintain their competitiveness, provide quality products to their customer, and earn profits. Lean Six Sigma is one of those operational excellence approaches used in the work environment to adapt and improve organizations' processes and quality systems. For this design project, a background of Lean Six Sigma methodology will be discussed with focus on the DMAIC and DMADV methods.

Lean Six Sigma

The American Society of Quality (ASQ) defines "Lean" as a systematic method for waste elimination or minimization (Muda) within a manufacturing system without sacrificing productivity [1]. The first concepts of Lean Six Sigma were developed in the mid 1980 by the Motorola Company where the practices focused on the improvements of the manufacturing operations [2].

This methodologies and quality concepts are widely used in the manufacturing operations for continuous improvements, defect reduction, and financial benefits. These quality concepts provide the approach of data analysis for the identification of process improvements and variations. Lean Six Sigma concepts aims at meeting the customer's requirements by implementing a measurement-based approach that reduces variation through process improvement projects [3]. Lean Six Sigma quality concepts provide organization tools, and methodologies to identify process improvements, variations, and waste in order to obtain financial benefits, increase process capacity, and provide quality products to their customers.

DMAIC and DMADV Methodologies

The DMAIC method approach consists of stages of Define, Measure, Analysis, Improve, and Control. DMAIC Method is recommended to be used when a product or process is already in existence, but is no longer meeting the customer expectations [3]. The different stages provided by DMAIC approach provide the organization and a robust structure to analyze their manufacturing processes to identify improvements. The focus of the five stages of DMAIC are:

(D) Define – This stage provides the introduction of the business case and the problem statement definition. A Project Charter, Business Case, SWOT Analysis, and the identification of the Project Objectives are common tools and information used for the define stage.

(M) Measure – This stage provides the methods and data gathering of current state of the studied process. During this step of DMAIC, the focus is on describing the methods, data collection plans, and variables that are going to be analyzed to gain a deeper understanding of the process current performance.

(A) Analyze – This stage provides information, data comparison, and evaluation of the current state versus the future state of the project scope. In this stage of the DMAIC process will lead to provide and recommend possible solutions after the data analysis exercise.

(I) Improve – During this stage information obtaining during the data collection, solutions, and recommendations are evaluated and tested in the processes. Implementation exercise occurs during the improve stage of the DMAIC process.

(C) Control – The Control stage monitors the improvements implemented and identified in the previous four stages of DMAIC.

The traditional DMAIC method is used to solve issues dealing with current existence of defects and variation, whereas DMADV is used to design new products, ideas, or process [2]. DMADV Methodology consist of stages of Define, Measure, Analysis, Design, and Verify. This design methodology approach emphases on including inputs from the customer during the design process for better design of the product and processes [4]. The focus of the five stages of DMADV are:

(D) Define – This stage provides the introduction of the business case and the problem statement definition. A Project Charter, Business Case, SWOT Analysis, and the identification of the Project Objectives are common tools and information used for the define stage.

(M) Measure – This stage provides the methods and data gathering of current state of the studied process. During this step of DMADV, the focus is on describing the methods, data collection plans, and variables that are going to be analyzed to gain a deeper understanding of the process current performance.

(A) Analyze – This stage provides information, data comparison, and evaluation of the current state versus the future state of the project scope. In this stage of the DMADV.

(D) Design – During this stage the design of new process, products, services, or requirements are developed and tested thru simulations, small scale experiments, or design of experiments.

(V) Verify – This stage will focus on the verification and evaluation of the design proposed during the project.

The DMADV methodology will provide the research, analysis, and structure approach to identify the opportunities of the proposed layout re-design.

DESIGN PROJECT METHODOLOGY

This design project will use Lean Six Sigma tools and DMADV methodology to conduct a project feasibility study to analyze a manufacturing layout re-design proposal to reduce process cycle time and increase process capacity.

(D) Define – This stage will provide the introduction of the business case and the problem statement definition. A Project Charter, and Business Case are the tools that are going to be used for this stage definition. The information identified during this define step will help to establish and define the project’s objective and goals.

(M) Measure – This stage will provide the methods and data gathering of current state of the studied process. During this step of DMADV, the focus is on describing the methods, data collection plans, and variables that are going to be analyzed. A cross functional team was defined including several SMEs to identify process and equipment requirements, production constrains, manpower structure, production schedule among other variables to get a deeper understanding of the current manufacturing layout and potential opportunities areas that could fulfill the desire cycle time reduction and increase in productivity.

(A) Analyze – After the data gathering process, the analyze stage will provide information, data comparison, and evaluation of the current state versus the future state of the project scope. In this stage of the DMADV, the team identified a new proposed manufacturing layout design which was analyzed to determine if it will fulfill the process requirements.

(D) Design – During this stage the new manufacturing layout design, together with the process, products, services, or requirements are developed and tested thru Manufacturing Production Schedule (MPS) simulations to test the new proposed manufacturing layout.

(V) Verify – This stage will focus on the verification and evaluation of the manufacturing layout re-design proposed during the project and their simulations results. A summary of the feasibility study, results, and the conclusions will be discussed with management to make the business decision if the implementation of the project will be pursued.

RESULTS AND DISCUSSION

The first activities completed during this design project included the development of the project charter, project scope definition, kickoff meeting, and data gathering process of the current state of the manufacturing layout operation. A cross functional team composed of Manufacturing representative, engineering, scheduler/planners, technicians, plant management and potential contractors was selected as subject matter expert (SMEs). In collaboration

Project Charter			
Project Title	Feasibility study of proposed manufacturing layout re-design to improve process capacity and reduce cycle time of a Downstream Operation of Product A	Project Manager	Lyanne Aponte Santiago
Start Date	10/01/2022	End Date	02/06/2023
Project Sponsor	Edgar Acevedo		

Business Need
The feasibility study will provide data to understand, identify, and recommend changes to the actual manufacturing layout where we can be able to reduce cycle time of the process and increase process capacity. The current layout create space constrain between the unit operations used at the beginning and the final steps of the downstream operation of product A. Improvements in the layout design will provide more flexibility and process capacity to fulfill future demand of company products, more weeks or manufacturing windows to implement projects, opportunity for new product introduction, and improve the company operations competitiveness.

Project Scope			
In-Scope	Manufacturing Downstream Operation of Product A.	Out- Scope	Other products and manufacturing processes.

Goal
Complete the feasibility study and present assessments to management for project approval, funding request and implementation strategy definition during next year 2023.

Risk and Issues
Time constrain of project implementation, and project cost.

Team Members
Manufacturing Staff, Manufacturing Management, Process Owner, System Owner, Quality Representative, Engineering SME, Process Development SME

Financial Impact
Business continuity and improve process capacity.

Resources Required
External Company for the completion of the feasibility study for the project constructions requirements.

Milestones and Deliverables
Feasibility Study Completion, Final Assessments completed, Present Findings to Management

Figure 1
Project Charter

the team developed the project charter and scope, refer to Figure 1.

During the initial meetings with the project team, information, and data of the current state of the manufacturing layout was discussed and gathered. Personnel from Scheduling and Planning provided the current state that has a cycle time of 14 days for Product A and production is in series which require to complete the processing of one lot to initiate the next one. In addition, it was discussed the current production capacity of Product A during a calendar year which were in the range of 11-13 lots.

This feasibility study was looking for options to increase days available in the production schedule during a year. The following information, and data were obtained through the different stages of DMADV and project lifecycle:

(D) Define – during this stage the project charter tool was completed defining the following statement: this feasibility study will provide data to understand, identify, and recommend changes to the actual manufacturing layout where we can be able to reduce cycle time of the process and increase production capacity.

Improvements in the manufacturing operation layout will prevent space constraint within unit operations and provide more flexibility and process capacity to fulfill future demand of the company products, more weeks or manufacturing windows to implement projects. In addition to create more opportunity for new product introduction and improve the company operations competitiveness.

The following project objectives and goals were defined:

- Complete a feasibility study of a manufacturing layout re-design proposal.
- Reduce process cycle time and increase process capacity.

(M) Measure – meetings with a cross functional team integrated by process owner, system owner, manufacturing personnel, quality assurance representative, senior management staff, and other subject matter experts (SME’s) were held to gather information of the current state, and to design and formalize the manufacturing layout re-design proposal.

The current state of the Downstream Operation of Product A includes eight (8) operational units and steps represented by the numbers from one (1) to eight (8), and two (2) manufacturing suites (suite A and suite B), refer to Figure 2.

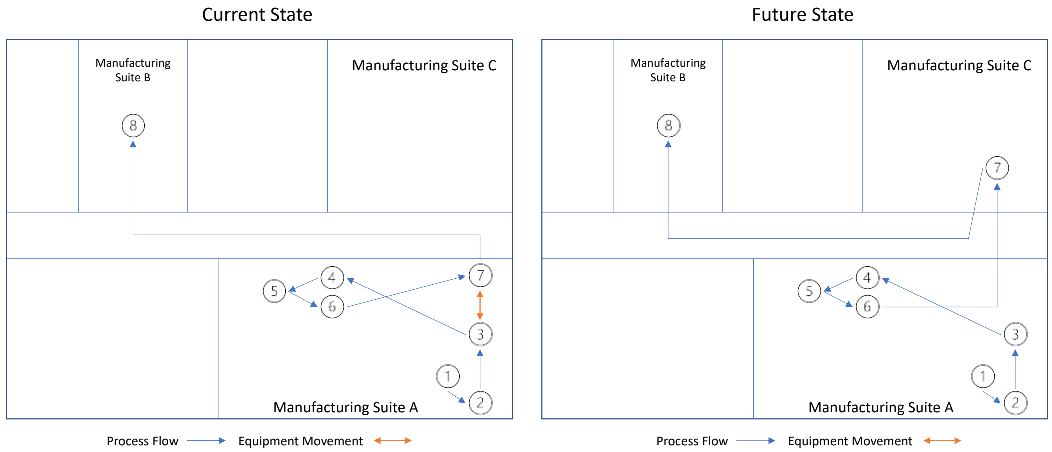

Figure 2
Current and Future State of Manufacturing Layout for Product A

Currently, two different equipment's are required to execute step 3 and step 7 for the manufacturing of Product A and this two equipment's occupy the same footprint within Manufacturing Suite A; therefore, an equipment movement (swap) is needed creating a constraint to increase production, adding cycle time for equipment movement and limitation to execute parallel preparatory activities. This also limited the plant to start subsequent lot while the process is in the final steps.

The manufacturing layout re-design proposal consists in the relocation of the operational unit and process step seven (7) of the Downstream Operation of Product A to the Manufacturing Suite C, refer to Figure 2. The plant already counts with a third manufacturing suite (Manufacturing Suite C), however the footprint was underutilized and allowed for the relocation of process step 7 with a capital investment to adapt the operational unit (manufacturing equipment and utilities).

Process requirements and specifications were discussed with the cross functional team and SME's during the project meetings. In addition, to support the feasibility study, an external company was hired to provide SME's input regarding the construction requirements and cost with the proposed manufacturing layout re-design for operation unit number seven (7) of Product A.

(A) Analyze – During the analyze stage the project team supported on site visits and provided additional information of the process flow to the external company. SME's assessments regarding the project scope were completed and discussed in the project meetings. The external company presented the initial assessments regarding the construction requirements of the project scope and submitted a proposal to the team for revision and approval.

From the manufacturing process perspective, the project team and SMEs concluded that the manufacturing layout re-design of the operational unit and step seven (7) will fulfill the requirements and will not represent a major impact to the current standard operating procedures (SOP's), electronic batch records (EBR's), process bill of materials (BOM), and regulatory commitments since the project scope will not change the manufacturing equipment or any of the operational parameters of the current validated process.

(D) Design – For the design process of the new layout proposal were held brainstorming meetings for the identification of process constrains, manufacturing suites space constrains, manpower needs to changeover activities, and the risk of ergonomic or injures for manufacturing personnel due to the heavy equipment movement requirements in the current layout design.

Other benefit identified during the meetings was the ability of the re-design layout proposal to provide flexibility to the operation to perform activities in parallel which will result in decreasing the process cycle time. Refer to Figure 3 for the main benefits comparison between current and future state of the manufacturing layout design for Product A.

Manufacturing Schedule Production (MPS) simulations were performed and analyzed with the Scheduling and Planning personnel. From the assessments, it was determined that the manufacturing layout re-design could result in a production capacity increase within a range of 14-16 lots per calendar year due to a reduction of time between lots of Product A from every 14 days to every 7 days. The actual purification process will continue with a process cycle time of 14 days due to preparatory activities requirements and resources, the benefit of the reduction in the time between lots with the layout proposal will be obtained after the second lot since its activities can be initiated after 7 days of the first lot, hence, the plant will have the capacity to produce a lot every 7 days instead of every 14 days.

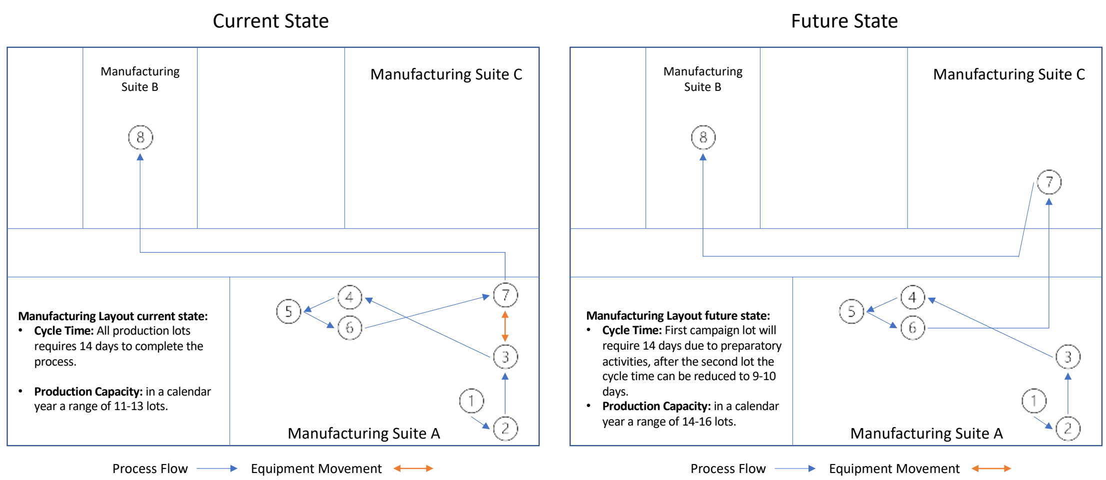

Figure 3

Main Benefits Comparison between Current and Future State of Manufacturing Layout for Product A

The re-design layout proposal provide flexibility to the process because when the production of a lot is in the step four (4) in the manufacturing suite A can allow to start another lot in step one (1) in the same suite manufacturing suite A, because the completion of the first lot will be moved and performed in manufacturing suite C. There is no longer space constrains for the step seven (7) since it would not require the equipment movement and same space uses.

In addition, during this stage the external company submitted additional information and floor plans proposal for the project team revision and approval.

(V) Verify – during this final stage of the DMADV methodology all the information and data obtained and discussed in the previous stages of the project was gathered and presented to the project team and SMEs. Documentation and tracking of the feasibility study was updated and presented to management, the project team, and SMEs. After the completion of the process feasibility study is expected to finish the construction requirements assessments and cost estimates with the external company.

Conclusion

In conclusion, this process feasibility study of the proposed manufacturing layout re-design of the Downstream Operation of Product A provided key information of the benefits and viability of the project. The project output concluded that the proposed manufacturing layout re-design will provide and represent a potential reduction of approximately 29-36% of the current process cycle time between lots. At the same time this represents an increase in production capacity per calendar year of approximately 15-25%. These main benefits can lead to improve the company's competitiveness and obtain financial benefits. Other benefits that could be obtained from the project implementation would be a reduction of potential ergonomic injuries and reduce manpower efforts due to the reduction in equipment movement and changeover activities requirements.

Furthermore, this project design will help to present this proposal and project benefits to management and executive personnel of the company for project approval and to continue with the next steps for funding and implementation. In addition, the second phase of the feasibility study will include the completion of the construction requirements assessments and project costs estimate with the external company. The DMADV methodology used during the completion of the process feasibility study provided crucial information about the manufacturing process in scope and improvements opportunities identified during the assessments and completion of project activities.

REFERENCES

[1] Asq.org. 2022. Letter L - *Quality Glossary of Terms, Acronyms & Definitions with Letter LASQ*. [Online] Available at: https://asq.org/quality-resources/quality-glossary. Acessed 17 April 2022]

[2] Vootukuru, A. S. (2008). DMARC: A framework for the integration of DMAIC and DMADV (Order No. 1461441). Available from ProQuest Dissertations & Theses Global. (304356779). [Online] Retrieved from https://www.proquest.com/scholarly-journals/dmarc-framework-integration-dmaic-dmadv/docview/900577255/se-2.

[3] Deshpande, S. (2016). Introducing design for six sigma's DMADV methodology to the packaging industry (Order No. 10117536). Available from ProQuest Dissertations & Theses Global. (1802929877). [Online] Retrieved from https://www.proquest.com/dissertations-theses/introducing-design-six-sigmas-dmadv-methodology/docview/1802929877/se-2.

[4] Chauhan, Y. K. (2011). *The application of design for six sigma in a manufacturing organization for defect prevention and customer delight* (Order No. 1507400). Available from ProQuest Dissertations & Theses Global. (916923249). [Online] Retrieved from https://www.proquest.com/openview/31939d2da6c5802bb28ea9fbbfb6a4f2/1?pq-origsite=gscholar&cbl=18750.