Improving Cost Estimating Process in the Aerospace Industry Projects

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Abstract *— The cost estimation process in the aerospace industry is very important since this process help them to negotiate with the suppliers better offers and optimize the manufacturing process. The process is recent in this industry, and the company has reported an increase of 7% of rejected parts from April to July and 12 potential release which impacted internal and external customers' satisfaction. By applying lean manufacturing concepts the process was defined using a value stream map, improvements in the process were identified and implemented. With these implementations process time was reduced from an average of 26.16 hours to 20.36 hours. This is a reduction of 22.17% was achieved by identifying value in the process, decreasing inspection time, and eliminating waste. With the help of a form for the analysis approach to harmonize the inspectors' point of view with the analysts' rationale reducing the overall analysis documentation by 69.57% as well.*

Key Terms *— Cost Estimation, Lean Manufacturing, Process Time, Value Stream Map.*

PROBLEM STATEMENT

An aerospace company is experiencing some difficulties during the execution of a multistep process called Cost Estimating Analysis. The Cost Estimating Analysis is about quantifying how much money something should be exchanged for today, considering future benefits. This process is new in the company, resulting in overall operations cost far from competitive ones, released analysis with defects, and high process time. This research is about defining the analysis steps, and identify any productivity improvements that can result in a decrease of waste and operation times. With the development of this research, it is expected that the flaws in the process will be identified. Giving opportunities for productivity improvements and a more continuous flow process, in order to be competitive in the market, deliver a high quality product and achieve internal and external customer satisfaction.

RESEARCH DESCRIPTION

During the months from April to July of year 2016, a department of an aerospace company experienced an increase of 7% of rejected parts and 12 potential release defects while executing the Cost Estimating Analysis which impacted internal and external customer satisfaction.

RESEARCH OBJECTIVES

The research objectives are the following:

- Develop a Value Stream Map for the process;
- Identify possible improvement opportunities;
- Implement identified solutions;
- Reduce defects in the overall analysis documents by 10%;
- Reduce operation times by 15%.

RESEARCH CONTRIBUTIONS

The research contributions include the following:

- By preparing harmonized instructions, defects will be reduced, increasing the quality of the product. Also, internal and external customer satisfaction can be achieved.
- By reducing time and cost of the analysis the company can invoice at competitive rate in the market.
- By implementing the analysis approach meeting, the communication between analyst and reviewer will be more efficient, impacting a reduction in defects, questions and time.

LITERATURE REVIEW

Cost estimating is the estimation of the expected cost of producing a job or executing a manufacturing order before the actual production is taken up or predicting what products will cost [1]. There are two types of cost estimating, difference evaluation and from raw material evaluation. The difference evaluation is an analysis in which a comparison of two parts is made and only the difference is evaluated in term of the difference in cost and time. For example, a seal have been change from a completely solid seal, to one with various holes around the circumference. In this case the evaluation would be the difference in cost and time the manufacturing of the holes take. In other hand, the analysis from raw material evaluation is from scratch. Raw material selection, processing, machine set-up, inspections, packaging and boxing of the parts are considered in terms of cost and time. For example, a new bolt is added, since there is no other bolt to have a comparison with the evaluation of this bolt have to be from the raw material selection to the packaging.

The cost estimating process begins when the customer send a part list to the project manager. The project manager has to validate inputs submitted by the customer to avoid duplicate or errors of parts sent. After this step is done, the project manager sends parts to the analysts to begin cost estimation process. Once the analysts receive the part, he begins to search relevant data like blueprints, 3D models, purchasing data and creates a data folder. This information should help the analyst decide if the analysis difference evaluation or a from raw material evaluation. After the analyst do the analysis, it's send to internal inspection. If the analysis complies with the analysis requirements it's send to the customer for approval. If the client doesn't approve the analysis, the analysis it's send to the project manager and the cycle mentioned repeats.

In order for the analyst perform the analysis, he needs to have knowledge about manufacturing processes for components in the aircraft turbines such as forging, casting, welding, machining and assembly operations. These process are simulated using 3D modelling and the operations are cost estimated using a tool that has the cost and times the operations predetermined. A basic definition and important process parameters are the following:

Forging is the process of forming a metal into a desired shape and size by the application of localized compressive forces. The part may be forged in hot or cold condition. In case of hot forming the metal is heated to a high temperature below the melting point and is pressed into shape by manual or power hammers [1].

Casting is the process in which the metal is melted and poured into the molds to get the components in desired shape and size. One important element in the cost estimation for casting is the material required for the process. It must consider the process scrap generated by runners, gates and risers in the total weight, allowance for metal loss in oxidation in furnace [1].

Welding is the process where two or more metal pieces or parts are joined together by heating the surfaces to the point of melting. A filler material is used to fill the gap between the parts to be welded. For cost estimating this process the important element is the length of the filler material to be used in the welding process [1].

Machining is a process of removing volumes of material with a specified feed rate of a machine that could be a lathe, milling machine or drilling center. For estimating this process the most important element is the time it takes to remove certain volume in terms of length and depth, and the machine set-ups time to perform the operation [1].

The cost estimation analysis is new in the aerospace industry. Since its new it has some flaws in the process that can be improved over time and elimination of waste is necessary. A good methodology to elimination of waste if the implementation of lean manufacturing and its structure DMAIC. DMAIC is a structured problem solving methodology widely used in different types business. The letters are an acronym for five phases of Six Sigma improvement: Define-Measure-Analyze-Improve-Control. These five phases' help

to define a problem through implementing solutions linked underlying causes, and establishing best practices to make sure the solutions stay in place [2].

Define phase - the project's definition, goal, potential resources, project's scope, the customer or stakeholders, and critical to quality (CTQs) should be clearly stated in this phase. This information is what the team normally states in the project charter document. Project charter provide a means to control and manage projects, it serve as a contract between the project sponsor and the project team. Unlike legal contracts, they are "living documents", they can be updated as new information is discovered in the DMAIC methodology.

Project Charter: Order Processing Efficiency

Start Date: 9/17/07			**Planned End Date: 3/17/08**	
Problem/Project Description: Current capacity in Sales is constrained, while there are untapped opportunities for increased sales. Sales involvement in order processing should be limited to free up resource for lead follow-up and revenue generation. Errors and omissions in Order Processing data increases time to generate marketing & software renewal emails to clients and prospects, further draining Sales resources. Data correction requires senior sales staff, who might otherwise be engaged with clients, marketing efforts, or product development. Lost opportunity cost is significant.				
Project Scope: Limited to order processing of software products.				
Project Objectives & Goals: Impact cycle time & costs ➢ Reduce Order Processing cost 50% ➢ Reduce email marketing costs 98% ➢ Increase renewal rate 20% ➢ Increase renewal revenue 20%	**Metric**	**Baseline**	**Goal**	**Benefits**
	Cost/Order	$40	$20	$27,000
	Campgn. Cost	$500	$10	$24,000
	% Renewal	x %	1.2x%	$50,000
	Renewal $	$250,000	$300,000	$50,000
Business Need	**Customer Impact:** Improved notification rate for renewals & upgrades; reduction in order processing cycle time.			
	Shareholder Impact: Reduced costs for order processing and marketing to existing clients; Increased capacity in sales and marketing; Increase in renewal rates.			
	Employee Impact: Clearer responsibilities; Less interruption in process flow.			
Project Sponsor: Peter Keene, VP	**Stakeholder Group:** Sales & Operations	**Signature / Date** Peter Keene		
Team Black Belt: Patrick Killihan	Operations	Patrick Killihan		
Team Members: Don Debuski	Sales	Don Debuski		
Helen Winkleham	Shipping & Packaging	Helen Winkleham		
Anne Sheppard	Accounting	Anne Sheppard		
Resources: Programming/IT Support; CRM database				

DEFINE	MEASURE	ANALYZE	IMPROVE	CONTROL
Objective / Date	Objective / Date	Objective / Date	Objective / Date	Objective / Date
➢ Project Def. 9/17/07	➢ Process Def. 10/03/07	➢ VSA	➢ New Process	➢ Standardize
➢ Process Def. 9/19/07	➢ Metric Def. 10/03/07	➢ Var Sources	➢ Benefits	➢ Control
➢ Team Form 9/19/07	➢ Baseline 12/27/07	➢ Drivers	➢ FMEA	➢ Lessons

Figure 1
Example of a Project Charter [2]

Before starting the project some previous work should be done to identify opportunities. Some useful tools could be Matrix diagrams to select projects that are aligned with the company goals and objectives. Work breakdown structures to define a manageable project scope. Pareto diagrams to help identify significant opportunities. Process maps to provide a visual means to define process and identify stakeholders or SIPOC to identify process activities, key inputs and outputs, and stakeholders.

Measure phase – this phase is based in establishing process performance baselines and collecting relevant data. The performance metric baselines from this phase is the one that will be compared to the performance metric in the conclusion of the project to determine the improvement that has been made. Some useful tools in this phase is the flowcharts and process maps to define the process activities necessary. Control charts for investigating process stability and evaluating process capability, histograms to display process output relative to the requirements. Also Repeatability and Reproducibility (R&R) studies to quantify the measurement error associated with the equipment, personnel and procedures.

Analyze phase – in this phase the team identify, validate and select root cause for elimination. It is important to list and prioritize potential causes of the problems. Also it's important to analyze the necessary steps that produce value for the customer in the value stream. Value stream mapping (VSM) visually documents a process including key data, providing fact-based process description as basis for understanding current problems and improvement opportunities. Helps to visualize the process future state one the waste is eliminated from the current process, and show the information inside and outside the organization. The steps that creates value to the customer are classified as value-added activities, the ones that not create value to the customer are the non-value-added activities. Finally, the steps that creates no customer value but are required by one or more activities, are classified as business-value-added.

Improve phase – at this phase an implementation of a solution for the problem's root cause is made. New process operating conditions are determined, benefits associated with the proposed solution are estimated by the team, and process improvement is implemented and verified. The results of the value stream analysis regarding on the non-value added activities can be reduced or eliminated in the improve stage. In order to do that, it is necessary to reduce process complexity via standardization, remove unnecessary process steps,

eliminate unnecessary movement of resource and reduce setup times. A comparison to the Critical to Quality (CTQ's) determined in previous phases can serve as baseline to determine improvement. Benchmarking best in class processes or industries can provide useful input for redesigning a process flow.

Control phase – at this phase the team make sure to sustain and monitor the gains or improvements to ensure continuous success. New methods must be standardized, the predicted impact of the improvements, must be continually verified, lessons learned should be documented. Control charts is a very useful tool to assess the stability of the process over time. Other good practices are work instructions, flowcharts, and process maps to document process procedures and responsibilities. Trainings are essentials to personnel if roles are change in the new improvement.

Today's companies are living in economically difficult times and optimization of the processes are often wanted by all kinds of industry. Aerospace industry is no difference, they've come with the cost estimation process to know the suppliers better and negotiate better prices but the process itself is new and still there's room for improvement and waste elimination.

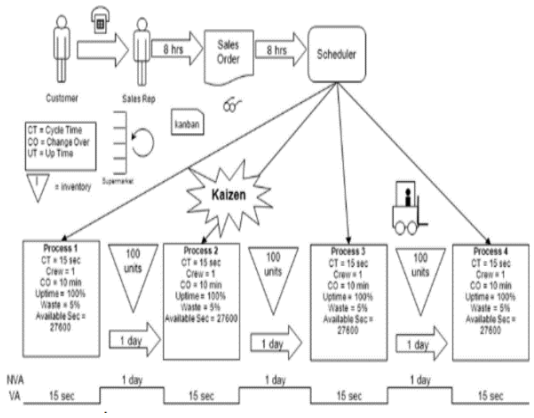

Figure 2
Example of a Value Stream Map [3]

METHODOLOGY

This study will define the cost estimation process steps to identify possible productivity improvements, reduce defects and reduce times. To perform this study it will be necessary to do a value stream map. This chapter will cover in detail the methodology that will be performed to achieve the project objectives.

Since the cost estimation process is new in the aerospace industry, a value stream map is necessary to define value added and non-value added activities. The process can be described as the following:

- The external client sends the parts list.
- The project manager corroborates the data for mistakes or duplicates.
- Project manager sends the part to the analyst to make a cost estimation analysis.
- The analyst search for relevant that such as 3D models, drawings, purchasing history, material information. With this information the analyst should decide if the analysis is a comparison analysis or a from raw material analysis and creates a data folder.
- The analyst performs the analysis.
- When the analyst finishes the analysis, the data folder is sent to internal inspection.
- If the analysis doesn't pass inspection, the data folder is sent to the analyst to perform the corrections. If the analysis pass inspection the project manager is notified electronically.
- The project manager makes a report of finished parts, and send it to the external clients, and have to upload parts manually.

By developing the value stream map of the current state of the cost estimation process, the value and non-value activities, and areas for improvements or kaizen events can be identified. Also process times and delay times can be identified in the process. A list of the possible kaizen events and benefits will be listed in the table 1. In this project, only Kaizen events #2 and #3 will be analyzed. Kaizen events #1 is an effort of the external client to improve the process of sending inputs and Kaizen event #4 requires time to develop a tool internally that can help the project manager to improve the delivery process.

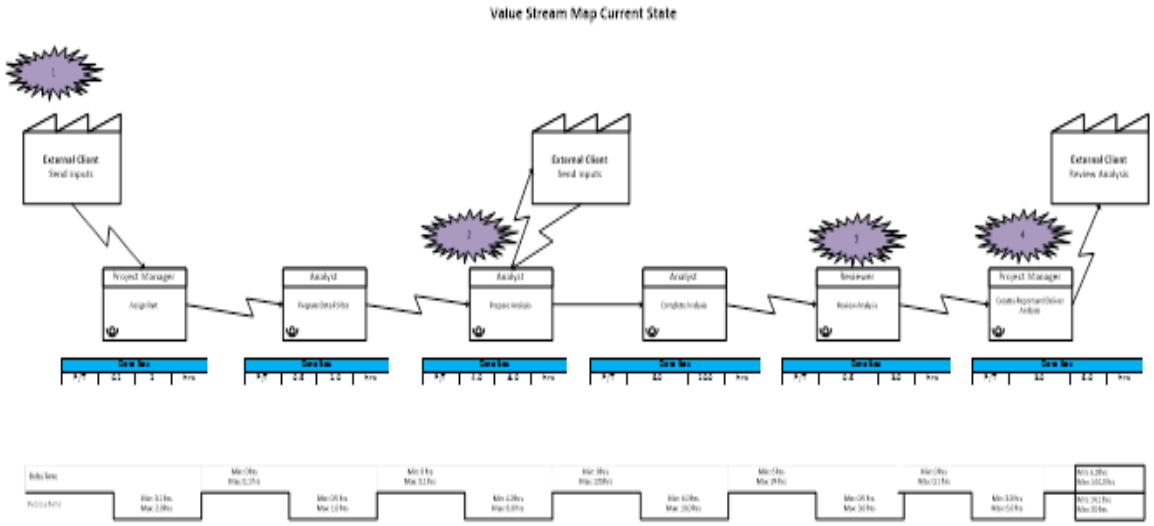

Figure 3
Value Stream Map Current State

Table 1
Possible Kaizen Events

Location in VSM	Kaizen	Benefit	Problem
1	Supermarket, where the project manager can pull parts from external client database	Will help to align production capacity with customer demand, switching the process from push to pull concept. Will help to eliminate errors in inputs	There has been duplicate of parts and error on inputs of the parts sent.
2	Implement a meeting between analyst and the reviewer to discuss the analysis approach.	It will help decrease the analysis approach questions for the analyst. It harmonize the point of view of the analyst and the reviewer, decreasing inspection time at the end of the process. Help in the analyst development and critical thinking.	The reviewers focus on different aspects when reviewing analysis. Like the process is new, the analyst has to question many time about the analysis approach.
3	Standardize the review process.	Harmonizes the reviewer's inspection criteria. A standardization of the inspection process will help reviewers to focus in specific point.	The reviewers focus on different aspects when reviewing analysis.
4	Develop a tool that can pull data from the Excel spreadsheets to help project manager optimize the report in the delivery process	Optimizes the time required to fill the report and simplifies the acquisition of the inputs by eliminating to enter each spreadsheet individually. This will also significantly reduce possible errors.	Human errors in the delivery report. Has to enter individually the Excel spreadsheets to acquire inputs.

With all the kaizen events implemented the process should look like figure 4. But as mention before the supermarket is an implementation that the client must implement and the tool that pulls the excel data for the delivery report takes time to develop and implement. By this factors the project will focus on kaizen #2 and kaizen #3, and the future value stream map will look like figure 5.

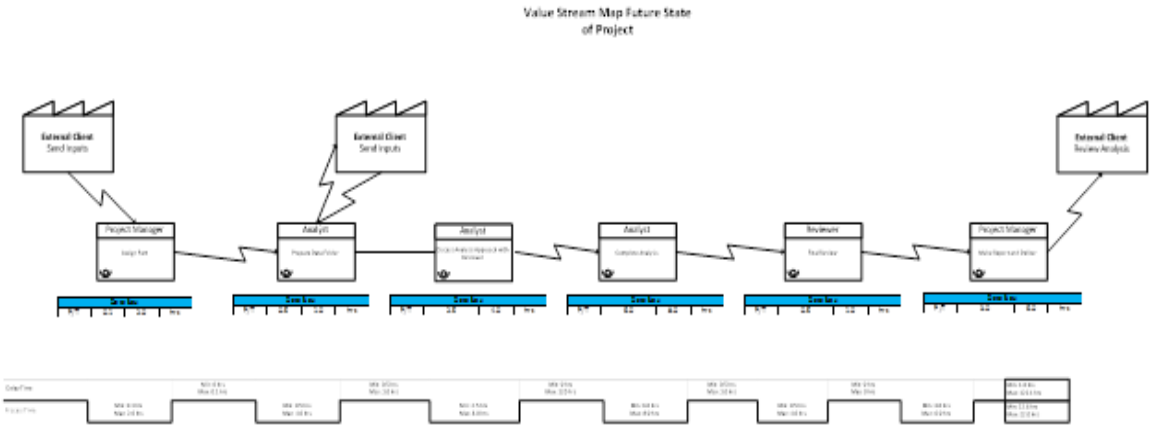

Figure 4
Value Stream Map Future State

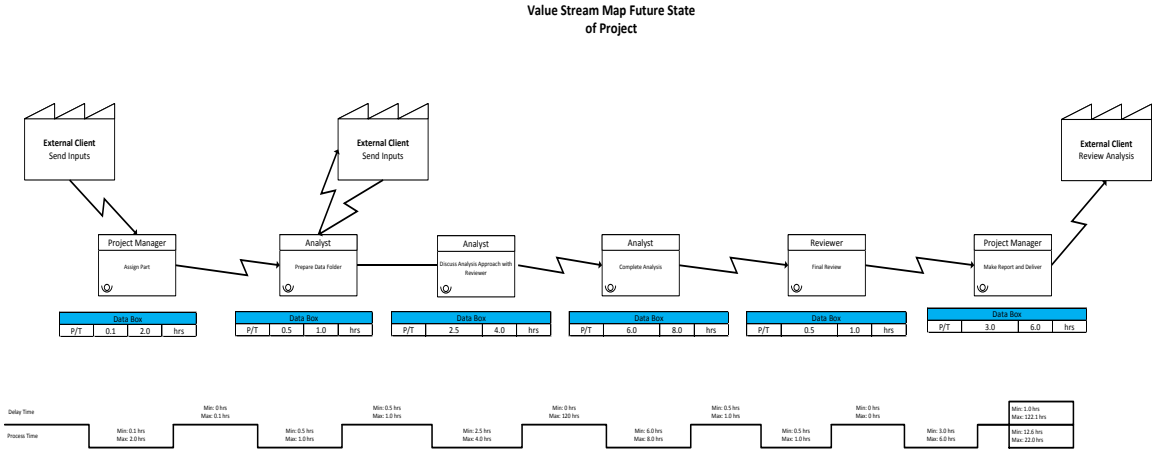

Figure 5
Value stream Map Future State of Project

RESULTS AND DISCUSSION

In methodology, a value stream map was created to understand better the cost estimation process and identify improvements, as consequence a future value stream map was also developed reducing the operations times. In this section, the future value stream map is already implemented and 25 samples are taken to analyze if the process time was reduced with the implementation. Figure 6 shows the process time before implementation of the VSM and Figure 7 shows the process time after the implementation of the VSM.

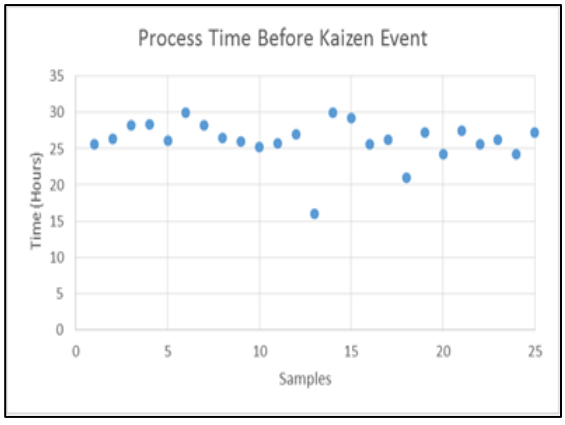

Figure 6
Process Time before Kaizen Event

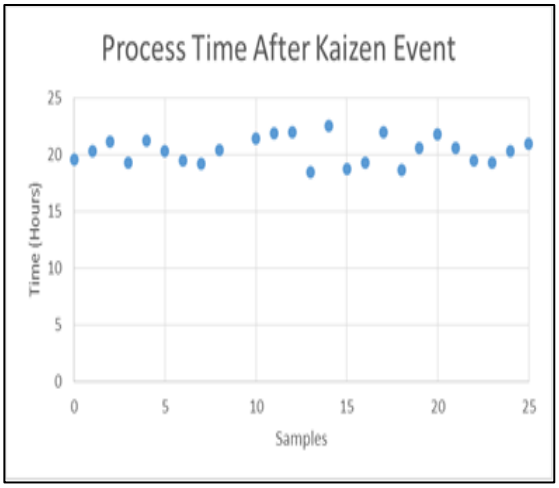

Figure 7
Process Time after Kaizen Event

According to the samples taken, the average process time before kaizen event is 26.16 hours and after the kaizen event is 20.36 hours. A reduction of 22.17% in process time was achieved with the new process.

In other hand, a Pareto Chart was created and three principal causes for defects in overall documentation were identified. This causes are incorrect analysis rationale, incorrect manufacturing sequence, and incorrect information in report template, as shown in figure 9. The other two causes are wrong customer inputs, and no reason for rejection. These causes are not taken in consideration in this analysis, since those are errors from the external client as seen in the VSM in methodology section.

A form for the meeting approach as shown in figure 8, was created reducing the overall analysis document errors. The analyst fills all the free text boxes that goes into the final report. At the meeting approach, the analyst and the inspector discuss the analyst's approach, and the inspector makes recommendations. If there's anything that has to be change the analyst change it before send the analysis to inspection. If there's nothing to change then the analysis goes to inspection right away.

Another Pareto chart was performed after the implementation of this form as shown in figure 10. A 69.57% of the overall documentation defects were reduced. Errors from the external clients are still present due to wrong input and without reason.

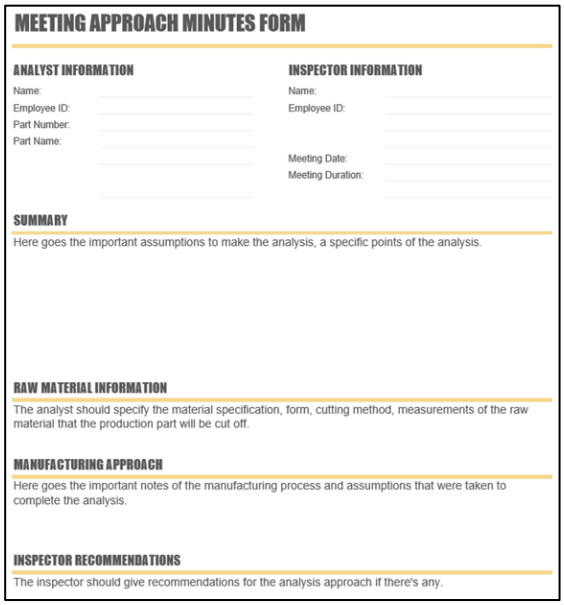

Figure 8
Meeting Approach Minutes Form

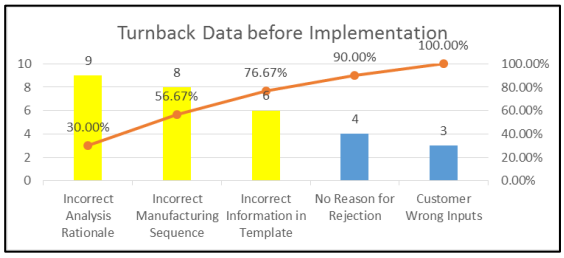

Figure 9
Turnback before Implementation

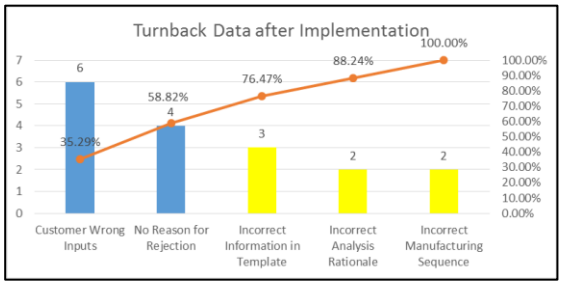

Figure 10
Turnback after Implementation

CONCLUSION

Lean Manufacturing provides very useful tools for time reduction and continuous process

improvements, internal and external customer satisfaction, and high quality products.

By the implementation of lean manufacturing in the cost estimation process a value stream map was developed to this new process, improvements was identified and were implemented. As result of the implementation the operations time was reduced by 22.17%.

Furthermore, a form was implemented for the meeting approach to harmonize the inspectors and the analyst. The overall documents defect was reduced by 69.57%. This form helped reduced incorrect analysis rationale, incorrect manufacturing sequence, and incorrect template information filled in the final template.

REFERENCES

[1] M. Adithan, *Process Planning and Cost Estimation*, Daryaganj, IN: New Age International, 2007.

[2] P. Keller, *Six Sigma Demystified*, 2nd Ed., McGraw-Hill, 2011.

[3] J. Arthur, *Breakthrough Improvement with QI Macros and Excel: Finding the Invisible Low-Hanging Fruit*, New York: McGraw-Hill, 2014.