Process Optimization for the Suction Low Runners Family Products

Maria del Mar Rosado Pabon
Manufacturing Competitiveness
Edgar Torres, Ph.D.
Industrial Engineering Department
Polytechnic University of Puerto Rico

Abstract — *Nowadays the first thought of many manufacturing companies is to increase the headcount number in the manufacturing line once it is found with inconsistency of results in productions or quality problems, this rational sometimes bring inefficiencies to the manufacturing process and creates process variation. In recent years the concept of the Six Sigma has become the standard way to solve operational and design problems in manufacture, however this tool can be used together with the concept of Lean Manufacturing, creating an infusion of both concepts called: Lean Six Sigma. This synergized managerial concept results in the elimination of waste and reduces process variation. Through this article we will discuss how the use of Lean Six Sigma methodology focusing on DMAIC tool will help to do a process redesign to standardize three manufacturing lines. The idea is to convert waste into value using different lean techniques, resulting in cost reductions and reduction in the variation of quality problems.*

Key Terms — *DMAIC, Efficiencies, Lean Six Sigma, Manufacturing Process.*

BACKGROUND INFORMATION

This design project was conducted at Stryker PR, a Medical Device Manufacturing Company located in Arroyo, Puerto Rico. One of Stryker's business units was facing an increase in sales of an average of 20% in the low runners of the Suction Family Products. These classifications of products are composed of three different products, with similar functionality. These medical devices are used for performing the suction and irrigation of fluids in endoscopic operations during operational processes. Through the past years the manufacturing process of these products has not been reviewed since these products are part of the low runners and therefore the monthly manufacturing demand is minimum. As a result every time these products were to be manufactured the efficiency would decrease on an average of 28%. The sales of these products were increasing and because of that therefore the demand in monthly manufacture was being increased continuously. In Figure 1 below, the table presents the increase in sales for the different products vs. the inefficiency of manufacture of each product which results in a negative impact cost.

Products	Increase in Sales 2010 vs. 2013	Manufacture Inefficiency
250-070-530	28%	-3%
250-070-640	12%	-45%
250-070-540	20%	-36%

Figure 1
Sales vs. Manufacturing Inefficiency

The inefficiency was developed as a result of a variation in the yield and scrap affecting the quality. Also the manufacturing line was not consistent in the manufacture of boxes, affecting the product availability.

PROBLEM STATEMENT

The incorrect layout and balancing of the manufacturing lines has been affecting the quality, scrap and yield causing inefficiency in the Low Runners of the Suctions Products of Stryker PR. This situation affects the increase in the manufacturing capacity. The main problem is that the cycle time for each workstation is not balanced causing overflows of units in some areas and under flow of unit in others areas of the manufacturing lines. This scenario is repeated in the three products which the design project is focused. On the next figures (Figure 2, Figure 3, Figure 4) the current layout of each product that are affected before the implementation of the DMAIC tool are shown. [1]

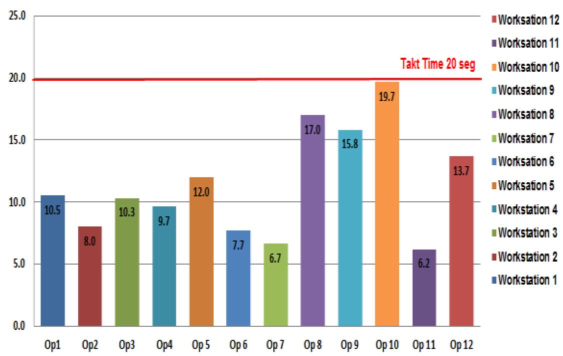

Figure 2
Actual Process Layout for 250-070-530

Figure 2 shows the actual scenario before the implementation of the DMAIC tool. The manufacturing line of this product runs with 12 workstations and the tacktime is 20 seconds. Currently most of the workstations runs below 10 seconds and only three workstations run over 15 seconds. The chart shows the imbalance that it exists between stations.

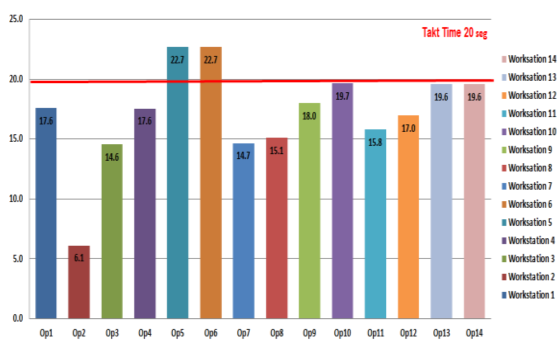

Figure 3
Actual Process Layout for 250-070-540

Figure 3 shows the actual process layout scenario. The manufacturing line of this product runs with 14 workstations and the tacktime is 20 seconds. This line has two workstations running over the taktime, three workstations running close to the tacktime and the other workstations running at different times; the chart shows the imbalance that exists between stations, affecting the manufacturing output.

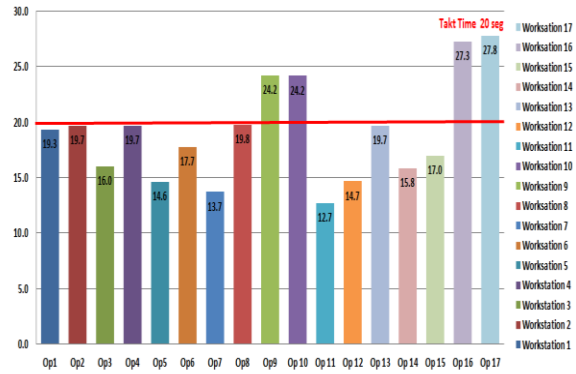

Figure 4
Actual Process Layout for 250-070-640

Figure 4, shows the most dramatic scenario when in comparison with the others two. The manufacturing line of this product runs with 17 workstations and the tacktime is 20 seconds. This process runs with a big variation of the times. In this manufacturing line the balancing process will be a challenge; four workstations runs over the tacktime, five workstations run very close to the tacktime and the other ones run at different times.

These task imbalances in every workstation cause a variation in the line, because in some areas the assembly of the units runs very fast and in other areas the product runs slower because of the complexity of the workstations. All this variations in the times affect the different functional areas, causing unnecessary movements, reworks, scrap, excesses of material and waste. All of these opportunities are translated into inefficiencies of the manufacturing line and poor quality, impacting the cost of the product. [2]

RESEARCH OBJECTIVE

The main objective of this design project is to standardize and balance the manufacturing process to reduce the variation and waste. As the final result it is expected to see an increase in the quality, reduce cycle time and cost reduction. With these objectives it is expected to stabilize the operational capacity to meet with the increase in sales and increase the efficiency.

RESEARCH CONTRIBUTION

After the development and completion of this project, it is expected to have a labor cost reduction as a main contribution. This project supports the Company's goal of increasing the capacity and efficiency, also new standard operation procedures (SOP) will be developed for the manufacturing lines. In additional, the methodology used in this project can be further used to develop new projects. This project is an example of the company values which ensure that every action taken in this assignment to accomplish its objectives is developed keeping in mind that quality is first.

LITERATURE REVIEW

The concept of *Lean Six Sigma* is an innovation concept of Six Sigma, this one was created to incorporate Lean Techniques into the Six Sigma tools. Many companies used Lean Six Sigma to achieve broad-based innovation and superior financial performance. Lean Six Sigma is a combination of Lean methods and Six Sigma approaches. In this way, Lean Six Sigma approach drives organization not just to do things better but to do betters things. This project will focus on the problem solving process proposed by Lean Six Sigma method, using the DMAIC tool to direct this project into its different steps. [3]

METHODOLOGY

In this project the DMAIC tool will be used as a methodology in the problem solving, as a part of the Lean Six Sigma method. This tool is used to reduce variation and control the process. The DMAIC refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs. DMAIC it is an acronym for the five phase process of Define, Measure, Analyze, Improve and Control. [4]

Define Phase

In this phase the Six Sigma project team identifies the objectives and the needs and requirements of the customers. Practitioners begin by defining the process. They ask who the customers are and what their problems are. They identify the key characteristics important to the customer along with the process that support those key characteristics. For this project we will use the business impact chart and other tool to understand the scope of the project. Many tools are used by companies in this phase that help to create a map of the process to be improved with defined and measurable deliverables and goals.

Measure Phase

In this phase all types of data will be collected in order to understand and identify were the root cause for the costs and poorly productivity generated is located in the process. In the measure phase the team will assess the amount of variation within the variables. Teams are expected to identify and measure both input and output process variation. This phase is very important because if the data is not gathered, then one will likely end up with a lot of quick projects with short lived or disappointing results. At the same time if the data is collected erroneously then the entire project will be a failure. The measure tools used in this project were the Pareto Chart and the Time Study worksheet; both tools are an infusion between Lean Techniques and the Six Sigma method. These tools help you decide where your improvement effort will be concentrated and can be used only when the problem under study can be broken down into categories. In summary the measure phase is about understanding the current process, how the process is measured and its baseline performance.

Analyze Phase

The analyzing phase is about finding the top causes of the problem we are attacking. When executed, this phase starts with the team regarding potential causes. The objective of this phase is to make sense of all the information and data collected, where this data is used to confirm the source of the process variation, poor quality or other objectives. The challenge in this phase is to analyze properly the data and have a rational and neutral judgment about the analysis to make the correct improvement decisions around the root cause. There are a number of methods for exploring potentials causes, in the case a VSM- Value Added & Non Value Added Steps, Flowchart and Control Charts of the process was developed to analyze the manufacturing process. [5]

Improve Phase

The fourth step is to improve the process. Solutions to the problem are developed, and changes are made to the process. Results of process changes are seen in the measurements. In this step, the company can judge whether the changes are beneficial, or if another set of changes is necessary. This is the phase where all the work you have done so far in your project can come together and start to show some success. All the data mining and analysis that has been done will give you the right improvements to make to your processes. This phase starts with the creation of an improvement implementation plan. Now that you know what improvements need to be made, you have to figure out what you need to do in order to implement them. For the improve phase we implement Lean tools to correct the problem exposed in this project. For the success of this stage it is important that the project team is aligned with the possible solutions to be used.

Control Phase

This is the final phase in where you will see if the improvements that you have implemented are working. This phase unfortunately is one of the most overlooked phases in the methodology. One of the main reasons for improvements not showing any sustainability is because this phase has been overlooked. One of the big reasons of why Six Sigma programs fail is also because people get so excited after the improve phase, that they do not pay much attention to the control Phase - which leads to short-lived improvements. The key to the sustainability of the implemented action is the discipline and the continuing reviews of the actions taken. For this final phase we can implement the monitoring of different business metrics that impact directly the problem that was analyzed.

Results and Discussion

The final results were developed after the implementation of the Lean Six Sigma method. In this section we are going to discuss the analysis done before and after the implementation of DMAIC tool. In the Problem Statement chapter, the problem definition was exposed and the time study was exposed through a pareto chart which was conducted to help us to have a better visualization of the problem. The time studies were developed in the measure phase. The data collected was analyzed through a Value Stream Mapping (VSM), in this phase a flowchart was developed for a better to understanding of the opportunities, also the brainstorming techniques were implemented in the analyzed and improvement phase to find the root cause and possible solutions. To analyze the data and the process variation was developed a control charts for the before and after of each scenario to evaluating the process changes and improvements. The purpose of this tool is understand what causes that variation or waste to helps us decide what kinds of actions are most likely to lead to lasting improvement and work to minimize variation around a target. The following figures show the VSM for each manufacturing process. [6]

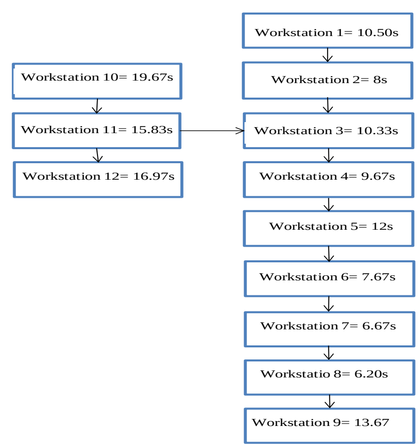

Figure 5
Product 250-070-530-Before the VSM & Balancing Exercises

Figure 5 shows the Value Stream Map Exercise for the product 250-070-530 before the improvement implementation. The total manufacture lead time to assemble one unit was 137 second, since each box has 6 units; the goal is 200 boxes in 8 hours. The following Figure 6, shows the Control Chart before the evaluate variation process.

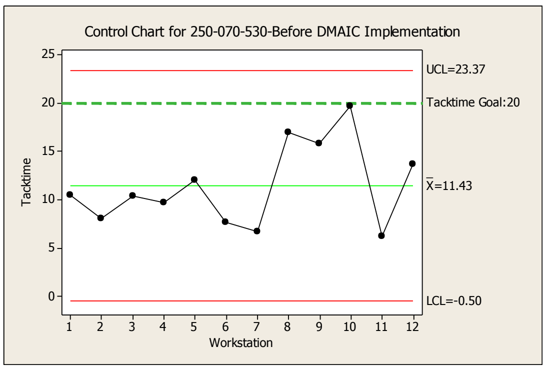

Figure 6
Product 250-070-530-Before the Evaluation of Process Variation

This Figure shows a time variation between the first workstations vs. the last workstations. The main of the workstations runs below the mean. As a result of this exercise, the following was found: the first fourth workstations ran in Kanban process, for that reason a quality problem was found. The most of the assembled units suffer from displacement of a component as a consequence of the waiting time to go one unit to the other workstation. That defect caused continuous units reworks and scrap. The line ran with three workstations (workstation #10, workstation #11, workstation #12) that were above the 15 seconds; these workstations are primary used to assemble sub-assemblies and therefore are ran in kanban, for this reason the flow in this line is slower than in the main assembly line. This caused that in many occasions the line leader to deviate from is tasks in order to help these workstations to continue the manufacture. For all these findings, potential solutions were developed through different improvement tools like standardized work and pull system implementation. Figure 7 shows the new scenario after the DMAIC implementation.

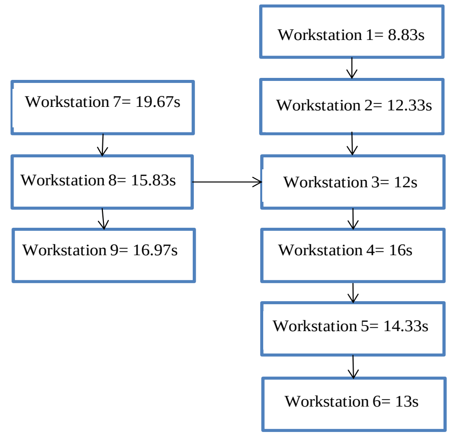

Figure 7
Product 250-070-530- After the VSM & Balancing Exercises

After the balancing exercises we achieved a reduction of the cycle time from 137 seconds to 130 seconds. Also the workstations where decreased 12 to 9 workstations. The quality problems diminished because the manufacturing process changed to running the line in one-piece flow. Figure 8 shows the progress after the process changes and improvements.

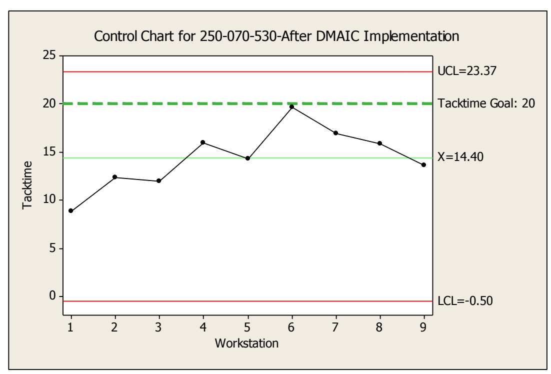

Figure 8
Product 250-070-530-After the Evaluation of Process variation

Figure 8 shows a stable process in comparison with the previous process. The time variation is less and staying with a minimum time variation between workstations, helping to promote an acceptable process flow in the manufacturing line. The next

Figure 9 shows the new process layout after the balancing process.

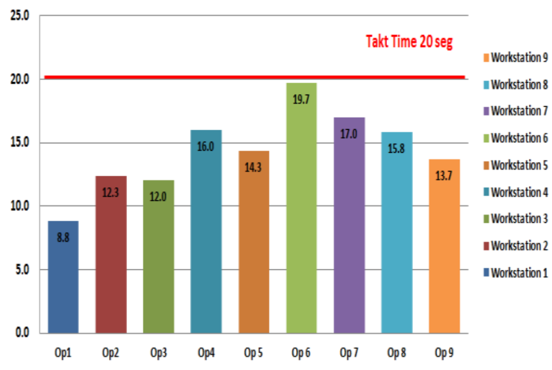

Figure 9
New Process Layout for 250-070-530

This new manufacturing process is more efficient by a 19% and allows an increase in the manufacturing capacity, with this new task balancing allows the manufacture process ensure the goals of manufacturing boxes.

The next Figures 10, 11, 12, 13, 14 shows the scenario before and after the implementation of DMAIC tool for the next product to evaluate 250-070-540.

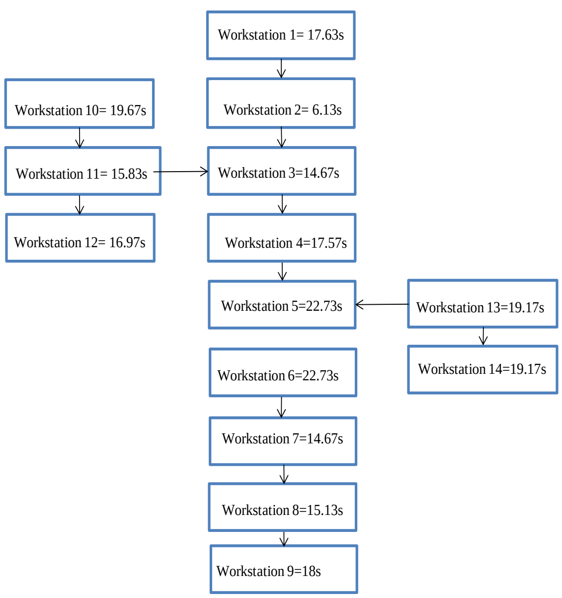

Figure 10
Product 250-070-540-Before the VSM & Balancing Exercises

The total manufacture lead time to assembled one unit was 241 seconds, each box has 6 units and the goal is 200 boxes in 8 hours. For a better understanding of this process a Control Chart was developed to indentify the process variation for this product.

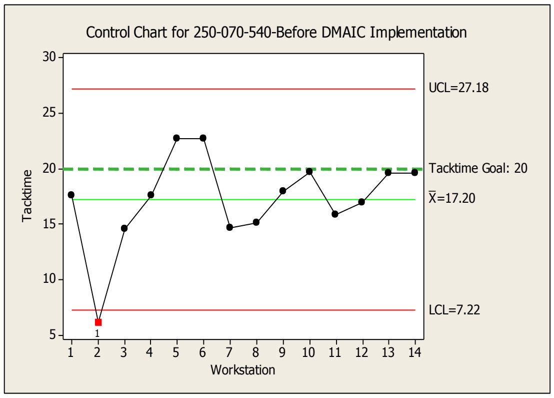

Figure 11
Product 250-070-540-Before the Evaluation of Process Variation

The last two charts show the before scenario, both charts show a big variation in the process, this is presented clearly in workstation two, because the time is out of the limits control. Also, we can identify a pattern of variation represented in workstation five and six that the time is out of the tacktime target. For that reason the process is an unstable process, the variation is due to special causes as well as to common causes. The analysis phases shows that this product presents the same problem that was evaluated on the previous product were the first workstations would not go with the flow of manufacture as the rest of the line. The different situation is that this product does not present a specific quality problem, however an issue of rework is present in the workstation 5^{th} and 6^{th}. Both workstations perform the same functions; wriggle around the unit and putting a paper tape to the unit. As the rest of the line goes faster than this workstation the current design tried to address this problem, putting another similar workstation, but that possible solution does not fix the issue that the workstation task were not balanced and for that reason the past solution increased the product cost. After the implementation of the different lean tools, the new scenario is showed in the figure 12.

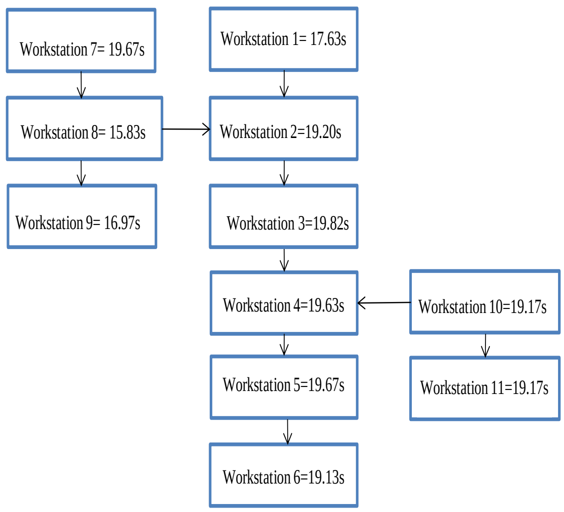

Figure 12
Product 250-070-540- After the VSM & Balancing Exercises

With the different initiatives and standardized work, the new manufacture lead time is 207 second between each unit. The workstations were reduced from 14 workstations to 11 workstations with this new process layout and now we are running to full capacity all the workstations. Also the over flow in the workstations 5 and 6 was eliminated. In Figure 13 and Figure 14 below, the new process and the new cycle time can be visualized.

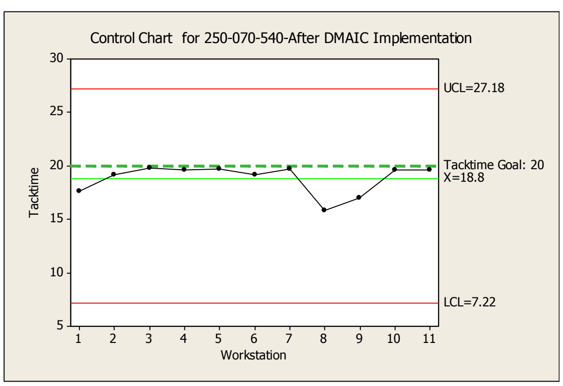

Figure 13
Product 250-070-540-After the Evaluation of Process Variation

Figure 13 shows the scenario after monitoring, evaluated and improves the process performance. Figure 14 shows the process with less variation and waste.

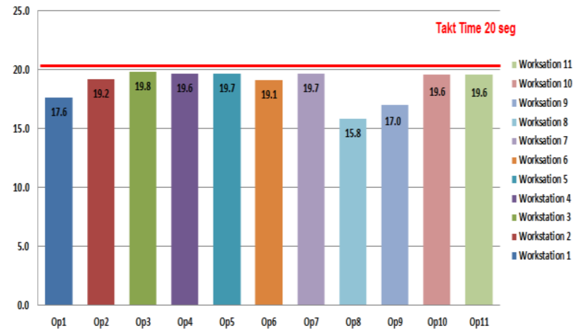

Figure 14
New Process Layout for 250-070-540

Figure 14 shows the new scenario; with all the implementations this product runs very efficient and the standardized work allows the implementation of One-piece flow. With this technique the material overflow was eliminated. The efficiencies of this line increased by 17% and for that reason this product had a labor cost reduction, impacting the capacity positively.

The last product to be evaluated is the 250-070-640, this product was the most challenging because of the times variation that the process presents. The following Figure 15 shows the process layout before the improvement implementation.

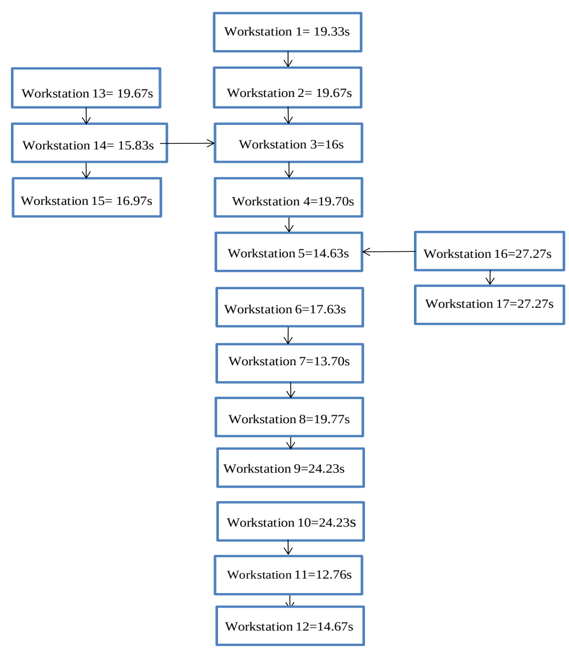

Figure 15
Product 250-070-640-Before the VSM & Balancing Exercises

This figure shows the current process before the analysis, this process was worked with 17 workstations, the total manufacture lead time to assembled one unit was 324 seconds, each box has 6 units and the goal is 200 boxes in 8 hours. Figure 16 below shows the Control Chart developed to analyze the manufacturing process.

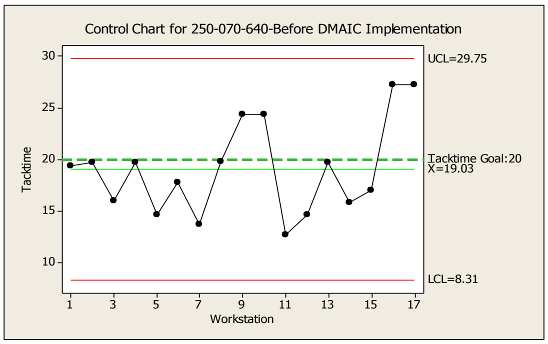

Figure 16
Product 250-070-540-Before the Evaluation of Process Variation

Figure 16 shows the before scenario and represent the unstable process composed by patterns of variation in the manufacturing process. This product has big variations of time between workstations; four workstations ran above the tacktime, five workstations ran much closed to the tacktime and the others ones ran in different times. In additional the production goal never was fulfilled. Through the Value Stream Mapping and the Balancing exercises, different issues where found. The workstation 9 and workstation 10 have the similar problem; both workstations perform the leaking test for the product. The issue is that both workstations only work with one leaking fixture. In additional the workstation 16 and 17 perform the sub-assembly for the product but this workstation did not ran in one-piece-flow like the main line. This workstation ran in Kanban and many components go to scrap because of the material excess. In summary these big variations of time are the result of different wastes. The following Figure 17 shows the process layout after the improvement implementations.

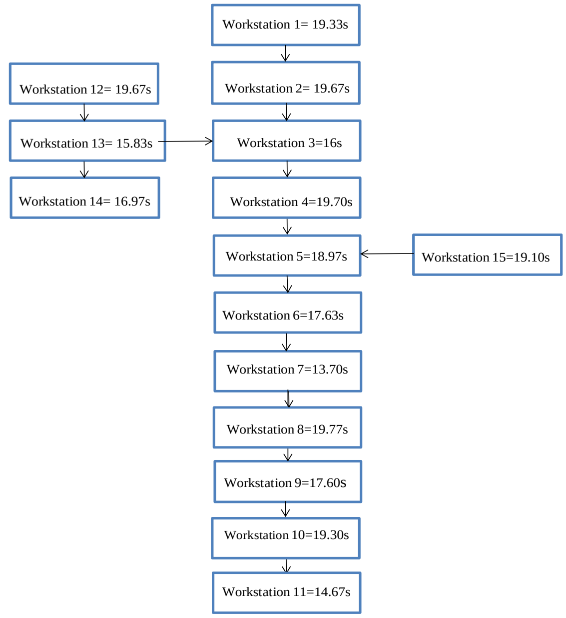

Figure 17
Product 250-070-640- After the VSM & Balancing Exercises

Figure 17 is the new process layout after the analysis. After the balancing exercises we achieved a reduction in the cycle time from 324 seconds to 268 seconds. Also the workstations were reduced from 17 workstations to 15 workstations. These results are a positive impact; in this case the improvement analysis was different, the approach was to work with the workstations that were above the tacktime and understand why these workstations were duplicated. In the analysis process it was found that these workstations were the problem for into the line and for that reason these workstations were the main balancing problem in the flow of the line. To reduce the cycle time another fixture of leaking testing was added, with this the Line Leader can help to floating the flow of the line and as a result the tacktime was reduced from 24.23 seconds to 17.60 seconds also a task balancing was executed between the others workstations. The workstation 11 increased the tacktime from 12.76 seconds to 19.30 seconds, both actions helped to eliminate the workstations that were duplicated. A similar situation was presented between the workstations 16 and 17. A balancing exercise was implemented in the workstations 5 and

16, as a result, workstation 17 was eliminated. The workstation 16 reduced the tacktime from 27.27 seconds to 19.10 seconds and the workstation 5 increased from 14.63 seconds to 18.97 seconds. Figure 18 shows the process variation scenario after the balancing exercise.

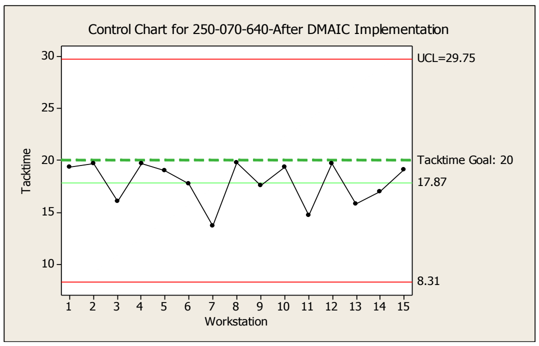

Figure 18
Product 250-070-640-After the Evaluation of Process Variation

Figure 18 represents the new process variation, that shows a process stable and in control after all the improvement. Figure 19 is the result of the DMAIC tools implementation.

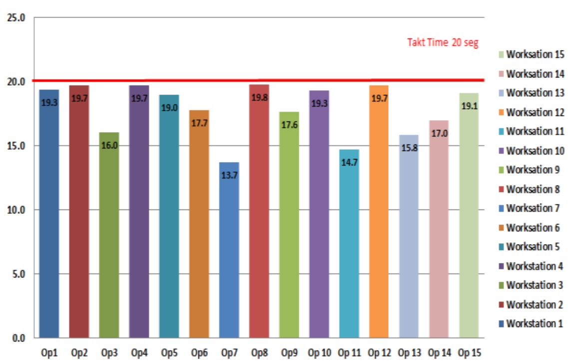

Figure 19
New Process Layout for 250-070-640

Another tool that was implemented to reduce the cycle time in these workstations was the 5S tool and standardized work, both tools helped to running the line in One-piece-flow. All these actions resulted in increasing the line efficiencies in 9%, also the scrap and yield was reduced, achieving a positive control, elimination the variation and the material wastes.

Conclusion

After the DMAIC implementation as a Lean Six Sigma method the results were positive, increasing the manufacturing capacity and the efficiencies. As a consequence the products had a cost reduction ensuring a good impact to the market and resulting in a sales increase for 2013. The following Figure 20 shows the increase in efficiency by product as a result of the implementation of the design project.

Products	Increase Efficiency
250-070-530	19%
250-070-540	17%
250-070-640	9%

Figure 20
Increase Efficiency by Product Chart

The efficiencies increased 15% in average; this means a manufacturing process with less variation in the process. As a result the scrap, excess of material, reworks and unnecessary movement was reduced. Another achievement was that the manufacturing process was changed from Kanban to One-Piece Flow. At the same time the yield and quality increased with zero reported non-conformances. An additional impact in the manufacturing process after the design project implementation was the labor cost. The following Figure 21 shows the labor cost reduction by product.

Old Scenario-Labor Cost Breakdown		New Scenario-Labor Cost Breakdown		DAILY CIP
250-070-530	Daily Cost	250-070-530	Daily Cost	Cost Reduction
Assemblers 12	$1,204.80	Assemblers 9	$903.60	$301.20
250-070-540	Daily Cost	250-070-540	Daily Cost	Cost Reduction
Assemblers 14	$1,405.60	Assemblers 11	$1,104.40	$301.20
250-070-640	Daily Cost	250-070-540	Daily Cost	Cost Reduction
Assemblers 17	$1,706.80	Assemblers 15	$1,506.00	$200.80

Figure 21
Breakdown of Cost Reduction by Product

All these results were due to a successful design project implementation. The Lean Six Sigma method in a combination of the DMAIC tool shows that it is good to get out of the usual way of the work in order to evaluate different situations involving innovative manners in order, to find different ways to solve problems and think outside the box. It is important to be open to the innovation of the concepts and by doing this positive results may emerge. This project shows how a simple methodology can add great value to the process.

REFERENCES

[1] Shook, John, "Five missing pieces in your standardized work", *Lean Enterprises Institute Inc*, 2009.

[2] Womack, James and Jones, Daniel, "Lean Thinking- 2nd Edition", *Simon & Schuster Inc.*

[3] Byrne George, Lubowe Dave, "Driven operational innovation using Lean Six Sigma", *IBM Global Services,* Copyright IBM Corporation, 2007.

[4] Nave, Dave, "How to compare Six Sigma, Lean and the Theory of Constraints", *ASQ Organization*, March-2002.

[5] Min Xie, Thong Ngee Goh, Vellaisamy Kuralmani, "Statistical Models and Control Charts for High Quality Processes", *Kluwer Academic Publisher*, 2002.

[6] Jones, Dan and Womack, James with D. Brunt and M. Lovejoy, "Seeing the whole Value Stream-2nd Edition", *Lean Enterprises Institute Inc*, 2011.