Improve Compliance to Schedule

Carla Ortiz Solano
Master of Manufacturing Competitiveness
Advisor: Wilfred Fonseca, Ph.D.
Industrial and Systems Engineering Department
Polytechnic University of Puerto Rico

Abstract *— One of the most difficulties in manufacturing is to explain the production colleagues the importance of following a production schedule and deliver product on-time to the next process. The facility in where this research project was conducted, had have a compliance to schedule within an average of 79.1% in the last eleven months, which it is expected to be 95% or above. This low performance to schedule is causing delivery issues from the dye house to the sew plant. In some instances, air shipments and overtime happened, to ensure the distribution center received the product to be able to deliver to the customer on the agreed date. This research project was performed applying the Six Sigma, DMAIC methodology. The structure of the DMAIC methodology truly helped in find out the root cause of the actual problem that was affecting the compliance to schedule. At the end of the project, the compliance to schedule was improved and sustained to 100% for 4 consecutive weeks.*

Key Terms *— Compliance to Schedule, DMAIC, Naïve Forecast, Six Sigma.*

INTRODUCTION

The company requested not to reveal the name, so the name that will be use is Company ABC. The Company ABC manufactures women's underwear. The main process of the supply chain is knitting, dyeing and sewing. The company production schedule is based on demand planning requirement (DPR). The demand planning requirement uses naive forecast, customer firm orders and inventory levels at the distribution center to determine a forecast of the different items. The naive forecasting method is based on a projection for a future period on data recorded for a past period and no adjustments are made to past periods. The demand is loaded in the system to create the production orders per specific item numbers. A planning tool consolidates the demand, considering actual inventory levels to determine what is needed to manufacture per processes. Lately, knitting has been a bottleneck of the supply chain. The process has been unable to deliver the specific items in the production plan on a weekly basis. This is resulting in delays to the dye house (dyeing), to expedite and keep the flow of the product to sewing based on the pre-defined process lead time. The opportunity is causing additional cost to the company such as overtime, an increase on orders in backlog and unplanned air shipments to fulfill customer orders. An investigation and analysis will be accomplished mainly focus to understand why the area is unable to produce the items on the weekly schedule and achieve compliance to schedule of 95% or above.

RESEARCH DESCRIPTION

This research project will help to understand the reasons why Knitting, cannot meet a weekly compliance to schedule of 95% or above. In addition, the research will facilitate to determine if there are opportunities to improve in other areas. The results of this project will not only benefit knitting, also will help the dye house to improve its product flow to the sewing plants and, consequently, the sewing plants will be able to deliver the orders on-time towards the distribution center, without the need of incur on air shipments. In this research project will be applying Lean Six Sigma methodology. The application of Lean Six Sigma Methodology in this research project will be beneficial by being able to make a deep dive analysis to the process, identify opportunities to improve by eliminating waste and non-value-added activities, reduce current variations that may exist in the process and stabilize the process. Finally, the most important thing is, will it be possible to

improve the compliance to schedule of knitting to 95% or above by applying Lean Six Sigma methodology?

RESEARCH OBJECTIVE

The main objective of this research project is to apply the Lean Six Sigma techniques and tools to increase the schedule compliance of knitting to 95%. The specific objective will be:

- To revise and analyze the whole process, since receive the production schedule until goods are transfer to the dye house.
- To identify the variables affecting the compliance to schedule.
- To address the underlying causes of having the compliance to schedule below the company goal.
- To apply solutions that causes of having the compliance to schedule below the company goal.

RESEARCH CONTRIBUTION

The application of Lean Six Sigma will contribute to:

- Improve knitting performance to schedule compliance from 79.1% to 95%.
- Satisfy customer's needs.
- Improve on-time product delivery.

LITERATURE REVIEW

One of the biggest manufacturing challenges is to deliver product on-time to customer. The on-time product delivery creates customer confidence which will end in higher revenues and profits for the company. Customer's expectations are to receive what they order on-time, in the right quantity and good quality. If a process fails to delivery, it will impact the other process ability to expedite what customer is requesting. This research will be focused to understand the factors and variables that do not allow knitting to manufacture 95% or above, the units in their weekly production schedule. This opportunity has had affected the dye house to deliver product on-time to the sewing plant and in a significant number of units in backlog or past due orders.

BACKGROUND

The facility of the Company ABC located at the eastern side of Puerto Rico. The ABC Company is a division of a well-known international clothing company in the United States. The Company strategy is to sell more, spend less and increase profit. The facility produces female intimate's product and has two main processes, knitting and dyeing. The streamline of the supply chain is illustrated in Figure 1. The main processes of the supply chain are in different countries. Knitting is the primary process that delivers product to the dye house and any delay causes to increase product lead time which at the end will result in a delivery issues to the final customer (final customer = retailer).

Figure 1
Supply Chain

The research project was carried out in the knitting area, which has a total of 218 machines. The differences between the machines are the size of the cylinder, which are 13, 15, 16 and 17 inches. The product per size may require to be knitted in different machine types, which refers to cylinder size. The product type manufacture is a circular knit fabric which is named a blank and the finished product is a garment. Each blank has a design, including the sew lines that will be used to produce the final product that consumer will wear. The facility operates 7 days a week, 24 hours a day. Capacity planning issue orders from the system and put together the textile plan, which is analyze by the facility production planner. The facility production planner evaluates the plan and issue the work orders to the knitting machines and schedule the machine changes needed. There are several reasons in a manufacturing process that can delay deliveries of a product to customer. Some of these

reasons could be, quality issues, increase of production demand, machine constraint, lack of raw materials and non-value-added processes such as re-inspections, reworks and over production of items not requested by the customer.

COMPLIANCE TO SCHEDULE

The compliance to schedule is an indicator that measure the ability of manufacturing to execute the production schedule in a pre-defined week to avoid delays to deliver the final product to the customer. It is calculated based on units produced versus the throughput of the area. A lower schedule compliance result may indicate that machines are running inefficiently, the area is unable to react to machine changes, quality issues, percent of waste higher than expected and cycle times longer than standards.

WEIGHTED WASTE

The waste is the non-conforming pieces (defects) found during the process. The weighted waste is one of the performance indicators of the facility and it's a percentage, calculated based on the total pounds (lbs.) of waste versus the total pounds produced (lbs.). Quality checks are performed during the process by the operator and the quality auditor. The non-conformity blanks found are segregated and at the end of the shift is weighed to determine the pounds of yarns consumed. The weighted waste is a percentage, calculated based on the total pounds (lbs.) of waste versus the total pounds produced (lbs.).

LEAD TIME

The manufacturing lead time is the total time it takes from the initial process until the order or product is ship to the customer or next process. Knitting process lead time is one week and started when the order is place in the system until units are produced and are transferred or shipped to the dye house. The lead time is a key for customer satisfaction. Customers normally want to receive the product as faster as possible, in the right quantity, at a lower cost and good quality. Longer process lead time can result in high levels of inventory which is one of most common waste and non-value added in Lean Manufacturing.

CYCLE TIME

Cycle time is all about the speed of delivery of the product/service to the market or customer [1]. Cycle time is the total time, including processing time to manufacture an item, which in this case, knitting produces blanks. The cycle time is a key factor for any manufacturing plant. A short cycle time means, lesser process lead time, which will result in a higher customer satisfaction, competitive advantage, cost reduction and productivity increased [1].

LEAN MANUFACTURING

Lean Manufacturing is a continuous improvement philosophy focusses on creating more value for customers. Lean seeks a process to achieve high quality, safety, keep a high employee's morale, cost reduction and reduce manufacturing lead times by the elimination of waste in all processes [2]. Lean considered waste, over production, idle time, unneeded transportation, waste of the process, high levels of inventory, non-value-added motion and quality defects.

SIX SIGMA

Jack Welch describe six sigma as "Six Sigma is a quality program that, when all is said and done, improves your customer's experience, lowers your costs, and builds better leaders" [3]. Six sigma is focus on process improvement and to reduce process variations through the use of DMAIC and DMADV. For this research project will use the DMAIC methodology. Six Sigma methodology can be used to improve quality and service. It uses process and product data, measurement and statistics to identify inefficiencies by applying tools to eliminate defects and reduce process variations.

Six sigma refers to a process of 3.4 errors per one million opportunities. It has been proven that helps businesses to reach process excellence and to stay ahead competition.

DMAIC

DMAIC is a systematic problem-solving process of Six Sigma that includes five steps, define, measure, analyze, improve and control. The figure 2 illustrated the phases of DMAIC process and a brief description of what is included on each stage.

Phase	Description
Define	Define the first step of define. The objective of this stage is to clear define the objectives, team member, project boundaries, scope, the expectations for the project and customers; requirements. The project ram should identify the CTQ's (Critical to Quality)
Measure	Once the proact is defines, the second phase includes data collection. The data will show how the process is performing.
Analyze	After the data is collected, the main focus will be eliminating and reducing the variance as much as possible. The analyze phase assists to identify the root of cause of the issues by dive deep into the process.
Improve	In this phase, is one of the most important because it is about finding a permanent solution to the problem. In this stage, the project team works on a pilot to test the effectiveness of the solution.
Control	If the pilot works, then the new solution is documented an information shared with the owners. The team develop a project timeline and monitors for the period defined the performance after the implementation of the project milestones.

Figure 2
Phases of DMAIC

SIX SIGMA TOOLS

Six sigma has different tools used for analysis that helps to understand the root causes of problems affecting a business. There a variety of tools that will be use in this project, through each phase of the DMAIC methodology.

- ***SIPOC:*** The SIPOC is a diagram that stands for suppliers, input, process, outputs and customers. The information is used to create a process map in a high-level outline. In the figure 3 shows the meaning of SIPOC.

Acronym	Area of the diagram	Description
S	Supplier	Provide description to the process
I	Inputs	Material, information and any other important aspect needed to complete the process
P	Process	Convey inputs and outputs
O	Output	Product or service out of process
C	Customer	Who receive the output of the process

Figure 3
Meaning of SIPOC

- ***Critical to Quality (CTQ's):*** Critical to Quality (CTQ) tree, outline customer wants and needs by hooking them into measurable operational performance. The CTQ tree supports businesses in providing high quality goods and service**.**
- ***Process Map:*** The process map is a diagram that visually describes the process flow. The process map helps to understand where the opportunities of the process are by detailing all the activities performed, in terms of the process itself and decisions.
- ***Time Series Plot (Run-charts):*** A process is defined as a series of activities that transforms a set of inputs into a specific set of outputs. Process change happens over time. Determining if a change has happened – and if that change lasts over time – is important to process improvement. A run chart is used to determine if the central tendency of a process is changing. It does not require tedious calculations or special software to produce. It plots observed values on the y-axis and the times they were observed on the x-axis [4].
- ***Cause and Effect Diagram:*** The cause and effect diagram is also known as fishbone diagram or ishikawa diagram. The cause and effect diagram identifies the possible causes of a problem. The diagram helps to organize all the possible potential causes of a problem while doing a brainstorming section [5].
- ***Pareto Chart:*** The Pareto Chart is a bar graph that helps prioritize causes of a problem. The Pareto Chart is based on the principle that 80% of the variations is produced by the 20% of the inputs. The graphical illustration of the Pareto Chart assists in recognize the variables, defects, processes causing the impact to the business. Recognizing and working with the variables will help in reduce variations.
- ***Why's Technique:*** Asking "Why?" may be a favorite technique of your three-year-old child in driving you crazy, but it could teach you a valuable Six Sigma quality lesson. The 5 Whys is a technique used in the Analyze phase of the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology. It is a great

Six Sigma tool that does not involve data segmentation, hypothesis testing, regression or other advanced statistical tools, and in many cases, can be completed without a data collection plan [6].

- ***2 Samples t-test:*** One of the most commonly used hypothesis is the t-test, is to tests in Six Sigma. It is applied to compare the mean of two samples.
- ***Project Plan:*** A project plan is a document that has all milestones defined for a project, including the timeline to complete activities, responsible, and scope. The primary uses of the project plan is to facilitate communication between all members of the project, process owners and stakeholders. In addition, it is used to document all action items that have been identified that would drive improvements.
- ***Histogram:*** The histogram is a graph that shows the frequency distribution of a set of data. The chart looks like a bar chart that illustrate a numerical distribution of a data.
- ***Probability Plot:*** The normal probability is a graphical method to evaluate if the data under analysis follow a normal distribution. This method compares two set of data.

METHODOLOGY

The study will be approached using DMAIC. The reason for choosing DMAIC for this research is because the methodology helps in covert a critical business issues into a statistical problem and get resolve by using a standardize method and providing the structure to help to improve the processes and productivity at the workplace. Sampsa Tikkala (2014) [7] established that DMAIC methodology can be applied to financial concern, customer problem, process inefficiency, product failure or flow bottleneck.

A kaizen event will be conducted to aim on improvements on the compliance to schedule. A kaizen is a lean tool. Kaizen is a Japanese word that stands for improvement and involve employees from different areas of the organization. A kaizen event helps to evaluate current state and improve existing process. The team members will be from different functional areas, planning, quality, engineering, manufacturing and technicians.

The data collection needed for this research will be from historical and current data of the process. The data will be analyzed to understand what factors are affecting the performance of knitting in terms of compliance to schedule

SIX SIGMA TOOLS

Lean six sigma is very beneficial for the business. Lean six sigma helps to grow businesses by decreasing cost and increasing profit, improve efficiency and effectiveness and develop effective teams and people. Six sigma uses statistical tools for the correct analysis of the data and conclusions are based on facts. Using actual outcome of the process, the correct statistical analysis and making decisions based on data, will be ending in good results by reaching or exceeding company goals and a satisfied customer. Next, the methodology that will be followed for the investigation:

- ***SIPOC:*** The purpose of using the SIPOC diagram is to provide a high-level overview of the process.
- ***Critical to Quality (CTQ's):*** The CTQ's tree will be developed to provide a clear picture of customer's requirements and needs.
- ***Process Map:*** The intention of using the process map is to provide details of how the process works. The process map will help to identify any opportunity in the actual process.
- ***Time Series Plot (Run-charts):*** The run charts will be useful to evaluate trends or patterns over the time and monitor the behavior of the compliance to schedule as the actions are being implemented.
- ***Cause and Effect Diagram:*** The cause and effect diagram will be used to stimulate the team's brainstorming on a root cause of the low performance on compliance to schedule.
- ***Pareto Chart:*** The aim of using the Pareto chart is to illustrate the specific item impacting

the compliance to schedule and which is the main problem driving to ship the goods on-time to the next process.

- ***5 Why's Technique:*** The usage of the 5 Why's Technique in this research project has the purpose of exploring which is the root cause of the problem.
- ***Sample 2 t-test:*** The sample t-test will be applied to compare the average of the cycle time for the same items knitted in different per machine types.
- ***Project Plan:*** The project plan will be used to organize all actions needed to be taken that will drive the improvements of the compliance to schedule
- ***Histogram:*** The histogram will be used to understand the distribution of the data collected to analyze and discover the distribution of the data based on frequency, allowing to see outliers and skewness.
- ***Probability Plot:*** The probability plot will be used to ensure the data to analyze is normally distributed.

RESULTS AND DISCUSSION

This research was conducted following the methodology of Lean Six Sigma, DMAIC and sections are divided by stage, following same phases outlined the methodology.

Define

The define phase of DMAIC, it is important to have a clear understanding of the process wanting to improve. The figure 4 is showing the SIPOC diagram of the knitting process. The SIPOC is showing, in a high level that the raw material is coming from the yarn vendor, process inputs are yarn, product specs and work orders, which are processed to produce the output which is knitted blanks that are ship to the dye house, located next door of knitting.

When working on an improvement project in an area, it is vital to know what the customer's requirements are. An important thing is to ensure that the improvements made in the area or process fulfill customer's needs, especially when they have been complaining about the service provided. In figure 5, the critical to quality tree for the dye house, figure illustrated the requirements for the dye house, which in summary are, correct item, less than 0.5% defects and the right quantity of units and pounds.

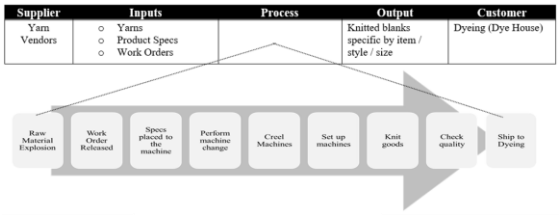

Figure 4
SIPOC Diagram of the Knitting Process

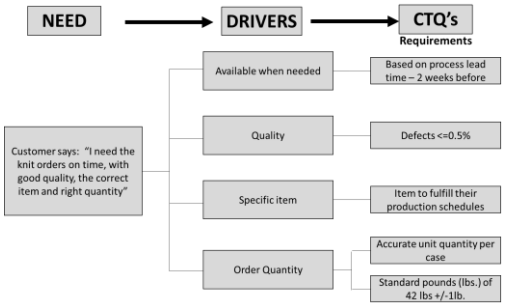

Figure 5
Critical to Quality Tree (CTQ's Tree)

Measure

The results of the compliance to schedule was investigated. The figure 6 shows the trend since January to November 2017. The data displays that the schedule compliance for this period had have been in average 79.1%. In another hand the production schedule had has been suggesting having a total of 190 machines running at 70% efficiency to be able to manufacture, 320,000 units per week, among all cylinder machine size. Data was collected for 13 days, to have the idea, of how many machines the facility have been able to run. The facility kept a total of 113 machines running on an average.

The waste of the facility has increased as well. The goal of weighted waste is 3.0% and the year to date is in 4.41%. The actual percent of waste is

38.7% more than the one included in the product standard cost.

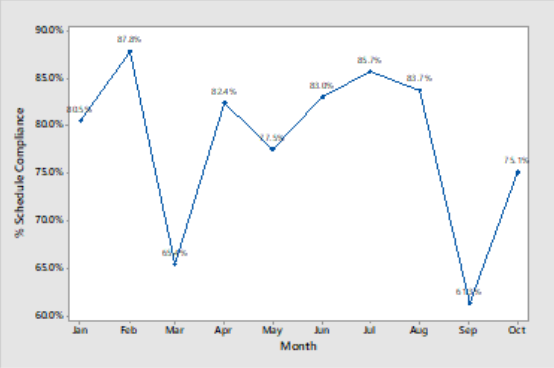

Figure 6
Knitting Compliance to Schedule

The dye house has complained because this lack of blanks from knitting, caused that they cannot meet sewing orders. The dye house compliance to schedule in average is 78.1%. Both areas have a goal of attain a compliance to schedule of 95% or above on a weekly basis.

Analyze

A cause and effect diagram, figure 7 was developed to display by categories the potential causes. The figure 8, the 2 main contributors are machine stoppages and cycle time change. It was found that the main issue of machine stoppages and cycle time were driven by the lack of preventive maintenances. The mechanics and technicians of the area were interviewed and they confirmed that the mechanical problems are associated to the lack of preventive maintenances and are causing that machine changeovers to take more than 2 hours, when in 15 minutes should be completed. This being happening because of the machine issues encountered, force them to do preventive maintenance to the machine to ensure the machine will be work with no issues when start to run. The changeover time is taking between 1.6 to 3.2 hours to be completed which validates that the changeover was taking 2 times more than planned, to complete.

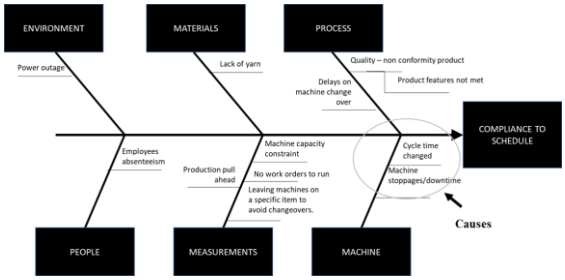

Figure 7
Compliance to Schedule – Cause & Effect Diagram

5 WHY's	
Cause 1 *Machine Stoppages/ Downtime*	Cause 2 *Cycle Time Changed*
Why does the machine stoppages impact the compliance to schedule?	**Why the cycle time impacts the compliance to schedule?**
Machines dorit run because unplanned stop.	When a machine has mechanical issues, instead leaving the machine stop, it is run at a higher cycle
Why machines stop?	**Why the machines have mechanical issues?**
Machine stop because improper operation.	Lack of preventive maintenance (PMs)
Why machines are not working properly?	**Why are not preventive maintenance offered?**
Because of lack of preventive maintenace.	There is not a schedule for machine PM's.

Figure 8
5 Why's - 2 Potential Causes

A changeover is considered as completed when the first piece produced complies with the expected product quality based on the established standards. The major offender defects causing delays on changeovers are barre and excess yarn, with 42.9% and 33.3%, respectively.

Additional data was collected to understand how much time a machine is stopped, in other words, how long a machine is not producing. The data were samples for a period of 2 weeks, in January 2018. The analysis demonstrated that machines were idled between 4 to 7 hours.

Figure 9 illustrates one of the items used as an example to evaluate the differences in cycle time per machines through the hypothesis test, 2 samples t-test. The probability plot and 2 sample t-test to study whether there is a statistically difference between the mean of 2 machines running one of the styles of the highest volume. The results were that both samples have a p-value above 0.05, which is equivalent to 5%, so it was concluded that the samples for machines number 100 and 2108 were normally distributed.

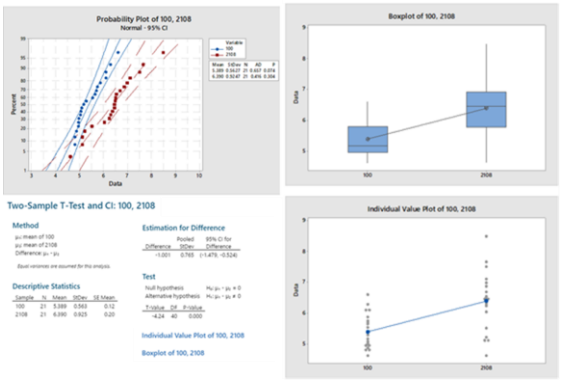

Figure 9

2 Sample t-Test of One of the Style with the Highest Volume

The results of the 2 samples t-test were that the p-value (it was assumed an equal variance) was 0.007, which it's less than the alpha level of 0.05, therefore, the conclusion was that there was a significant difference between the means of both machines. It was encountered that the cycle time of the machine 2108 was 1.3 minutes more than the cycle time standard of 5.1 minutes. On regards to machine 100, the average was closed to the standard cycle time. It was found that the reason why the cycle time is changed is because due to the machines conditions and continuous stoppages, by reducing the cycle time the machine can be run, instead of being down and at least produce between 50% - 70% the units in orders.

Improve

There were several activities worked out to drive the improvement on the compliance to schedule. All the improvements made were focused to improve the machine conditions. The following were the mainly activities that driven the enhancement.

- While the project plan was being executed, the team developed a contingency plan. The different functional teams get together to work a temporary plan to minimize the impact of not achieving the compliance to schedule on a weekly basis. The plan consisted in meeting to evaluate the requirements of the plan and the current machines conditions and carried out movements of orders towards other machines in which mechanical issues were being corrected.
- A preventive maintenance schedule was developed, prioritizing the machines with the highest frequency of stops and those machines which based on the data collected were the ones with the highest downtime.
- The activities currently included in the preventive maintenance were reviewed and incorporated to verify the air leaks, which wasn't one of the activities to check as part of the preventive maintenance and it is a key to ensure the machine works properly.
- An assessment was made to each machine to have a clear understanding of the current conditions. In this assessment was verified that the machine had all the parts properly connected, free of air leaks and running with the correct cycle time. Based on the assessment's results, it was given the priority in the preventive maintenance schedule.
- One of the findings of the assessment performed was that 55.6% of the machines were identified with mixed needles. The usage of different needle types in the machine causes the defects of needle marks, holes, selectors and excess yarn. The defects of needle marks and excess yarn were 2 of the defects that had caused delays to complete a changeover. To avoid mixed needles, all machines were identified with the needle type that should be use.
- The preventive maintenances were given first to the machines being the biggest offenders. The cycle times were corrected as well.
- A board was developed to illustrate the machine layout of the area. The board was developed mainly to improve communication of the priority to repair machines and the order to execute the changeover. It was found while doing the research that mechanics and technicians were repairing and doing changeovers to what they called, easier machines first and leaving the difficult ones to

the end and this was causing delays to perform a machine changeover and an increases of machine downtime. The impact of this behavior was that the machine changeovers needed to comply with the weekly schedule were made at the end of the week, so haven't enough time to produce the units of the plan. The same issue was happening with the machines stopped, mechanics were focused on repair the easiest machines first and the results were that the machines in average were stopped between 4 to 7 hours.

Additional samples were gathered after the preventive maintenance was given to machines 100 and 2108 to validate the effectiveness. The figure 10, displays the improvements made on the machine cycle time. The 2 samples t-test concluded that the p-value (it was assumed an equal variance) was 0.641, which is higher than the alpha level of 0.05, therefore, the conclusion was that there is not a significant difference between the means of both machines. Both machines improved the average cycle time by 1.3% and 16.12%, respectively.

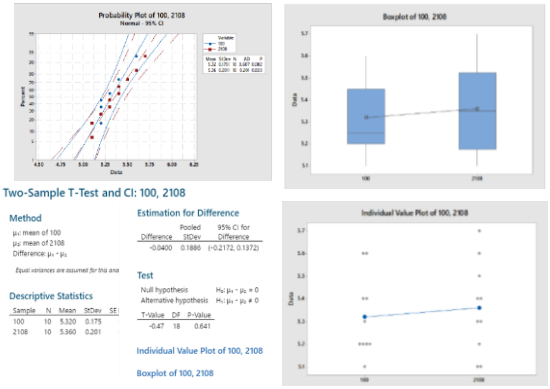

Figure 10

2 Samples t-Test after Improvement made on Cycle Time

This research project was carried out to improve the compliance to schedule. The figure 11 shows the results after implemented all actions defined. The project started with a baseline of 79.1% which was the average of the compliance to schedule for 11 months. The compliance to schedule improved to 91.76% in average and reached 100% on the last 4 weeks.

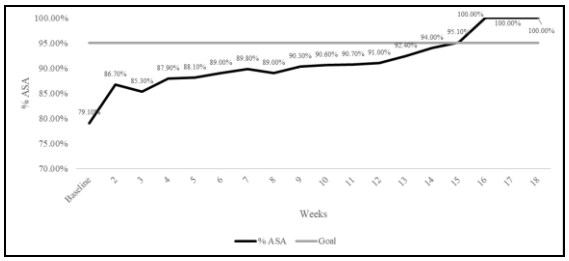

Figure 11

Knitting Compliance to Schedule (After)

One of the goals of this research project was to improve the compliance to schedule of dye house. The compliance to schedule of dyeing was improved 12.7%, from an average of 78.1% to 90.8%. The other area that improved was the % of waste of the facility. The baseline of the % of waste was 4.41% and in the last 4 months it was reached 3.98%, which represents 9.8% of improvement.

Control

The last stage of DMAIC is one of the most important. This stage is about, how to sustain the improvements made? There is vital to monitor the process performance to ensure the results are sustained and continue to improve. One of the controls established was a time series to monitor the compliance to schedule daily. The chart included the goal and it was posted and continue to be posted in the area for everyone to see how the area is performing against the weekly schedule. The chart displayed the results of the week, however, the progress on the schedule started to send it daily.

The employees perform daily stand up meeting to discuss different topics. There are additional topics added related to machine conditions. The results validated that this is really working. These controls have caused some desired behaviors, which are that employees are engaged and empowered. Today's, the employees take over the process and perform among themselves the necessary changes to improve results.

CONCLUSION

The main purpose to conduct this investigation was to improve the compliance to schedule of the

knitting area. In the sub-section, improve, are all the details of actions taken and results of the contributions made to others key performance indicator of the facility. The weekly trend is showing that for the last 4 weeks, the compliance to schedule, which was the area of interest, have been above the goal of 95%. The conclusion is that the facility was having a compliance to schedule of 76.1% in average, because of machine conditions driven by the lack of preventive maintenance. The absence of preventive maintenance was causing:

- Machines to work improperly.
- Machine downtime.
- Delays to complete a machine change over.
- Increase on waste.
- Cycle time changes to be able to run the machine at least at a longer cycle time.

One limitation is that the facility doesn't has a system to schedule preventive maintenance. The schedule is completed manually and there is a challenge to perform analysis of the data gathered. That's why it was determined to discuss the status of the machine PM's in the daily stand up meeting with the employees of the area.

The usage of the DMAIC methodology truly helped to encounter the root cause affecting the weekly compliance to schedule. Each of the stages of DMAIC, helps to organize and structure step by step the project to drive the improvement and desired results.

For future research, it is strongly recommended to continue to evaluate the actual system to schedule the preventive maintenance and try to incorporate an electronic system that fits the facility needs, to schedule, monitor and analyze the data of the preventive maintenance. The benefit associated is to strengthen the current process, analyze machine performance, reduce waste and eliminate that the system depends of one person.

REFERENCES

[1] What is Six Sigma? (2018). *Cycle Time*. [Online]. Available: http://www.whatissixsigma.net/cycle-time/.

[2] Lean Enterprise Institute. (2018). *What is Lean*? [Online]. Available: https://www.lean.org/WhatsLean/.

[3] I Six Sigma. (2018). *What is Six Sigma* [Online]. Available: https://www.isixsigma.com/new-to-six-sigma/getting-started/what-six-sigma/.

[4] I Six Sigma. (2018). *Run Charts: A Simple and Powerful Tool for Process Improvement* [Online]. Available: https://www.isixsigma.com/tools-templates/control-charts/run-charts-a-simple-and-powerful-tool-for-process-improvement/.

[5] ASQ, Learn about Quality. (2018). *Fishbone (Ishikawa) Diagram* [Online]. Available: http://asq.org/learn-about-quality/cause-analysis-tools/overview/fishbone.html.

[6] I Six Sigma. (2018). *Determine the Root Cause: 5 Whys* [Online]. Available: https://www.isixsigma.com/tools-templates/cause-effect/determine-root-cause-5-whys/.

[7] S. Tikkala. (2014). *Lean Six Sigma in a Manufacturing Lead Time Improvement Project*, pp. 12. [Online]. Available: http://www.doria.fi/bitstream/handle/10024/101921/Sampsa+Tikkala+-+Lean+Six+Sigma+in+a+Manufacturing+Lead+Time+Improvement+Project.pdf;jsessionid=390EBDB447A4AA18BED3F6CACA2E8D6C?sequence=2.