Using Lean Methodology to Reduce Changeover Time in Packing Line

Waldo Soto
Manufacturing Engineering Program
Edgar Torres, Ph.D.
Industrial Engineering Department
Polytechnic University of Puerto Rico

Abstract — *One of the metrics to measure efficiency in packing lines is Process Reliability (PR). It has been identified that the PR loss in packing Line X due to changeovers is 16%. The objective of this project is to use lean methodology to reduce the changeover time of Line X from 77 to 57 minutes during a three month time frame. This represents a 25% changeover time reduction obtaining savings of forty thousand dollars a month. Work Process Improvement tools were used in conjunction with the DMAIC approach to achieve an average changeover time of 46 minutes exceeding our initial objective. The data gathered from the change over critiques show that the improvement has been consistent and more than 80% of the changeovers are being completed on the new 46 minutes target, confirming that the use of the company's Work Process Improvement tools proved to be very efficient.*

Key Terms *– DMAIC, Machine Changeover, Six Sigma Tools, SMED*

BACKGROUND INFORMATION

One of the metrics to measure efficiency in packing lines is Process Reliability (PR). This metric is a relationship between the packing line schedule time and the packing line actual time. It has been identified that the PR loss in packing Line X due to changeovers is 16%. This means that when running a 24 hour operation, 230 minutes are spend on changeover activities. The actual changeover time is 77 minutes on the average therefore three changeovers are made on a daily basis. Each PR percent translates into ten thousand dollars a month, therefore making it very important to reduce the changeover time. Currently the changeover is performed by three maintenance mechanics and one line documentation technician. This project used rapid changeover tools to identify losses specifically in the changeover procedures and techniques and reduce this loss to 12%.

Rapid changeover is the change of a product or package as quickly as possible. It is measured as the going to going time of the line as opposed to only the time it takes to change parts of the equipment. It is focused on quick settings that can be performed by anyone, rather than lengthy adjustments by specialists [1]. Product quality is good from the first run as opposed to an erratic recovery or startup.

RESEARCH DESCRIPTION

The overall intend of the rapid changeover (RCO) is to implement tools that helps identify and eliminate waste and establish and maintain proper work process conditions. This combination yields an orderly work execution that is effective (zero losses or defects) and efficient (requires minimal effort). The use of these tools will be critical for the success of this project, since identifying gaps and losses in the changeover procedures will help to eliminate them, therefore reducing the changeover time and the process reliability loss.

RESEARCH OBJECTIVES

The objective of this project is to reduce the changeover time of Line X to 57 minutes during a three month time frame. This represents a 25% changeover time reduction from the current 77 minutes it takes from the moment the filler stops to the moment were it starts again after all the machines are changed for the next batch.

RESEARCH CONTRIBUTIONS

The project represents a cost saving of forty thousand dollars a month to the company. Also this 25% changeover time reduction will allow the company to remain competitive by aligning it to the current supply chain strategy. The company's current supply chain strategy is to reduce inventory levels. Cycle stock is a component of inventory; short cycles mean lower level of inventory but increase in changeover quantity, therefore making a priority to reduce changeovers time as much as possible.

RESEARCH BACKGROUND

Rapid Changeover is a simple but powerful lean manufacturing technique for reducing waster in a manufacturing process. It is a systemic approach that enables organizations to dramatically reduce changeover times. It provides a rapid and efficient way of changing the machine set up in a manufacturing process from one product to other. This term is often interchangeable with single minute exchange of dies (SMED) [2].

To understand how rapid changeover can help we have to look at the changeover process. Typically when the last product of a batch is made, the equipment is shutdown, the line is cleaned, adjustments are made to the equipment, materials are received and loaded in into the line, and eventually the startup process begins. This whole process is defined as the setup time. Long set up time results in a reduced number of changeovers, larger batch sizes and larger buffering work in progress inventories and poor process flow and performance. Since setup activities add no marketable form, fit, or function to the product, they are by definition non-value adding. By reducing this setup time, more setups can be completed each day, batch size can be reduced, and flow can be significantly improved. All this improvements will help manufacturing flexibility.

Rapid Changeover was developed by Shigeo Shingo a Japanese industrial engineer who was extraordinarily successful in helping companies dramatically reduce their changeover times [3]. Shingo and his team discovered that if setup time was greatly reduced, batch sizes could shrink proportionally. Today, inventory is the enemy of production efficiency and effectiveness. More than fifty years ago, Shingo realized that inventory costs more than originally thought [4]. Materials "on the shelf" have to be bought and paid for much sooner; and so does the labor used to make and store finished and work in process goods. The cost of floor space and new warehouses is considerable, as is the cost of insuring those facilities and the product they contain.

Currently most manufacturers who have not implemented rapid changeover still use EOQ (Economic Order Quantity) thinking to determine production batch sizes. For many years, it was believed that optimum inventory levels should be calculated by spreading the setup for changeover across as large batch as possible, within the production requirements of the plant [5]. This is why inventory levels grew and grew. New larger storage areas and warehouses became the rule, industrial engineers reasoned that you will never have product outages if you carried enough inventory.

The fundamental reason to implement rapid changeover is to reduce lead time and cut manufacturing costs, while maintaining quality. Rapid changeover allows for set up times to be reduced so parts can be produced in a short timeframe and become deliverable as fast as if they were already sitting in the shelf.

A good example of rapid changeover is a Nascar pit crew [6]. For many people changing a single tire can easily take 15 minutes. For a Nascar pit crew changing four tires could take less that 15 seconds. Many techniques used by Nascar pit crews (performing as many steps as possible before the pit stop begins; using a coordinated team to perform multiple steps in parallel; creating a standardize and highly optimized process) are also used in rapid changeover. In fact the journey from 15 minute tire changeover to a 15 seconds tire changeover is considered a rapid changeover journey.

Rapid changeover is made up of steps that are termed as elements. There are two types of elements: internal elements which are the ones that must be completed while the equipment is stopped, and external elements which are the ones that can be completed while the equipment is running. Rapid changeover focuses on making as many elements as possible external and simplifying and streamlining internal elements.

WPI Methodology breaks rapid changeover implementation into eight steps: preparation, understanding the situation, expose and eliminate defects, identify improvement ideas, plan, implement, check results, and consolidate gains [7].

Rapid changeover is a journey, a journey in which you are never done improving. Once you completed one journey and the targets are met, new goals should be set. The first journey for the project is to reduce the changeover time from 77 minutes to 57 minutes on a three on the timeframe.

RESEARCH METHODOLOGY

The methodology used in this design project will be a Work Process Improvement Tool (WPI) which consists of eight company approved steps developed to improve any given process [8]. As part of this design project I will group them to fall into the DMAIC methodology. The DMAIC process is a Six Sigma methodology for improving an existing or established process of service. Five steps compose this process and each step may be used in an iterative or cyclical fashion. Refer to Figure 1.

Figure 1
WPI Grouped in the Five Phases of DMAIC

DEFINE

This is the first step in our six sigma approach of DMAIC. DMAIC first asks leaders to define our core processes. It is important to define the selected project scope, expectations, resources and timelines. The definition step in the six sigma approach identifies specifically what is part of the project and what is not, and explains the scope of the project. Many times the first passes at process documentation are at a general level. Additional work is often required to adequately understand and correctly document the processes.

- **Step 1 Preparation**: they key outcome of this step is that resources, timing, and losses have been identified in the Team Charter and the team is now ready to understand the situation.

The team needs to know, understand and accept what is being proposed. Presentation of the problem by the area business leader, a written document that specifies what must be accomplished, some data and information about the problem, can all be used to help the team gain this understanding. Having the team developed this knowledge and understanding is important to ensure that each of the individuals come together to a common team understanding. This process is called team development.

Individuals are identified, to be on the team, based on the skills that those developing the charter

felt would, in combination, solve the problem. This does not mean that these individuals will automatically work well together. The intent of team building is to develop common principles and define common behaviors for the team. If the individuals are all from the same organization this may be simple and short. However, getting clear on how the team will function together is always critical.

Once a team knows and understands the problem, they need to formally accept doing something about it. Additionally, they need to accept the direction as given in the charter or they need to re-re-negotiate with the chartering group. This process of gaining clarity and agreeing to do what is being asked is called charter acceptance.

MEASURE

When starting this RCO journey, the most important thing to know is where you are going, what the goals and targets are. You cannot know how your improvements will affect the current status (positively or negatively) unless you measure first the current state.

- **Step 2 Understanding the situation:** The key outcome for this step is the time chart of the whole changeover from preparation to start-up. Using this information, I would be able to identify which particular area is taking more time and effort. At this step, I can decide to re-focus the issue to fix only the area with the biggest losses.

ANALYZE

Once the project is understood and the baseline performance documented and verified that there is real opportunity, it is time to do an analysis of the process. Any number of tools and tests can be used. The objective is to understand the process at a level sufficient to be able to formulate options for improvement. We should be able to compare the various options with each other to determine the most promising alternatives. As with many activities, balance must be achieved. Superficial analysis and understanding will lead to unproductive options being selected, forcing recycle through the process to make improvements. At the other extreme is the paralysis of analysis. Striking the appropriate balance is fundamental.

- **Step 3 Expose and eliminate defects**: the key outcome for this step is to identify and eliminate defects, only when defects have been eliminated or action plans are in place we can proceed to the next step. For this step it is recommended to develop a changeover CBA (Current Best Approach) for each equipment. The CBA is a document where it guides you step by step on the instructions on how to change the equipment from one product to other. This CBA will also include the centerlines all equipment. Centerlines are specific marks identified by numbers that will give an exact reference on the critical position of the guides and adjustments parts to aid the mechanic on the changeover.
- **Step 4 Identify improvement ideas:** Once all activities of the changeover are documented and displayed in a timing chart, ideas to improve the hang time and start-up time are identified following a five-sub step approach and in the end, the key outcome for this step is to be able to develop the ideal sequence of the changeover. The five-sub step approach is detailed below:
    1. Separate internal from internal – Once you have identified all your activities in your timing chart, you have to separate them between the ones that can be done while the equipment is running and the ones that cannot.
    2. Shift the internal to external – the more activities that can be done externally, the faster the changeover will be.
    3. Streamline the internal – identify more simple ways to complete internal activities to improve them.
    4. Perform parallel operations – do not wait to perform an activity unless it is strictly necessary for it to wait for a previous one.

5. Reduce ramp-up time – it is also very important to identify activities that can affect the ramp up times and prepare action plans to improve them. Changing the line fast is not good enough without a vertical ramp up time, meaning that as soon as the changeover is done and the startup button is pressed, the machine will start operating without any stops.

- **Step 5 Plan the improvements:** The key outcome of this step is to capture all the improvements (organization, methods, techniques, equipment, etc) with identified owners and completion plans.

IMPROVE

During the improve step of the DMAIC approach ideas and solutions are put to work. Few ideas or opportunities are so good that all are an instant success. As part of the six sigma approach there must be checks to assure that the desired results are being achieved. Some experiments and trials may be required in order to find the best solution. When making trials and experiments it is important that all project associates understand that these are trials and really are part of the six sigma approach

- **Step 6 Implement the improvements:** The key outcome of this step is to implement the improvements identify in the previous step. Make sure to conduct a risk assessment before any implementation of improvements, utilize the required processes to validate a change in the equipment and capture the learning via Kaizens.
- **Step 7 Check results:** The key outcome of this step is to develop a changeover critique form, for the mechanics to log in the time it took to change each machine. This critique form will serve to check the outcome of the action plan and its impact to the overall changeover results. It also validates the impact of the improvements made.

CONTROL

Many people believe the best performance you can ever get from a process is at the very beginning. Over time there is expectancy that slowly things will get a little worse until finally it is time for another major effort towards improvement. Contrasted with this I recommend the Kaizen approach that seeks to make everything incrementally better on a continuous basis. The sum of all these incremental improvements can be quite large. As part of the six sigma approach performance tracking mechanisms and measurements are in place to assure, at a minimum, that the gains made in the project are not lost over a period of time. As part of the control step we encourage sharing with others in the organization. With this the six sigma approach really starts to create phenomenal returns, ideas and projects in one part of the organization are translated in a very rapid fashion to implementation in another part of the organization

- **Step 8 Consolidate gains:** The key outcome of this step is to document and update procedures, create standards, and integrated them to current line standards. Results are summarized and reapplication recommendations are made.

RESEARCH RESULTS

The objective of this project was to reduce the changeover time of Line X to 57 minutes during a three month time frame. This represents a 25% changeover time reduction from the current 77 minutes it takes from the moment the filler stops to the moment were it starts again after all the machines are changed for the next batch. As it can be observed, Figure 2 represents the before state, and Figure 3 shows that the improved average changeover time of 46 minutes exceeding our initial objective.

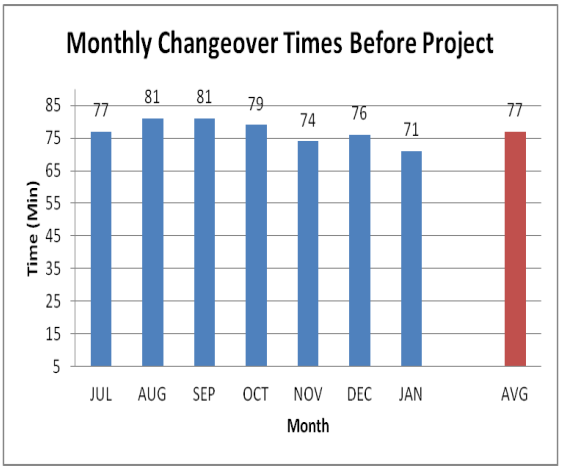

Figure 2
Average Monthly Changeover Times Before Project

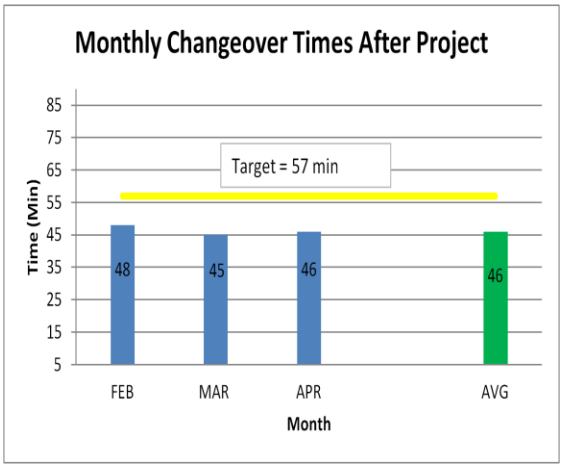

Figure 3
Average Monthly Changeover Times After Project

In order to achieve these results, all key outcomes for each one of the eight steps were completed on time and efficiently. The results of each one of these outcomes are discussed below:

Step 1 – For this step, the team project charter was completed. This one page document included the purpose of the project, background, business need, success criteria, and team members. The document was signed by each one of the team members and the Packing Manager.

Step 2 – For this step a changeover was observed in the line, and a time chart was developed. It was also noticed that there was no specific order developed for the changeover. Each one of the three maintenance mechanics started with a random equipment. Figure 4 lists all equipments, and the time it took to change each one of them.

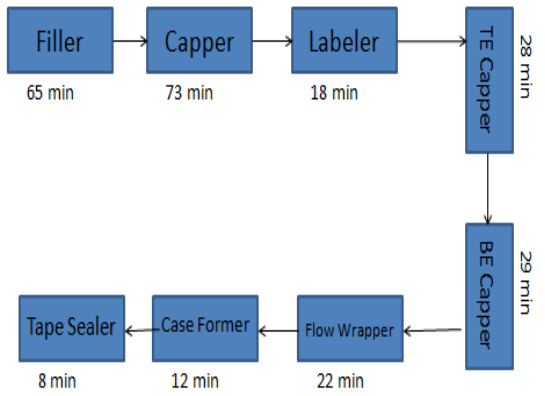

Figure 4
Observed Time Chart

Step 3 – For this step the equipments CBA's (Current Best Approach) were created. In order to complete this several meeting and hands on workshops were held with the three line leaders in order to optimize all steps and create and identified the centerlines to aid the equipment changeover. Figure 4 shows the proposed time chart after all CBA's were completed and tested.

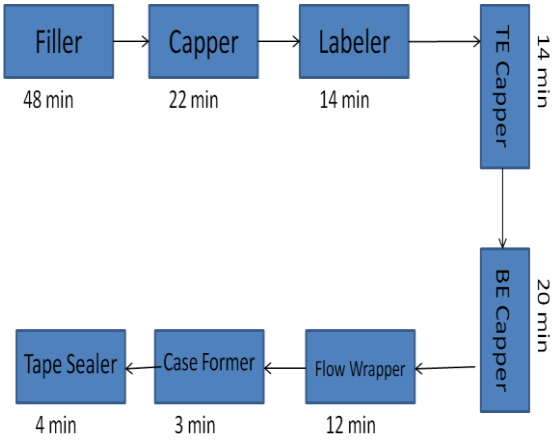

Figure 5
Proposed Time Chart

Step – 4 For this step several activities were shift from internal to external for example:

- Have the necessary change parts close to the machine before the changeover
- Have the fillers equipment already received from the washroom and verified
- Print the centerlines and have CBA's on hand

- Stop filling the hopper with material
- Group leader should have a changeover plan and discuss it with his crew.
- Print out changeover critique

Since it was identified in step 2 that there was no specific order created, in this step a formal process flow was implemented. If you observed the proposed time chart in Figure 4. You will notice that the equipment that consumes the most time is the filler with 48 minutes, however one of the process improvements proposed in this step has two mechanics changing the filler, one on the front side and one in the backside, and this reduced the filler time to 36 minutes. Also the tape sealer and case former were identified to be changed after the line started, since the time it takes the product from when it is filled to when is packed in cases is more than the 4 minutes required to change the tape sealer and case former by two maintenance mechanics. Refer to Figure 5 for the proposed process flow.

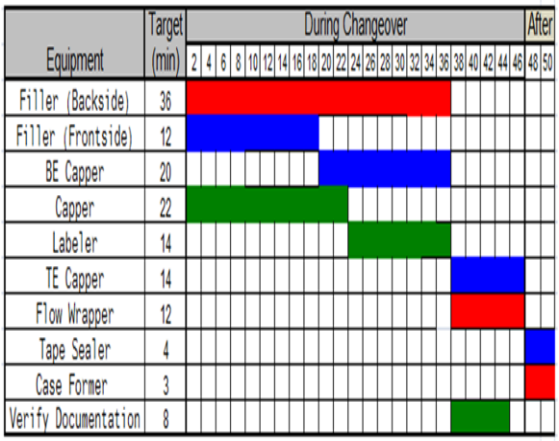

FIGURE 6
Proposed Process Flow

Step 5 – For this step several meetings were held with the team in order to discuss ideas and plan some improvement identified during our workshops and observations in step 2. Table 1 lists some of the improvements identified.

Table 1
Identified Improvements

Machine	Identified Improvements
Filler	Misaligned nozzles and rotary valves
Filler	Unadjusted pistons and clamps
Filler	Actuators are not fixed
Filler	Incorrect screws
Filler	Hoses are different size
Personnel	Manual labor personnel not clear on their tasks during the changeover
All	Tools not accessible or far from the equipment.
BE Capper	Not enough handles to fix star wheel
Capper	Changeover parts on the floor
Filler	Excessive time fixing set screw position
Filler	Nozzle mounting and dismounting time
Filler	Pumps necks are not standard
Capper	Not all products recipes created in HMI
Filler	Hopper moves while changing over
Filler	Hoses are not standard
Capper	Bended chucks pins
Capper	Center guide is too difficult to remove
Capper	Pumps Hopper tilted
Labeler	Head height adjustment is manual
Labeler	Too many different sponges format
Labeler	Not all recipes created in HMI
Filler	Bottle clamp adjustment is too long

Step 6 – In this step the improvements identified in step 5 were implemented.

Step 7 – In this step the changeover critique was completed. This changeover critique serves as a planning tool, as well as a tool to record the actual changeover times and key learning from each one of them. It was developed so each maintenance mechanic can see the equipments that are responsible to change, the target times (developed in the CBA's) and an opportunity to comment on gaps if targets are not met. Please refer to Figure 4 for a changeover critique sample.

Step 8 – For this step several standards were developed as consequence of the learning's of this research, and to close the loop on reapplication opportunities.

CONCLUSION

The use of the company's Work Process Improvement Tool to the Rapid Changeover proved to be very efficient. Not only the changeovers are faster, but are more efficient as well. The data gathered from the change over critiques show that the improvement has been consistent and more than 80% of them are being completed on the new 46 minutes target.

Since we successfully showed that the eight WPI steps can be grouped into the DMAIC Methodology, it was also confirmed that to make any process improvement, it is very important to define the process, measure it, analyze it, implement the improvements and check them. That was the key to our success.

FUTURE PROJECTS

Now that we have improved the PR Loss of packing line X by 4% due to the improvements in changeover time, the next step will be to improve the Process Reliability of the line by reducing minor stops. A minor stop is defined as any stop the line encounters that is not a planned activity (changeover, maintenance, trainings). The used to monitor minor stops is MTBF (Mean Time Between Failures) which is the Total Schedule Time of the Line on a given day divided by the number of minor stops during that period. Currently Line's X MTBF is 14 minutes, which means that every 14 minutes the line has an unplanned stop. The target for a future project is to reduce minor stops to achieve an MTBF of at least 60 minutes.

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