Downtime Reduction Driven by Evaluation of Material Unavailability

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Abstract *— In the manufacturing & life-sciences industry, increased competition has forced a cost-reduction philosophy in what was once a highly profitable business. Manufacturers now need to maintain or improve time to market and quality while keeping low costs. For this reason, manufacturing firms are now focusing on improving their processes to reduce sources of waste, including the waste of downtime in manufacturing processes. When a manufacturing process stops for an unplanned event it creates downtime. It is particularly important to define the difference between downtime and small process interruptions. For this design project, we define downtime as any unplanned stop that is five minutes or longer. For most manufacturers downtime is the single largest source of lost production time. It receives a high level of attention if productivity is affected due to material unavailability, especially when they estimate their downtime or manually record downtimes for each occurrence. This paper presents the process improvement using the DMAIC approach. DMAIC proved to be the most preferred technique for the defect identification and process improvement by use of various tools. As a result, the efficiency of the process will increase by the reduction of downtime up to 20%.*

Key Terms *— Downtime, DMAIC, Lean Manufacturing, Six Sigma.*

INTRODUCTION

When the manufacturing equipment is not running it is referred to as "downtime". Downtime can either be planned (no work, nighttime, etc.) or unplanned (material unavailability, mechanical breakdowns, etc.). Sometimes the cause for a given downtime may be explained by the downtime pattern if it is distinctive. Or the cause of the downtime may by a perception in the minds of the operational employees.

If your manufacturing process includes multiple pieces of equipment or material (such as in a packaging line) it is very important to focus attention on the constraints of the process. Focusing improvement efforts on the constraint ensures optimal use of resources and is the most direct route to improved productivity and profitability.

The latest best practice for reducing downtime is Total Productive Maintenance (TPM). TPM emphasizes proactive and preventive maintenance to maximize the operational efficiency of equipment. It eliminates the distinction between the roles of production and maintenance by placing a strong emphasis on empowering operators to maintain their equipment. TPM include the following elements:

- 5S
- Autonomous Maintenance
- Planned Maintenance
- Quality Integration
- Focused Improvement
- New Equipment Management
- Training
- Education
- Safety

Implementing TPM is a substantial task that involves high levels of support from executive levels of an organization.

COMPANY BACKGROUND

Medical Devices Manufacturing Facility in Puerto Rico which is one of the world's largest medical technology company, offering an unprecedented breadth and depth of innovative therapies to fulfill our Mission of alleviating pain, restoring health, and extending life. It has three restorative therapies group which includes: Neuromodulation, Spine, and Surgical Technologies.

The purpose of this project is to reduce 20% of downtime in one of the production line of a Surgical Technology plant due to material unavailability.

OBJECTIVES AND CONTRIBUTIONS

The reduction of downtime has many objectives. These objectives include the reduction of the following wastes of time:

- When kits are not ready.
- Extra transactions to move material back and forth (transportation) to and from the warehouse (physical movement and on the system).
- Material shortages when the kits are not accurate, making the lines wait.
- Reconciliation process (over-processing) is required (burden to the Coordinators and the MHs).
- No flexibility to move from one kits to another if it is not ready.

Certainly the main contribution of the reduction of downtime is economic. It provides:

- Less cycle time of product.
- Major output of product.

LITERATURE REVIEW

In today's global business environment, maximizing efficiency and utilization, while minimizing downtime in production are critical to success. Continuous improvement techniques, such as Six Sigma, Lean Manufacturing, Lean Sigma and TQM {total quality management) are key to achieving them in a robust and structured manner [1].

General Manager for Europe and the Middle East, Thomas Hinninger cites Amcor, one of the world's top global packaging company, which has been using Citect'sAmpU MES to gather real-time data from its automation systems, and to provide validation, data storage, analysis and reporting. Amcor's focus was on OEE (overall equipment effectiveness) as its KPI (Key Performance Indicator) to improve productivity, because the company links it directly to revenue and cost containment. Amcor has achieved 8% OEE improvement in six months, with what it describes as a direct impact on bottom line. Behind that, however, are equally important KPIs that have to do with reducing disruption to smooth production flows caused, for example, by unplanned equipment breakdowns, planned maintenance, product changeovers or run planned operational delays which results in downtime [1].

For this reason, the production improvement initiatives should start with manufacturers understanding their processes and consequently the likely causes, duration, frequency and impact of downtime.

Whether you are a buyer, a technician or a manager, immediately consider lean maintenance reliability methodologies to preserve uptime for the systems, machine tools, equipment and materials you have and those you will acquire. It will increase your competitiveness by reducing the cost of doing business. The cost of unscheduled downtime in lean manufacturing environments, without excessive inventory buffers, is five to thirty times what it is in other manufacturing environments because it results directly and immediately in lost opportunity, failed shipping schedules and lost sales [2]. It results directly and immediately in lost opportunity, failed shipping schedules and lost sales. Eliminating or reducing machine downtime and unscheduled maintenance, some of the largest expenses for any manufacture require preventive maintenance often confused with routine maintenance. While neither are new concepts, true preventive maintenance bears repeating in the context of lean manufacturing and related machine or material availability and waste reduction.

When Howard Cooper work for John Deere in the '70s, long before become a consultant on maintenance reliability to other companies. He knew the precise hourly costs of downtime and tried to reduce it whenever He could. In lean world, the cost of downtime is 10-20 times higher [2]. Lean methods can help companies become more prices competitive and increase their market share. The answer to increasing the reliability and uptime of equipment used in lean manufacturing environments can be derived from Six Sigma's Y=f(x) analysis and DMAIC. The Six Sigma-based lean maintenance models give manufacturers an effective way to view the whole concept of true preventive maintenance [2].

John Deere used this SS Problem/Cause thinking, Y=f(x), and five years of maintenance-log information to determine the seven root causes of most unscheduled downtime. Further, Six Sigma's DMAIC helped to determine ways to eliminate or protect against each root cause. Howard Cooper as a consultant to other companies using these methodologies to eliminate these root causes in many facilities, resulting in a 70-92% reduction of unscheduled downtime.

As John Deere, the DMAIC model helped to Howard Cooper to reduce unscheduled downtime by almost 80% in just over two years. Eliminating stressors like heat, vibration, dirt build-up, oxidation, hydraulic contamination, power surges, etc., increasing the mean time between failures, prolonged reliability, and increased machine availability and uptime. Since then, the lean maintenance reliability method has been further developed with exact means for protecting, or hardening hundreds of different machine and system types making it possible to implementing plant wide solutions in as little as 30 to 60 days. Some frequent results include [2]:

- Reduced mechanical downtime by 50% permanently.
- Reduced hydraulic systems downtime by 80%.
- Reduced electronic systems downtime by 92%.

As product lines and process technologies mature, management attempts to modify processes in order to gain necessary efficiencies. Answers to four questions help to determine planning and forecasting [3]:

- How can I make my process more efficient or better utilize my resources?
- How can I reduce maintenance costs?
- How can I better prepare for future process modifications and expansions?
- How can I improve the security of my facility and the safety of the employees within?

We may be able achieve the goals mentioned in above paragraphs, or even better results if you manage lean manufacturing and six sigma DMAIC’s methodology in the correct manner.

METHODOLOGY

In order to achieve the proposed objectives, this section provides an overview of procedure and methodology that will be applied in the design project.

Lean manufacturing is a business model and collection of tactical methods that emphasize eliminating non-value added activities (waste) while delivering quality products on time at least cost with greater efficiency. The objective of the project is reduction of downtime. Downtime is a waste associated with waiting. Basically this project is a lean-six sigma project, The Lean Six Sigma methodology views lean manufacturing, which addresses process flow and waste issues, and Six Sigma, with its focus on variation and design.

DMAIC is the methodology proposed to drive the project, six improvement strategies coming from Six Sigma principles. Six sigma is a methodology that has five phases which are: Define, Measure, Analyze, Improvement and Control.

- Define: State the problem, specify the customer set, identify the goals, and outline the target process.
- Measure: Decide what parameters need to be quantified, work out the best way to measure them, collect the necessary data, and carry out the measurements by experiment.

- Analyze: Identify gaps between actual and goal performance, determine causes of those gaps, determine how process inputs affect outputs, and rank improvement opportunities.
- Improve: Devise potential solutions, identify solutions that are easiest to implement, test hypothetical solutions, and implement actual improvements.
- Control: Generate a detailed solution monitoring plan, observe implemented improvements for success, update plan records on a regular basis, and maintain a workable employee training routine.

DMAIC is a very powerful process but the old approach relied on ‘left brain’ statistical thinking and methods for analyzing problems, neglecting the more ‘right brain’ intuitive solutions. Maybe the more traditional methods were suited to manufacturing and operations management, but, although still appropriate for the service and public sector, they are favored less well than the more ‘up beat’ and attractive applications of organization development [4].

Results and Discussion

The main purpose of the define phase is the problem statement and the project goals. For this reason is important the creation of a project charter. The project charter illustrates the following:

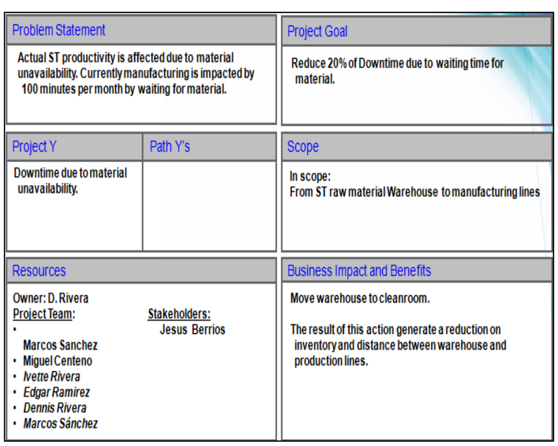

Figure 1
Project Chart

The actual ST productivity is affected by different reasons. These reasons include:

- Waiting for materials
- Not alcohol available
- Few blades left by operator
- Equipment issue
- Urania issue
- Lost equipment
- Others

In the measure phase the data of three months was collected and plotted in a pareto chart. The following pareto chart in Figure 2 represents the reasons of the material unavailability and the quantity of downtime in minutes for each reason.

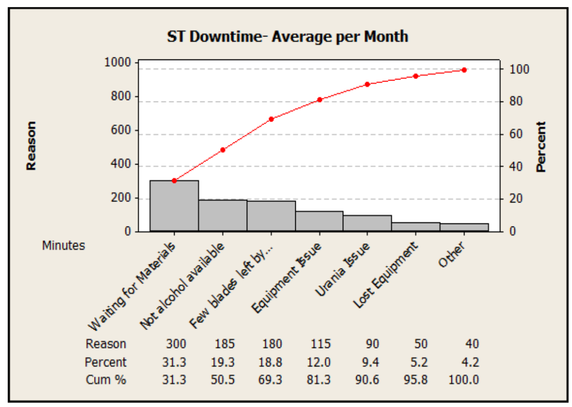

Figure 2
Pareto Chart

As shown in Figure 2 the major offender is material unavailability. Currently, manufacturing is impacted by 100 minutes per month by waiting for material.

The following cause and effect diagram in Figure 3 was utilized to obtain more data about the major offender.

As part of measure phase the actual material flow is drawn and shown in Figure 4. That was used to analyze if some change can be applied to improve the process. The kitting time on this route is 2 hours. These two hours are from receiving area to the production line.

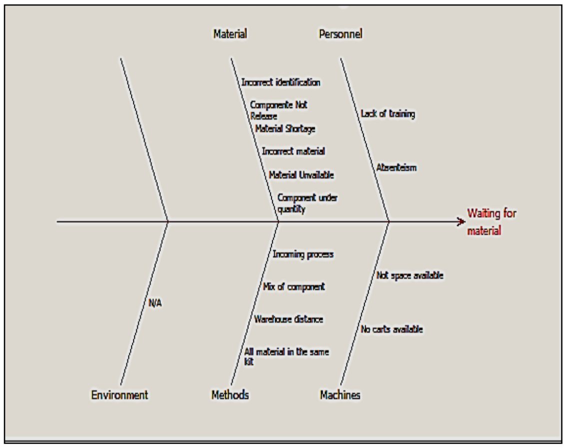

Figure 3
Cause and Effect Diagram

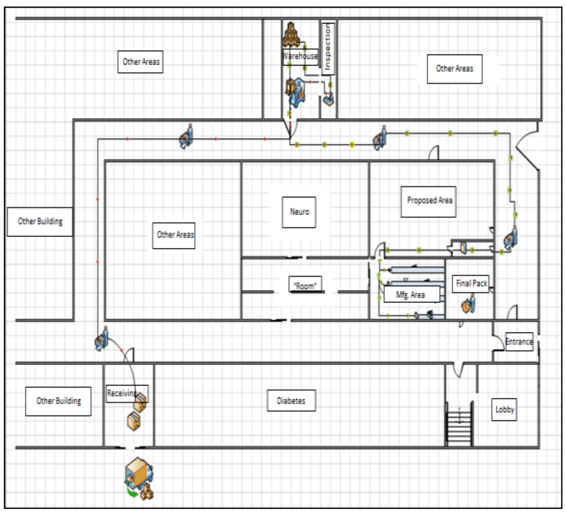

Figure 4
Current Material Flow Diagram

At analyze phase the following material flow diagram was proposed:

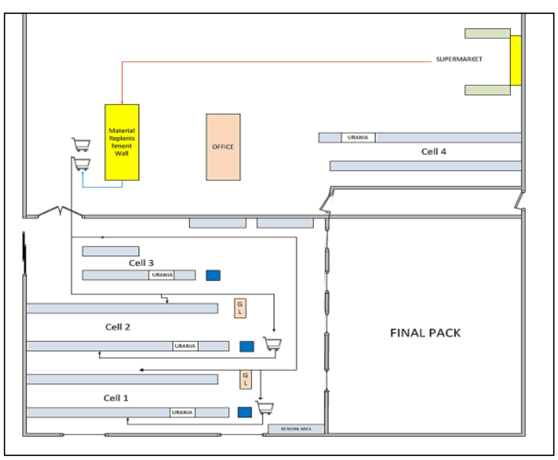

Figure 5
Proposed Material Flow Diagram

In the actual manufacturing push system the production was based on a projected production plan, where the information flows from management to the market. Actually to start the Work Orders in ST manufacturing area the MMT's needed to complete the Kits for this activities take 2 hours to complete. The Waiting time for components and materials to do the kits is the major offender impacting the lead time. The kits are making without specific quantity during the process, if manufacture has a material short we need to change the lot and the quantity of changeover increases. Actually the distance of the Warehouse and Transportation affected the lead time.

The proposed manufacturing pull system is based on actual daily demand, where the information flows from market to management in a direction opposite to that in traditional (push) systems. Pull system with kanban signals. The new proposal material flow diagram in Figure 5 consist in a supermarket with multiples bin system kanban, close to the line, will reduce the material replenishment cycle time to 10 minutes or less.

The warehouse work load reduced by **50%** allowing more interaction with production lines. Also "over processing" waste is reduced by simplifying system flexible allowing replenishing each station separately, shorts setups and changeovers.

In the improve phase basically the new design includes:

- Warehouse in ST area.
- Material on line all time.
- Activities like counting eliminated
- Warehouse work load reduced by 50% allowing more interaction with production lines.
- Over processing waste reduced by simplifying system.
- Flexible system allowing replenishing each station separately.
- Shorts setups and changeovers.
- Some next steps in the improve phase include:

- Logistic design at development stage.
- Join physical material replenishment design with line design process.
- Auto-consumption will be used.
- Visual management to provide a report of material per inventory location (station).
- Stop & fix to provide means to flag when more than one lot of the same component is at the same location.

Besides a new components are included. The following Figure 6 will show the new components per work station.

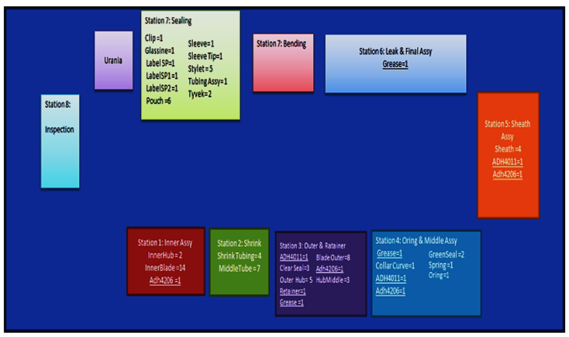

Figure 6
Components per Work Station

When the improvement phase was implemented we obtained a new pareto chart. The pareto chart in Figure 7and the comparative chart in Figure 8 had shown the reduction in downtime due to waiting for material. Now, as shown in Figure 7 the major offender is not the waiting time for materials and the others offenders can be work in a new project to maximize the process efficiency.

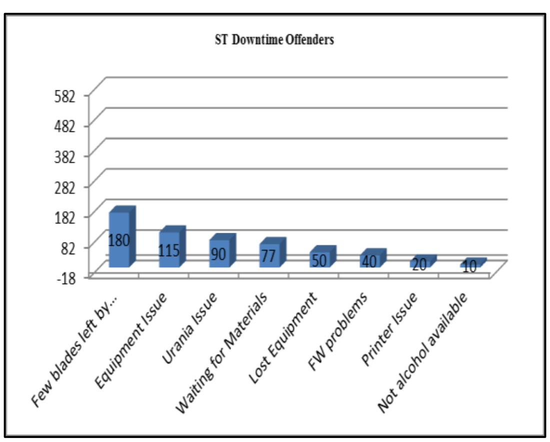

Figure 7
Pareto Chart (After)

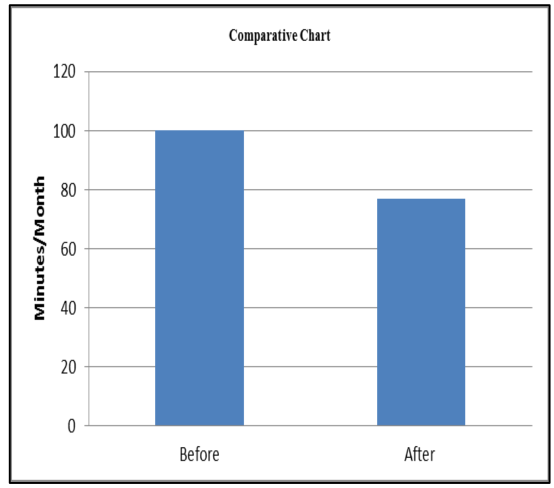

Figure 8
Comparative Chart

In control phase is important to generate a detailed solution monitoring plan. This plan includes instructions, standardization and these instructions are showed in the Figure 9 and Figure 10.

Material Handler (Supermarket) Standard Work	
1	In the Stock Endo Manufacturing area power up computers along the SAP & Factory Works systems.
2	Verify the wall for empty bins to replenish.
3	Verify plan per part in order to replenish empty bins taken from the wall.
4	If there is no material available to replenish empty bins, put the bin in the wall labeled as "Not Available Component for Replenishment".
5	Put the bin located in the ST Inventory Endo area in the rack, matching the green label with the red label.
6	Verify Heijunka in system in order to initiate W/O.
7	Bring materials in pass thru delivered by the Shipping and Receiving clerk.
8	Separate materials received according to the plan per part. Make sure to enter the locations in the "Stock Endo Manufacturing" area.
9	If any additional material is needed in the area, create a reservation in JDE system.
10	Repeat all tasks mentioned before.

Figure 9
Material Handler (Supermarket) Standard Work

Material Handler (Water Spider) Standard Work	
1	Upload procedures & Factory Works in the workstation before shift starts.
2	Supply materials to all the cell lines.
3	Pick up W/O to prepare in the "W/O Ready for Generate" area.
4	Verify Heijunka board to identify what is currently produced in manufacturing area, and identify what comes next.
5	Create lot in Factory Works & print corresponding labels.
6	Prepare material replenishments cart from the ST Inventory Endo wall. (Refer to ENG 0170, 0171, 0172 or 0173 for more info.
7	Supply material to all the work station in the cell lines.
8	Patrol the workstation in the manufacturing cell.
9	Cut shrink tubing.
10	Take shrink tubing and more to supermarket.
11	Take the material during changeover.
12	If the Andon call sounds and the signal is yellow or green, go directly to the manufacturing cell and turn off the signal. Follow escalation process afterwards.
13	Assure there are enough lots to manufacture for the next shift.
14	Return material to the ST Endo wall and identify it. Make proper adjustments in the system as well.
15	Repeat steps mentioned before.

Figure 10

Material Handler (Water Spider) Standard Work

In addition to the previous instructions a control plan is included to maintain a downtime record. This monitoring plan is exactly as the Figure 10:

Project Owner: Danny Rivera — Origination Date: 14-OCT-14 — Frequency: Every 6 months
Process Owner: Marcos Sanchez — Last Updated: 14-JAN-15 — Next Audit Date: 14-APR-15

Y	X	Specification	Capability/Date	Documentation	Monitoring	Prevention	Reaction Plan
Downtime due to material unavailability.			100min per month/14-OCT-14	Hour by hour document template.			
Downtime due to material unavailability.			77min per month/14-JAN-15	Hour by hour document template.	Daily downtime monitored Tier 1 & Tier 2	Estimated route/ schedule for Material Replenishment.	Escalation process using red cards system in Tier meetings.
	Material flow from push to pull system.			Material Replenishment. Standard Works.	Plan per part review. Every 6 months & Lean scored card.	Two bin System and established route to water spider and MTM.	

Figure 11
Control Plan

CONCLUSIONS

At the end of this design project the downtime reduction was 23%. It means that the reduction was 23 minutes per month. Production was increased by seven units per month. In addition to reduction of downtime, the project results in some additional savings.

An example can be the reduction of personal. One material handler per shift was reduced in the process. This material handler was reduced because the new layout consists in placing the material close to the manufacturing line. For this reason, at start of the project, the material took 2 hours from the receiving to the preparation of the kit and now the material only takes 10 minutes from the supermarket directly to the line because the kit was eliminated. Besides of reduction in headcount, a new space into the warehouse was left. This space was utilized to other needs, including the material of other processes.

Also, the conversion of push system to pull systems helped to decrease the material on inventory. In addition it helped to maintain the control of material and reducing wastes produced by forgetting of the employees, the excess of material needed and many other reasons.

Another contribution of the new area of Supermarket is that the area is close to the process and allows maintaining the control of employees because all the employees are close to the manufacturing line and the area of supervision is smaller.

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