Maintenance Cost Reduction in Facilities and Utilities Areas

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Abstract *– Maintenance and repair spending is a normal and expected cost of facility ownership. However, the cost can be minimized through an aggressive facility management program and the use of applicable diagnostic tools. Costs of parts consumption and preventive maintenance activities were evaluated for Mylan LLC, Caguas Site. These costs were accounted for $59,700 in utilities, facilities and environmental areas. The voice of customer requested reduce costs of spare parts consumption in the preventive maintenance activities, preventive maintenance (PM) frequency rationalization and eliminate non-value added (NVA) tasks in preventive maintenance activities. DMAIC approach methodology was used to reduce the maintenance costs. Fishbone and others Root Cause Problems Tools were used to determine what the possible cause of the highest costs of parts consumption, redundant frequency of preventive maintenance activities and tasks with no value added. Method, equipment and materials were the most probable causes. Improvements in the procedures and forms used to perform the preventive maintenance as well as the rationalization in the frequency of the tasks using the ANSI/ASHRAE/ACCA Standard 180-2012 "Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems" as a guideline for frequency assignment were actions implemented to reduce the maintenance costs [1].*

Key Terms *— DMAIC, Highest Costs, PM, Reduction.*

PROJECT STATEMENT

Preventive maintenance (PM) is applied to most mechanical equipment, utilities, facilities or environmental areas in pharmaceutical or biotechnological industries [2]. It is important to identify the potential failure in equipment, utilities, facilities or environmental areas and define the intervention time for preventive action to take place before the functional failure happens. There is a necessity of the companies to keep the balance between their operations and the dedication of resources for maintenance. It makes the constant evaluation of the programs and executions. For this reason, Mylan, Caguas on 2017 evaluated the costs associated to maintenance of utilities, facilities and environmental areas as well the preventive maintenance program. It was determined that these costs are excessive and the process to complete the PM activities is long, repetitive and no rationalization in the PM frequency was considered. Therefore, non-value-added tasks are included to the PM activities.

Research Description

To evaluate the maintenance costs, an evaluation of the costs by parts was performed. First, a query to find the high costs, then the PM associated to contractors was completed. The purpose of evaluating the PM associated to contractors was looking for activities of valued added that could be performed as Mylan personnel instead of external contractors, therefore, savings maintenance costs. The evaluation reflected that the cost of parts consumption for PM activities during 2017 accounted for $59,700. The cost associated to PM tasks associated to external contractors was $62,963. In addition, the frequencies assigned to the PM tasks were evaluated. It was observed that different frequencies and tasks were assigned to the similar type of utility, facility or tasks related to environmental area. This was discussed during a Gemba exercise with the mechanical personnel that are the responsible to execute the tasks. During this Gemba it was observed that the frequencies were randomly assigned and no guidelines or Standard Operating Procedures were used to assign these frequencies.

Research Objectives

The objectives were defined based on a requirement of the plant to improve performance and be more reliable. The following are the objectives of this research work:

- Obtain a total cost reduction between 15% to 20% per year;
- Reduce the cost of spare parts consumption in PM activities by 15% to 20% per year.
- Rationalize the PM tasks.
- Eliminated non- value-added tasks in the PM activities.

Research Contributions

The implementation of improvements in the Mylan PM program will contribute to reduce the maintenance costs. These improvements resulting in earnings for the company and will provide a better and efficient workflow. Thirty-eight percent (38%) of PM tasks (20 of 53 tasks) will be modified to reduce their frequencies. A total parts savings of approximately $10,200 per year (17% of parts cost reduction vs 2017). Yearly PM work orders reduction of approximately 430 PMs (40% reduction vs 2017) by PM frequency changes, PM consolidation and PM elimination. This represents approximately 320 hours released annually for the mechanics to perform other tasks.

Cost reduction from NVA PMs executed through Contractors Services added to approximately $34,000 per year (54% of evaluated 2017 services). It includes the elimination of the Monthly and Bi-annual PMs service in backups for compressors and modifications to the quarterly PM that was reassigned for in-house execution. These values will be revised upon completion of the project work.

In addition, an important contribution of this project is that it will help to promote a culture of continuous improvement, since it leads the organization to periodically evaluate the maintenance program and avoid inappropriate or obsolete practices or policies.

LITERATURE REVIEW

Manufacturing pharmaceuticals are continuously looking to reduce waste and improve their processes. Mylan, Caguas identified the Maintenance Costs as one of the top offenders in engineering processes on Year 2017. For this project, the customer focused in reduce costs of spare parts consumption in the PM activities, in rationalize the PM frequency and eliminate non-value added (NVA) tasks in PM activities using Lean Manufacturing methodology.

Lean Manufacturing is a systematic methodology applied for continuously improvement that seeks to eliminate waste in a process to improve its productivity. The productivity is a measure of the efficiency of a person, machine, factory, or system in converting inputs into useful outputs. Lean Manufacturing principles were applied to this process to eliminate NVA tasks. The company will create more value for customers with fewer resources. Mylan understands the customer value and focuses its key processes to continuously increase it. For this case, LEAN will be applied to the High Maintenance Costs in a determined period using the Kaizen Methodology. DMAIC methodology will be developed to improve the process and to effort the customer needs.

The Lean Thinking Philosophy was the focal point of this project, for this reason it was observed the current state or process which has waste, variation and rigidity. In this case, the PM current process is mainly performed by Engineering personnel. If a new PM is required for a facility, utilities or environmental area, a PM order is created in a software application named System, Applications and Products (SAP). All PM orders are managed through SAP. Other software used in Mylan to maintain a computer database of information about maintenance operation is Computerized Maintenance Management System

(CMMS). Engineering personnel uses these two (2) tools to manage the PM tasks, schedules and spare parts inventory. Once time the PM is created in SAP, the PM orders can be printed and executed by the mechanics or qualified personnel in the tasks. After the tasks are performed, the PM orders are manually signed and then entered by Engineering personnel in SAP program.

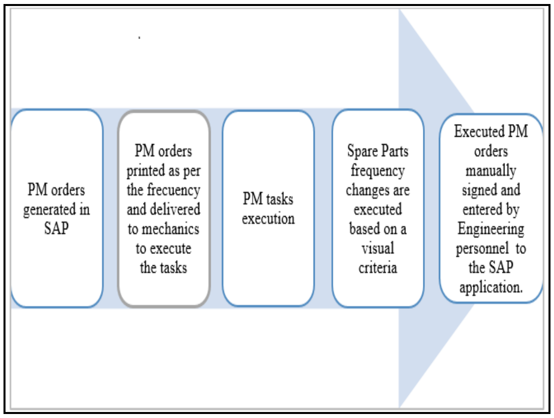

Figure 1
Current Process of the PM Activities

In the current process, it was identified that activities as waste, and the variability or rigidity in the process. These identified activities are the following;

- Some PM instructions include change equipment parts as per mechanics criteria. The criteria are mostly visual, since no standardized or quantified method is included in the PM orders to change the spare parts.
- Some services are performed by external contractors instead of internal resources.
- The frequency of the PM orders is weekly, bi-weekly, monthly, quarterly or annual basis. However, different frequencies and tasks are assigned to the similar type of utility or facility, therefore, suggest no consistency in the manner to assign the frequencies.
- The Standards Operation Procedures (SOPs) related to the PM process does not include instructions or guidelines to assign these frequencies.

After the waste activities were identified, the next step was eliminated the activities using LEAN tools as DMAIC methodology. This project is focused on process flow optimization and addition of customer value activities. The customer value added activities must be improved. These are the activities absolutely required to meet the need of the customer. However, the activities that uses process resources as time, money and people for which the customer is unwilling to pay should be eliminated. These activities are the NVA.

DMAIC approach methodology will be selected to reach the main goal to reduce the maintenance costs. DMAIC is a data-driven quality strategy used to improve processes. It is an integral part of a Six Sigma initiative, but in general can be implemented as a standalone quality improvement procedure or as part of other process improvement initiatives such as Lean Manufacturing [3].

The DMAIC approach will be used in this project as a problem -solving methodology designed to guide the improvement team from Mylan LLC, Caguas Site through a systematic approach, from defining the problem through implementing solutions linked to underlying causes and establishing best practices to make sure the solutions stay in place.

DMAIC is an acronym for the five phases that structure the process. It should be executed in order and the phases are Define, Measure, Analyze, Improve and Control.

During the first phase, the customer, their Critical to Quality (CTQ) issues, the core business process involved, the project boundaries that can stop and start of the process were defined. In this phase, it was also defined the process to be improved by mapping the process flow. The second phase is to measure the performance of the process involved. A data collection plan for the process should be developed. Data is collected from many sources to determine types of defects and metrics. Customer studies results are compared to determine gaps. The third stage analyze the data collected and the process map to determine root causes of defects and opportunities for improvement. Identify gaps between current performance and goal performance. Prioritize opportunities to improve and identify sources of variation. The fourth stage improve the target process by designing creative solutions to fix and prevent problems. Create innovate solutions using technology and discipline. Develop and deploy implementation plan. The last stage Control the improvements to keep the process on the new path. Prevent reverting back to the "old way". This stage promotes continuous improvement for a process, therefore, require the development, documentation and implementation of an ongoing monitoring plan. Finally, institutionalize the improvements through the modification of systems and structures through the training and incentives.

METHODOLOGY

This project will apply the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to improve the maintenance cost, rationalization and eliminate the non-value tasks in Preventive Maintenance activities. The five phases that structure the process in which is based this project are:

- **Define Phase:** The first step consisted in describe the problem, select a project team and stakeholders, and develop goals based on the voice of customer. This stage lays the foundation for the project. The team defines the problem, identifies customers and their requirements, and selects the project team, including members who are directly affected by those issues related to the problem. Project measures, financials and a communication plan are established [4].
- **Measure Phase:** The goal on this phase is to measure the process to determine its current performance and quantify the problem. Measurement systems are identified or developed, validated and improved as required. Baseline performance is established with trustworthy data [4]. Data and information about the current process is collected to understand the problem. The data can be showed in graphical and statistical forms.
- **Analyze Phase:** In this phase the cause (s) of the problem are identified. The critical inputs are identified. Inputs that have a strong relationship with the outputs and root cause are determined [4]. These critical inputs are the drivers of the performance.
- **Improvement Phase:** This phase consists in improve the actual process by designing solutions to fix and prevent problems. Potentially solutions are identified and evaluated, and the process is optimized. The critical inputs that must be controlled are determined. Process capability and project financials are estimated [4].
- **Control Phase:** The main purpose is to control the improvements to keep the process on the new path. This phase promotes continuous improvement for a process, therefore, require the development, documentation and implementation of an ongoing monitoring plan. This is the stage that establishes mistake proof, long term measurement and reaction plans. The team develops standard operating procedures, establishes process capability. Project financials are updated, verified and reported. Ownership and control are transitioned to the process owner, and lessons are documented.

RESULTS AND DISCUSSION

This section presents the problem analysis and improvement results using the Lean Methodology and DMAIC approach.

Define Phase

This project arises from the need to improve the processes of Mylan LLC, Caguas and promote a culture of continuous improvement.

High PM costs in the utilities, facilities and environmental areas were identified as a potential problem to be reduced using Lean Methodology and DMAIC approach.

A multidisciplinary team was selected to work with this project. The team consisted of one (1) project manager, three (3) Engineering Department representatives, one (1) Operational Excellence representative and, one (1) Financial Department representative. The team developed a project charter that presented the process problem in measurable terms, how well the process is performing today (the baseline), and how performance should be after executing the process improvement (the goal). Other activities for the team during the DMAIC measure phase included: collecting data of the current process, focusing on overall time of each step, having meetings to analyze the data, and executing brainstorming activities to identify possible solutions.

The problem statement was defined as High Costs on parts' consumption for PM activities during 2017 for the utilities, facilities and environmental areas. The customers (engineering supervisors and managers that are on charge of the PM program) and their requirements were identified. The voice of customer indicated the need to reduce the costs of spare parts consumption in PM activities, rationalize the PM frequencies, and eliminate NVA tasks in PMs.

The PM current process is mainly performed by Engineering personnel. In the current process, it was identified that the activities have waste, and that there is the variability or rigidity in the process. As example of such activities is that some PM instructions include change in equipment parts as per mechanics criteria. The criteria are mostly visual, since no standardized or quantified method is included in the PM orders to change the spare parts. Some services are performed by external contractors instead of internal resources. The frequency of the PM orders is weekly, bi-weekly, monthly, quarterly or annual basis. However, different frequencies and tasks are assigned to similar type of utility or facility. Therefore, it suggests no consistency in the way frequencies are assigned.

In this stage, project measures, financials and a communication plan were established. The costs on parts' consumption for PM activities during 2017 accounted for $59,700 for the utilities, facilities and environmental areas.

The main goal of this project is to obtain a maintenance cost reduction between 15 to 20% focused on the client voice of reduce costs of spare parts consumption in PM activities, PM frequency rationalization and eliminate NVA tasks in PMs.

Measure Phase

In this stage, the data gathering was obtained from SAP reports. First a query to all PM reports from the years 2015 to 2017 was performed. The query was focused in the PM parts with highest costs. Also, it was focused in the highest contractor's services costs. Then, the inputs and output were identified. To measure the performance of the PM program and quantify the problem, the data was classified, segregated and plotted in different graphs, and pareto charts. A baseline performance was established with trustworthy data.

The first graph obtained was a monthly comparison on parts consumptions. Data obtained by month and the costs of parts consumptions was measured and compared for years 2015, 2016 and 2017. Figure 2, "Monthly Cost Comparison on Parts Consumptions for PMs" presents the information gathered.

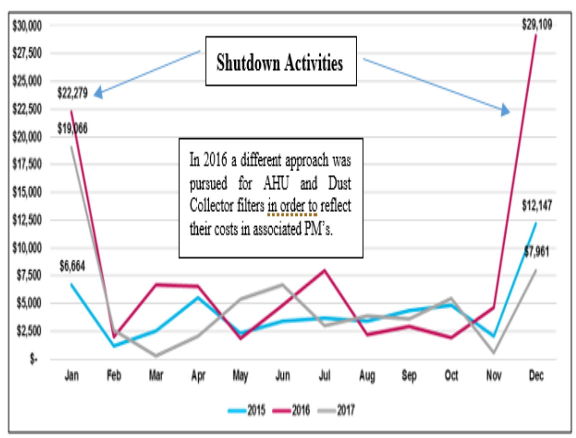

Figure 2

Monthly Cost Comparison on Parts Consumptions for PMs

In 2016 a different approach was pursued for Air Handling Units (AHU) and dust collector filters to reflect their costs in associated PMs. In addition, the outlier data showed during the months for December and January was due the shutdown activities performed during these months. The three

(3) graphs for years 2015, 2016 and 2017 revealed similar behavior, except by the outliers previously described.

After showing similarities in behavior of the monthly costs of the parts consumption for years 2015, 2016, and 2017, it was analyzed the parts consumption for the year 2017. A statistical analysis was generated to evaluate the average, and standard deviation for this data.

The statistical analysis was performed for 10 months and 12 months due the outliers for the January and December months for shutdown activities. The mean for the costs of parts consumption was $5034, 26 for 12 months and $3,338.44 for 10 months. A similar behavior was showed in the median values, with a median of $ 3,742.15 for 12 months, and $3,287.38 for 10 months. Figure 3, “2017 Monthly Cost on parts Consumption for PMs” presents this information.

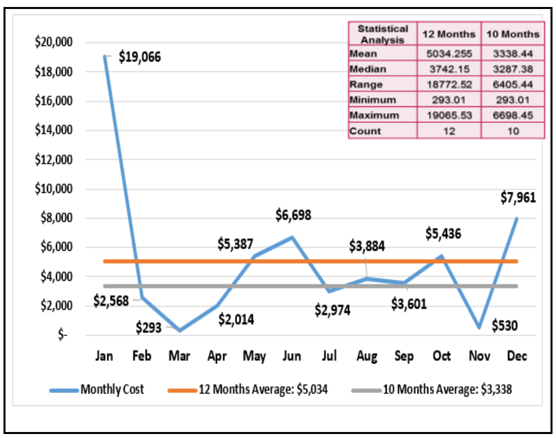

Figure 3
2017 Monthly Cost on Parts Consumption for PMs

Figure 4, “2017 Costs and Distribution by Part Group in PMs” shows the costs obtained for 2017 year re-grouped in categories using a pareto chart. The left vertical axis of the Pareto chart has "cost consumption by part group". Each vertical bar represents the contribution to the total from a given "high cost on part consumption" area. The bars are placed on the graph in rank order, that is the bar at the left has the highest contribution to costs. The parts were distributed and regrouped in ten (10) categories. The first two (2) categories represents the 82.6% of costs consumption for 2017. If the improvements to PM frequencies are performed to these two (2) categories, the cost reduction could be significant.

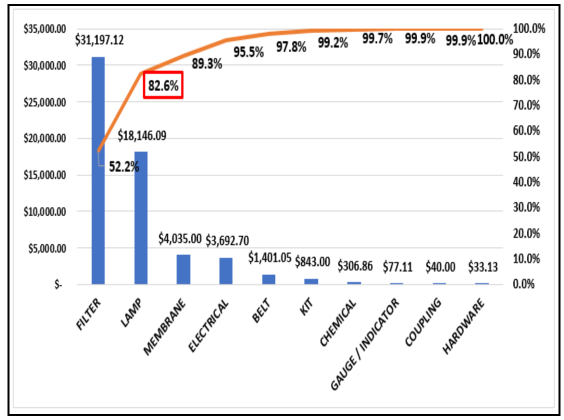

Figure 4
2017 Costs and Distribution by Part Group in PMs

A pie chat was created to visualize the PM costs and distribution by part group in a different perspective. The pie chart portraits the percentage by each category of PMs group. Figure 5, “2017 Pie Chart of Distribution by Part Group in PMs” presents this information.

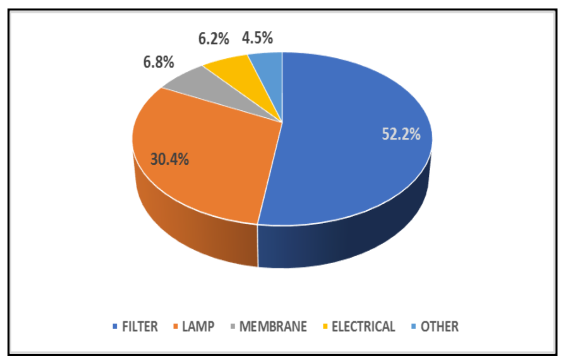

Figure 5
2017 Pie Chart of Distribution by Part Group in PMs

In the pareto chart presented in Figure 6, “2017 Costs and Distribution by Equipment/System Group in PMs”, the data regarding in what system or equipment the categories (filters, lamps, membranes, electrical, others) are located, and how are the costs distributed is portraited.

The left vertical axis of the Pareto chart has "cost consumption by equipment/system group". Each vertical bar represents the contribution to the total from a given "high cost on part consumption" area. The parts were distributed and regrouped in seven (7) categories. These are: compressed air point of use filter (CA POU FLTR), laboratory lamps (LAB LAMP), air handling unit filters (AHU FLTR), reverse osmosis membrane (RO), air lock system (AIR LOCK), dust collector system (DST COLLEC) and OTHERS that represents purified water system (PWS), shower, down flow, safety fire, waste water treatment plant (WWTP), fan and uninterruptable power supply (UPS) equipment/system groups.

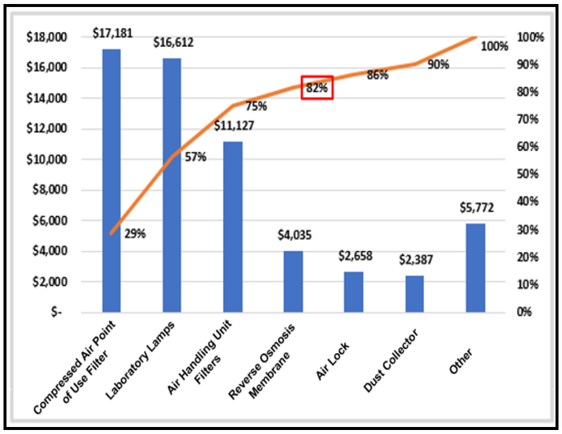

Figure 6

2017 Costs and Distribution by Equipment/System Group in PMs

The previous analysis and information were necessary to review the tasks in the worksheets of the PM, verify their frequencies, and the reason/purpose of the work assignment. This was performed through Gemba and other methods to interview the mechanics.

The percent (%) of PM costs and distribution by equipment/system group is also represented in Figure 7, "2017 Pie Chart Distribution by Equipment / System Group in PMs". This figure demonstrates that the equipment/system group with the highest maintenance costs are; (1) compressed air point of use filter, (2) laboratory lamps, and (3) air handling unit filters. Then, reverse osmosis, air lock systems and dust collectors follow in terms of the highest maintenance costs. The other category that represents PWS, showers, down flow hoods, safety fire, WWTP, fan and UPS equipment/system groups accounts for 10% of total costs in 2017.

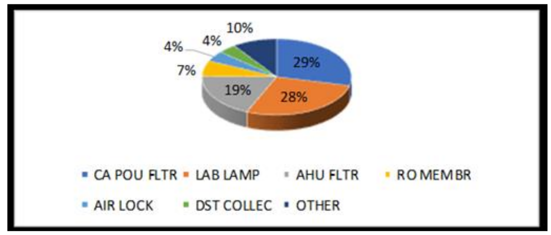

Figure 7

2017 Pie Chart Distribution by Equipment/System Group in PMs

Analyze Phase

In this phase the cause (s) of the problem are identified. Inputs that have a strong relationship with the outputs and root-causes were determined. Fishbone diagram was used to analyze the root causes. During this exercise were evaluated material, method, machine, mother nature, measurement and management. The top offenders of the current process that are identified as equipment, method and materials are represented in Figure 8, "Fishbone Diagram".

For equipment, the design of the equipment was evaluated, and it was noticed that some designs require more maintenance than others depending on the complexity or the validity of the equipment. In addition, there are different configurations with the same equipment group or category, which means, no standardization was applied when the PM tasks were assigned.

For material, it was found that there are not parts/supply agreements or parts/price comparison between suppliers. No evaluation of the parts is performed during the failures, therefore, a root cause analysis to the failures was not performed.

For method evaluation, it was noticed that in the PM Revision/Update Control Form does not exist a reviewer that indicate that the content of the document is complete, correct, accurate and rationale. This form is specific for new PMs or changes in PMs. The form does not provide for specific fields such as PM frequency and parts to be used. There is no a qualified method/measurement to establish a time to replace parts. There are no guidelines for PM structure and content. Instructions are not included in the Standard

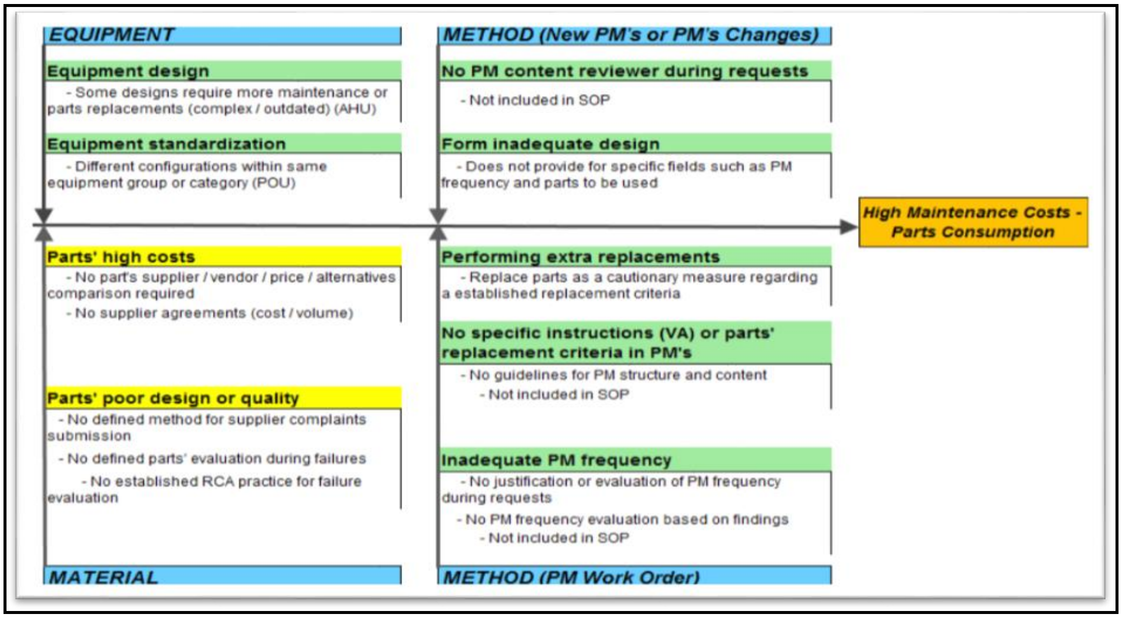

Figure 8
Fishbone Diagram

Operating Procedure. Also, there is no a frequency evaluation based on the findings of the PM orders execution, therefore the PM frequency is inconsistent for the same task within the equipment/system group.

After evaluating the causes of the findings during the Fishbone Diagram exercise, it was determined actions to be taken to correct or prevent these failures. Some of these actions will be explained below:

- **Finding #1 - Inadequate Form Design:** During the evaluation of the Preventive Maintenance Revision/Update Control Form of procedure PR-SOP-ENG-GEN-0001 "Preventive Maintenance Program", it was determined that the form should be reviewed to include necessary PM information fields. PR-SOP-ENG-GEN-0001 "Preventive Maintenance Program" need to be reviewed to provide guidelines when creating and requesting PM tasks.
- **Finding #2 - No Content Reviewer:** During the evaluation of the procedure PR-SOP-ENG-GEN-0001, it was found that the Preventive Maintenance Revision/Update Control Form included in this procedure does not have space neither instruction to perform a review of the content form. The corrective actions were: reviewing the procedure to provide adequate instructions to perform a data review and reviewing the form to include the space where the person certify that perform this action.
- **Finding #3 - No specific instructions or parts' replacement criteria in PMs:** For no specific instructions or parts' replacement criteria in PMs, procedure PR-SOP-ENG-GEN-0001, it was determined that the procedure should be reviewed to include guidelines. In addition, the PM tasks were reviewed, and the indicators of unacceptable conditions were used following as guideline the ANSI/ASHRAE/ACCA Standard 180-2012 [1]. Regarding to perform extra replacements, instructions were provided to the mechanics to perform replacements as per replacement criteria in the PM tasks.
- **Finding #4 - Inadequate PM Frequency:** The ANSI/ASHRAE/ACCA Standard 180-2012 "Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems" was used as a guideline for frequency assignment [1]. The SOP will be reviewed.
- **Finding #5 - Different Configurations within Same Equipment Group or Category:**

Different configurations within same equipment group or category that did not facilitate the frequency change in same group. The PM tasks were separated to provide new PM frequency and to standardize the tasks according the equipment design.

Improvement Phase

This phase consisted in improving the actual process by designing solutions to fix and prevent problems. Particularly, creating innovate solutions using technology and discipline. For this stage, Project Management Fundamentals & Kaizen DMAIC tools were used to develop and deploy an implementation plan. The following actions and their benefits were part of the implementation plan. These actions and benefits included:

- 38% of Preventive Maintenances tasks (20 of 53 tasks) were modified to reduce PM frequencies. This contributed to a total parts' savings of approximately $10,200 per year (17% of parts' cost reduction vs 2017).
- Yearly PM work orders reduction of approximately 430 PMs (40% reduction vs 2017) by PM frequency changes, PM consolidation and PM elimination. This represents approximately 320 hours released annually for the mechanics to perform other tasks.
- Cost reduction from NVA PMs executed through Contractors Services:
  - Approximately $34,000 per year (54% of evaluated 2017 services)
  - Backup compressors Monthly and Bi-annual PMs eliminated and modify quarterly PM to be reassigned for in-house execution.
  - Elimination of other NVA PM activities.
- A form of procedure PR-SOP-ENG-GEN-0001" Preventive Maintenance Program" was revised and placed effective.
- The selected PM task lists was updated with new frequencies, the NVA activities eliminated. Indicators of unacceptable condition as replacement criteria was included in the procedure.

Control Phase

The main purpose of this phase is to control the improvements identified, and thus, keep the process on the new desired path. This phase promotes continuous improvement for a process, therefore, require the development, documentation and implementation of an ongoing monitoring plan. Finally, institutionalize the improvements through the modification of systems and structures through the training and incentives. Some tasks or documents that will be periodically monitored are:

- PM Request Form
- Procedure PR-SOP-ENG-GEN-0001 "Preventive Maintenance Program"
- Personnel Training
- SAP Reports: Finance / PM
- Inventory Control in Stock Room Area

CONCLUSION

Using DMAIC approach it was possible to reduce costs of parts consumption and preventive maintenance activities at Mylan Activities, Caguas Site. After collecting and classifying the data, Lean Manufacturing tools were used to determine what are the possible cause of the highest costs of parts consumption, redundant frequency of preventive maintenance activities, and tasks with no value added. Improvements in the procedures, and forms used to perform the preventive maintenance as well as the rationalization in the frequency of the tasks using the ANSI/ASHRAE/ACCA Standard 180-2012 "Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems" as a guideline for frequency assignment were actions implemented to reduce the maintenance costs [1].

A 38% of PM tasks (20 of 53) were modified to reduce their PM frequencies. A total parts savings of approximately $10,200 per year (17% of parts cost reduction vs 2017) were reached. In addition, yearly PM work orders reduction of approximately 430 PMs (40% reduction vs 2017) by PM frequency changes, PM consolidation, and PM elimination. This represents approximately 320 hours released annually for the mechanics to perform other tasks. Cost reduction from NVA PMs executed through Contractors Services added to approximately $34,000 per year (54% of evaluated 2017 services).

Even though the improvements were successful, and the expectations and goals complied, there are lessons learned, and additional opportunities to improve the Preventive Maintenance program. Some opportunities are to extend PM program improvements for Operations (Manufacturing and Packaging areas), evaluate implementation of supplier agreements/ complaints management, complete a study for gold lamp (UV filtered) lights elimination in the laboratory, and evaluate the installation of compressed air filter indicators in Point of Use's (POU's), to implement replacement criteria.

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