Puerto Rico Water and Sewer Service Calibration Operation Cost Reduction

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Abstract — *For the last few years, the economy of Puerto Rico has been negatively affected, increasing the operational cost of the industries in the Island. In addition, regulatory agencies have been increasing their requirements and conditions that enforce activities to ensure environmental protection for a cleaner, healthier environment, and protect the public health. Companies focus on production efficiencies and often drive attention from inefficiencies in their calibration programs, promote practices that can significantly increase cost and put quality at risk. Under this panorama the calibration department for the* Puerto Rico *Water and Sewer Service Industry determine to look into the process, following managerial concept that combined Lean Manufacturing techniques and Six Sigma strategies. This project has been developed under the Lean Six Sigma principles and using DMAIC five-step approach, in order to identify opportunities to enable the company to reduce overall cost and gain efficiencies and breakthrough the calibration department operation cost.*

Key Terms — *Calibration Operation, DMAIC, Lean Six Sigma, Water and Sewer Service Industry*.

PROJECT STATEMENT

Through the years, the amount of calibration equipment increase significantly due the new regulations and requirements with state and federal agencies. At present, the calibration cost exceeds the $300,000 annually. This situation affects the budgeted cost and the purchase of new calibration equipment. The service industry is looking for a reduction in calibration and maintenance cost; without harming the process, system compliance and following manufacturer recommendations. In order to impact the calibration cost, the instruments subjected to evaluation was the Flow Meters of Cayey Water and Sewer Service Area.

Research Description

This project has been outlined with the purpose of analyze and evaluate the current calibration system to make it reliable, while maintain compliance. Primarily to reduce the calibration and maintenance cost, starting with the Flow Meters in Water Filtration and Sanitary Plants of The Cayey Service Area. This area has 77 flow meters distributed in 14 facilities. Some of the possible causes that increase the high calibration cost include the calibration frequency, installation requirements, equipment diversity and calibration procedure.

Research Objectives

The objectives for this project are:

- Cost reduction;
- Maintain compliance and the reliability of the system;
- Never compromises the disciplines of good metrology in the pursuit of cost reduction.

Research Contributions

With the project implementation, the Cayey Water and Sewer Operational Area will breakthrough cost savings and gain efficiencies by eliminating waste and implementation of process improvements. This assessment may extend other Operational Regions, eventually impacting the Calibration Department through the island and creating a precedent in the service industry.

LITERATURE REVIEW

To guarantee the quality of a product and service, it's necessary to ensure the accuracy and validity of process equipments, delivering reliable measurements within a degree of acceptance. This is performed by the calibration program that established and maintains the equipment calibration frequencies and maintenance in accordance to manufacturer recommendation, following good metrology practices. To achieve a successful calibration, the instrument readings shall be representative of the process; equipment must meet the installation requirements and shall be tested with proper standards.

All equipments within the calibration system are classified in High, Moderate, and Low (noncritical) criticality as follows:

- **High critical**: Instruments that control or monitor regulatory process parameters and calibrated every three months or a minimum of four times per year.
- **Moderately critical**: Instrument that monitors unregulated processes and calibration frequency is every six months.
- **Low critical**: Instruments who not monitored regulated processes and calibrated once a year.
- **Reference instrument**: Instrument used for verification and reference purpose to other instruments.

In addition, equipments found incorrectly installed, have installation failures, and those who are not used for any quality decision making are categorize as reference instruments and do not required calibration.

A key instrument in terms of process indicators are the flow meters. The flow meter is an instrument used to measure the volumetric flow rate of a liquid or gas. Currently, flow meters are classified as high, moderate and low criticality. It depends primarily of their purpose and instrument functionality. Our calibration procedure brings the opportunity to reduce or increase its calibration frequency (increase interval) for those instruments evidencing with historical data shows successful calibration results tolerance for the last three calibrations[1].

In order to meet the proposed objectives, will be used Lean Six Sigma methodology. Lean Six Sigma is a type of method focused on business and process improvement. Lean Six Sigma is based on the combination of the concepts of Lean Manufacturing and Six Sigma principles, using DMAIC strategy [2]. DMAIC project methodology involves and promotes the use of tools for process improvement, reduction in variation and customer satisfaction.

Lean Manufacturing is a philosophy derived from Toyota Production System that maintains a continuous flow of product, eliminate waste and improve customer satisfaction. There are seven types of waste which are in between these: overproduction, excess inventory, waiting, transportation, unnecessary motion, over-processing and defects [3]. As a complement to the philosophy of Lean Manufacturing, Six Sigma methodology pursues the decrease in variation and process improvement. This methodology began in the manufacturing industry and has expanded to other industries such as service, health care and banking [2].

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. The project methodology to be used is DMAIC improvement strategy coming from Six Sigma principles [4]. DMAIC is an acronym that has five phases: Define, Measure, Analyze, Improvement and Control.

- **Define Phase**: This phase consists in defining the scope, goals and project statement. It will use a project charter in order to describe the process and identify the possible opportunities of improvement.
- **Measure Phase**: The objective of this phase is the collection of the key aspects of current process and relevant data. As well as the

identification of potential factors that may affect the process. It will use data collection and detailed process flow diagram. The tools to be use to show visual representations of the current state are graphs, charts, flowcharts and SIPOC diagram.

- **Analyze Phase**: This phase consists on identifying deep causes with the objective of validate them with relevant data. The key components of this phase include cause-effect, root cause and value- non value added analysis. It will use a cause-effect diagram.
- **Improvement Phase:** The objective of this phase is optimizing the current process based on data analysis. The key components for this phase include lean manufacturing tools, optimized process parameter settings and standardized work.
- **Control Phase**: This phase includes designing and documenting the new controls and procedures, in order to hold the gains. Key components to this phase are visual workplaces, periodic audit exercises and training process to monitor the success.

RESULTS AND DISCUSSION

This section presents the problem analysis and improvement results using the Lean Six Sigma Methodology and DMAIC tool.

Define Phase

The calibration and maintenance costs have been increasing through the years, due the increase of equipment quantity since the regulatory agencies have enforced new requirements. At the same time, the operational increasing costs are struggling industry operations. Therefore, the calibration department is looking for new initiatives to reduce the calibration cost and comply efficiently with the rules and regulations of Calibration Program.

The project goal pursues to reduce the calibration and maintenance cost for flow meter equipment of The Cayey Water and Sewer Service Area by 25% of reduction after project completion. The project scope includes the Flow Meters of Cayey Water and Sewer Service Area that are currently in service and has historical data of at least four consecutive calibrations to perform the assessment. Out of service equipment and those with no data available are out of the project scope. This project implementation must not harm the process and system compliance with the regulatory authorities and the installation requirements.

The project team members include the calibration supervisor, technicians and the calibration service area coordinator. The role of the team members consists in recurrent problem discussion, progress meetings and the collection of information related to instruments, equipment, standards, calibration historical data, installation requirements, currently equipment status and calibration plans. The satisfactory completion of this plan, can serves as model for other operational areas. As a guide for team members and managers to see whether the project is conducted in the right direction as proposed and the goals has been reached in time, a Project Charter was performed.

Measure Phase

In order to identify the relation between the suppliers, input product, process, output and customers a SIPOC Diagram was created. The calibration process is described as follows:

- The process begins when the SAP system (business management software) alerts the service coordinator the nearest expiration of the equipments of a facility “X”.
- The coordinator manually generates the calibration and maintenance work orders. The supervisor brings the work orders to the calibration technician.
- The technician visits the facility “X” and performs calibrations using the required calibration standard as per procedure.
- After completion of the calibration execution the technician generates the calibration certificate.

- Then Calibration data is entered in the SAP PM system (SAP module for Preventive Maintenance).
- SAP PM System generates a calibration certificate, which provides evidence of equipment compliance.
- Finally, equipment will start the new calibration cycle.
- The direct customers are the service subscribers and the indirect customers are the calibration department.

The team arbitrarily selected the flow meters among all other equipment as a parameter of interest to perform calibration system process evaluation. Currently at the Cayey Water and Sewer Service Area, comprise of 77 flow meters distributed in 14 facilities. Currently, 73 instruments are in service for a 95% of the total of the equipment as shown in Figure 1. The calibration plan for flow meter will vary according with the technology and criticality ranking of the instrument.

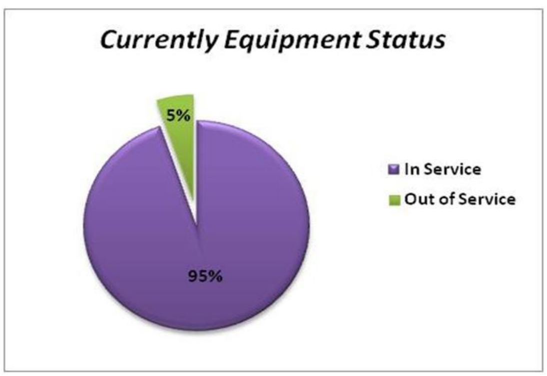

Figure 1
Currently Equipment Status

Of the in service equipment, 10 of these are classify as high critical instrument. These instruments control and monitor a regulatory process and its calibration frequency were defined quarterly (every intervals of 3 months). Other 61 flow meters are classified as a moderately critical instrument that are calibrated biannually (at six-monthly intervals) and only 2 instruments, which are not used to monitor any regulated process, are classified as low non critical instrument that are calibrated annually (every 12 month). The current equipment calibration frequency by quantities is show in the Figure 2.

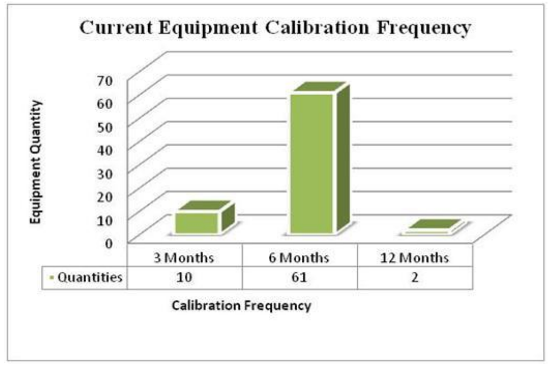

Figure 2
Current Equipment Calibration Frequency

Data of the past calibrations for each of this equipment was collected. This data shows equipments that have been in tolerance in the last calibrations. Figure 3 shows the historical data of the equipment and the corresponding quantities. Equipment with no available data, reference instruments and new equipment that has not been calibrated are represented with a cero number. In turn, equipment with only and last calibration is represented by number one. Equipment classified with the number two, three or four, means the quantity of successful calibrations.

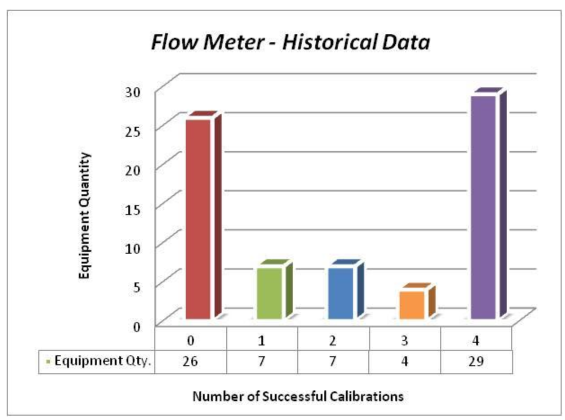

Figure 3
Flow Meter- Historical Data

Figure 4 shows the calibration frequency for these equipments who meets with the four successful calibrations. A 93% of the equipment was classified moderately critical instruments and a 7% was classified as high critical equipment.

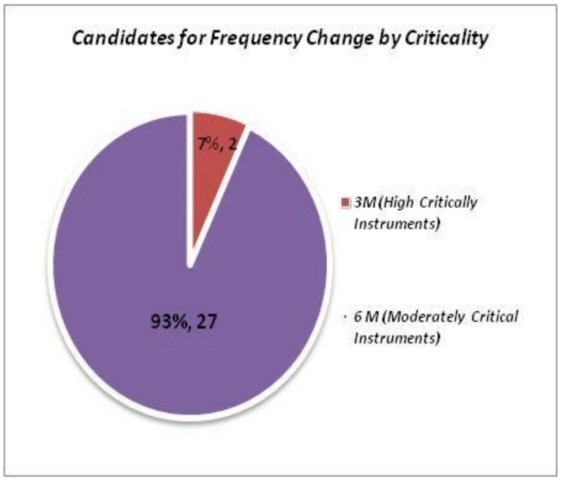

Figure 4
Candidates for frequency Change by Criticality

The following Table 1 shows approximately the calibration and maintenance cost of the last year. Equipment with no historical data available and reference instruments were excluded from the costs analysis. The current calibration cost was performed using an approximately calibration and maintenance cost of $97.50/each and $17.25/each respectively. The calibration company billed the calibrated equipment, not by the hours of service.

Table 1
Last year Calibration and Maintenance Costs

Current Calibration and Maintenance Cost	
Total of Intruments	47
Calibration cost of High Critical Instruments per year	$ 2,346.00
Calibration cost of Moderately Criticality Instruments per year	$ 7,624.50
Calibration cost of Low Critical Instruments per year	$ 195.50
Total Calibration Costs	$ 10,166.00
Maintenance Cost	$ 34.50
Total Annually Current Costs	**$ 10,200.50**

Analyzed Phase

The focus in this phase is about finding opportunities for improvement within the current calibration process. The first step is to analyze all measured data. Then understand all feasible causes that affect calibration costs by performing a Fishbone analysis and set priorities among them discovered causes. As presented in the measure phase, the 95% of flow meter equipment are currently in service as shown in Figure 1. From the Historical data shown in Figure 3, an area of opportunity was seeing for equipment that contained the required historical data in order to perform a calibration frequency change.

According with the calibration manual, instrument with history that show they have been successful calibration results for the last three consecutive calibrations can be consider for a frequently change[1]. The following criterion was used for the frequency analysis:

- **High Critical**: Should have at least year of data or the last four successful calibrations for a frequency change evaluation.
- **Moderately Critical**: Should have an historical data of two years or the last four successful calibrations to be considered for a frequency change evaluation.

It was chosen to use historical data of four successful calibrations instead of the required three consecutive successful calibrations to increase the confidence in the data obtain and provide less risk to the system with the implementation. Following the previous analysis, equipment that complies with the above requirements will be selected for a frequency reduction (interval increment) change. Figure #6 shows the calibration frequency for these equipments who meets with the four successful calibrations. A 93% of the equipment was classified moderately critical instruments and a 7% was classified as high critical equipment.

A cause-effect analysis was performed shown in Figure 5, in order to find these possible causes. The main possible causes identify in the fishbone diagram that affects calibration cost were selected to be evaluated and categorize under the following 4 categories:

- High Impact– Low Difficultly
- High Impact – High Difficult
- Low Impact – Low Difficultly
- Low Impact – High Difficult

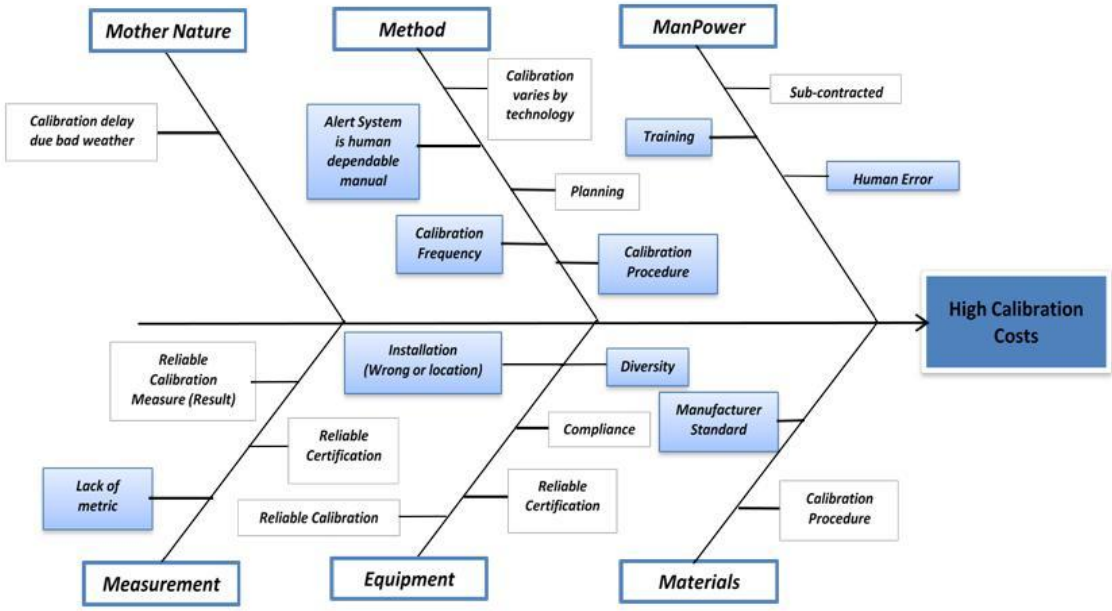

Figure 5
Cause and Effect Diagram

The High / Low Impact factors were defined in terms of the effect productivity and operation cost. As well, the High / Low Difficultly factor were defined in term of the investment cost and time/effort to implement, and quality risk. The Figure 6 shows the analysis performed and the selected causes following the previous approach.

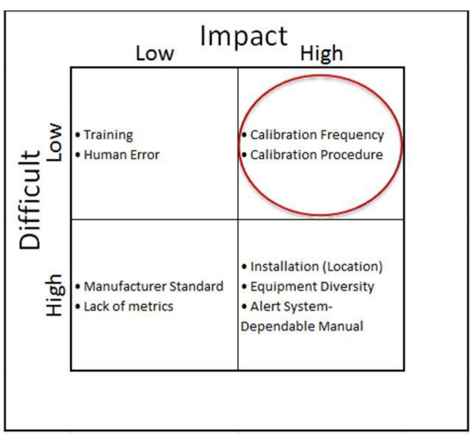

Figure 6
Categorized Analysis

After a discussing with the team members, there were nine primarily aspects selected and categorized as shown in Figure 6. The primarily focus in the selection pursues the initiative that are considered to have low difficulty and provide high impact. Therefore, the calibration frequency and calibration procedure were selected as process causes that can achieve great revenue with minimal investment and less implementation time/effort required.

The calibration procedure is contained in the calibration program manual and was identify as a contributor factor for Over-processing waste. Procedure has the proper instructions to reduce calibration frequencies but does not provide a strategy to take action and perform the changes. Additionally, Motion as a form of waste was identify since the procedure have no indication to support a reliable method of tracking the equipment results. The calibration frequency is determined at the moment the equipment is created in system. This contributor cause is an agency high cost one. Overproduction was identify as waste within the calibration frequency established since the calibration intervals are not optimized during the equipment life cycle.

All equipment evidence of historical data of the last four successful calibrations was evaluated, as shown in measure Figure 4. Further investigation was performed to determine whether equipment installations are in accordance to the manufacturer recommendation. This evaluation allowed the categorization and declaration of equipment with historical data that not meet manufacturer requirements as reference instruments. By the contrary, equipment that was installed in accordance to the manufacturer recommendation was chosen for the allowed a calibration frequently changes as per calibration program procedures.

To ensure the compliance of the agency further investigation was performed to confirm instrument that were found not to be correctly installed were not use to control or monitor regulatory process parameters and only used for verification and reference purpose to other instruments.

The Figure 7 show the evaluation performed for the equipment with historical data and installation analysis.

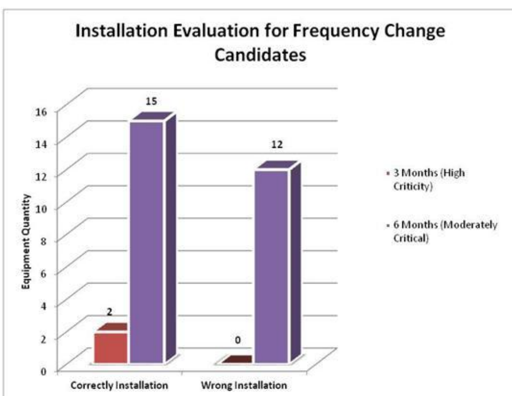

Figure 7
Equipment Evaluation due installation requirements

The screening was achieved after a deep evaluation with the team members, analysis and investigation of the information and the supporting team. From the 27 equipments, 17 had a correct installation and 12 had a wrong installation. A frequency change was performed for these 17 equipments, 2 high critical and 15 moderately critical instruments, from high and moderate criticality to low criticality frequency. Therefore, the 12 equipment with a wrong installation was declared as a reference instrument following the requirements of the calibration program manual.

Improvement Phase

Figure 8 shows the final determination of these instruments after the plan implementation.

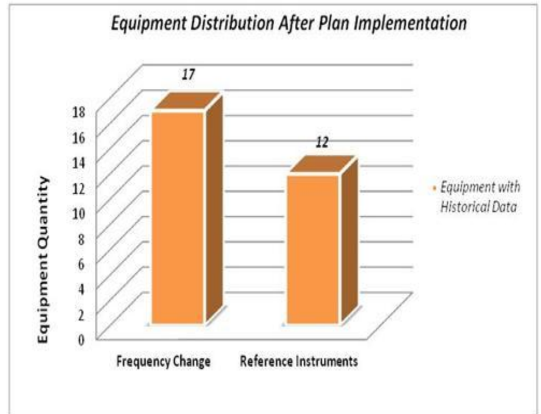

Figure 8
Equipment Distribution after Plan Implementation

However, equipment with no historical data, equipment with one, two or three successful calibrations remain as equal until the instrument has the historical data for evaluation. The equipment frequency distribution after project implementation is shown in Figure 9.

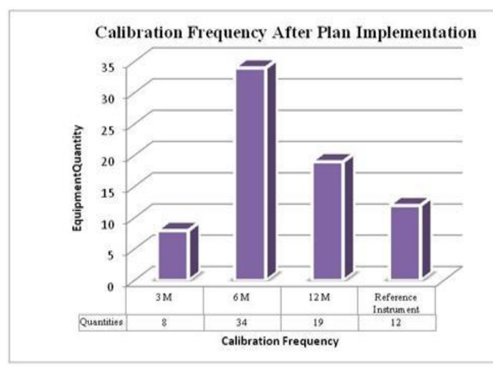

Figure 9
Calibration Frequency after Implementation

A cost projection was performed after plan implementation. This evaluation excludes out of service equipment and equipment with no available data. The cost analysis included 47 in service equipment from the Cayey region Water and Sewer Service Area. Twelve equipments were considered as a reference instrument making not investing in calibration and maintenance cost. At the beginning of the project, the calibration and maintenance cost was $10,200.50. However, after plan implementation the calibration and maintenance cost was $5, 801.75 and cost saving of $4,398.75. This means a 43% in cost saving. The Table 2 shows a comparison between the current cost and after plan implementation costs.

Table 2
Cost Analysis after Plan Implementation

	Current Calibration and Maintenance Cost	*Calibration and Maintenance Cost After Plan Implementation*
Total of Intruments	47	47
Calibration cost of High Critical Instruments per year	$ 2,346.00	$ 1,564.00
Calibration cost of Moderately Criticity Instruments per year	$ 7,624.50	$ 2,346.00
Calibration cost of Low Critical Instruments per year	$ 195.50	$ 1,857.25
Total Calibration Costs	$ 10,166.00	$ 5,767.25
Maintenance Cost	$ 34.50	$34.50
Total Annual Cost	$ 10,200.50	$ 5,801.75

To sustain and constantly assess the equipments if forward to more cost savings, a Frequency Change Form was created. This form provides a simplified way to know historical information, current status of the equipment and the actions to take. The calibration technician will be required to fill this form after the completion of the calibration execution as part of the calibration procedure. The form contemplates two scenarios; in tolerance and out of tolerance calibration results. It will be part of the current calibration manual of the service industry. This Frequency Change Form will aid the Over-processing and Overproduction waste since will provide a reliable method of tracking the equipment results and maintain optimized calibration frequencies during the equipment life cycle.

Control Phase

The purpose of DMAIC control phase is to provide a control plan to prevent the counter measures and solutions in place that can be controlled to prevent future problems and provide a sustainable financial benefit. As mention in the improve phase, the team designed the Frequency Change Form. It was created with the objective of received historical data and currently equipment status in an active and simplified way. The Frequency Change Form allow to perform a continuously evaluation of the data systematically. The handling of this form was contained in addendum called Appendix D, which will be part of the existing calibration manual.

The Appendix D contains brief information about the Frequency Change Form, the handling procedure for a frequency change and reference instrument declaration. The process begins when the technician intervenes with the equipment. Then, the technician filled the Frequency change form. If the calibration was not successful, the equipment remains with the current calibration frequency. The Calibration supervisor verified the deep causes for damage. Otherwise, the equipment was a successful calibration, the maintenance Supervisor fills the document and it is evaluated and approved by the Compliance Director and Maintenance Manager. Therefore, the maintenance coordinator performs the frequency changes in SAP PM System. Once the change was made, the information is entered to maintenance data base and the information is stored in the regional list. For reference instrument, the equipment identification will be contained a letter R indicating the instrument as reference. However, if the equipment is found out of tolerance after frequency change, this should be returned to its original frequency.

Also, a visual aid should be added to remind the parameters, facilities and impacted equipment. The use of lean manufacturing techniques simplifies the workplace, providing an accurate sense of perception and bringing work and information to worker. In addition, a successful plan implementation includes constant training and monitoring. Those controls can be made in order to maintain and ensures the standard work, key to continually improve a process.

CONCLUSIONS

From start to finish, DMAIC tool provides a structured way for business improvement with a road map for solutions. This technique allowed the identification, evaluation and categorization of opportunities under their impact and difficultly.

After a deep analysis performed, the flow meter of Cayey Water and Sewer Service Industry had a cost reduction of 43%. It shows a higher cost reduction in comparison with the initial estimate. Translate in a decrease of the annual investment of $4,398.75 for Cayey Operational Area. In addition, the implementation achieves the elimination of waste and standardized work, never compromises the quality and compliance.

In order to make a standardize work plan, the team designed the Frequency Change Form. The implementation of this form allows the continuously flow of information in a simplified way to recognize equipment candidates for frequency change and reference instruments declaration. The Appendix D was created with the purpose of explained the document handling process of this form. This addendum will be part of the current calibration manual.

To keep a successful implementation of the control plan, it requires training and monitoring program. Due a successful project implementation, this achievement will be extended to all other calibrated equipment in the calibration system of the Cayey Operational Area under the same Calibration operational manual and will be proposed to other Operational Areas and Calibration department through the island, serving as a model for the Water and Sewer Service Calibration Operations in Puerto Rico.

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