Water Efficiency Improvement Using DMADV Methodology

Gilbert Cruz Moreta
Master of Engineering in Manufacturing Engineering
Advisor: Rafael Nieves, PharmD.
Industrial Engineering Department
Polytechnic University of Puerto Rico

Abstract *– Water utility optimization using manufacturing methodology to investigate ways we can generate more revenue and a more efficient service. Considering different types of manufacturing process which could have a positive effect on the optimization of the water distribution process and complies with the objectives of the company. Acknowledging the factors that make take to implement a new process and taking in to mind the fiscal position of Puerto Rico. Benchmarking and performance optimization programs can widely help the need for a more efficient process, and that is why that a DMADV (Define Measure Analyze Improve and Control) process is being propose. Is a known fact that utilities need innovative solutions and advanced technology in order to thrive.*

Key Terms *— Defects, DMADV, MGD, PRASA, Quality, Sedimentation Tank, Water Treatment.*

PROJECT STATEMENT

With the economic state that the island of Puerto Rico has experience for the past decade, is no other time to understand the value of our utilities and the importance of good management of our assets to help maintain a successful infrastructure. Like most of the country of Puerto Rico Aqueducts and Sewers Authority (PRASA) is in debt and helping to find ways to contribute to pull through is the responsibility of every citizen.

Research Description

The primary focus of this investigation is to identify possible target points or weak spots in the process for the high loss of water in PRASA system. Using quality manufacturing methodologies can help to study the current infrastructure and provide solutions in the increase of the current performance levels. Hoping to find vulnerabilities that can be analyze and improve and eventually lead to a more efficient system and reduce cost that eventually end up in a higher revenue rate.

Research Objectives

Use a DMADV process to set ambitious but realistic goals that can be met in the near future:

- Find failures in the water management process.
- Raise questions of why 55% of their daily produce water is loss.

Research Contributions

This study will address ways to reduce the over 42% of physical water loss daily do to the deficiency in the process. Putting the process through a DMADV to determine new technologies that have not been use by PRASA or are not being used correctly. Technologies that comply with social, environmental and economic standard that PRASA has to fulfill. PRASA currently has 116 water treatment plants and over 220,000 miles of pipelines all over Puerto Rico and this study hopes to be blueprint for the improvement of this infrastructure.

LITERATURE REVIEW

With the world’s constant change and how climate change is affecting its resources, seen in massive hurricanes or even extensive periods of water drought. Today the U.S. drinking water industry is facing growing challenges in providing water supplies necessary to sustain the country’s economic and population growth. Americans are the world’s consumers. As shown in Fig. 1, their water consumption ranks them as the world’s highest per capita water users, when assessing source water withdrawals for all uses [1].

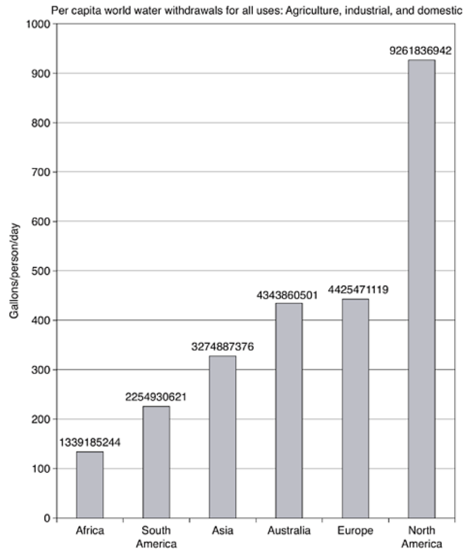

Figure 1
Comparison of Water Utilization

Knowing the high demand of water in our society is important for PRASA to stablish a better plan to control the existing problem for high volume of water loss without revenue. Understand that a total of over 55.1% of the water produce by PRASA everyday do not represent any revenue, and 42.1% of that water is loss without any accountability as show on Table 1 for Water Production Balance. The table shows that of the 557 MGD (millions of gallons per day) produce at least 234.8 MGD are loss. That's a lot of loss water and that non-revenue water is a problem for all utilities representing a significant amount of revenue that isn't collected [2].

Table 1
Water Production Balance [3]

Water Production Balance			
Total Volume of Water 557 MGD	Authorized Consummation 258.1 MGD (46.3%)	Authorized and Billed 250.2 MGD (44.9%)	Authorized and Billed 250.2 MGD (44.9%)
		Authorized but not Billed 7.8 MGD (1.4%)	Produce with no return revenue 306.8 MGD (55.1%)
	Water Loss 299.0 MGD (53.7%)	Commercial Losses 64.2 MGD (11.5%)	
		Physical Losses 234.8 MGD (42.1%)	

The reduction in the high volumen of physical water loss will represent a reduction in operational cost for PRASA plus locating accountability for this water will represent a better return revenue. This investigation will present various types of technologies that can help detect high volume of water loss in any type of pipeline, technolgies with high precision that can report losses in real time.

METHODOLOGY

This project will apply the DMADV Six Sigma strategy to improve water utilization. The DMADV methodology is a Six Sigma framework for implementing new strategies in a current process. The DMADV approach also known as DFSS varies, of course, according to whether the design is of a product or of a process. It might also vary according to the type of product [4]. The DMADV model is usually a five-step process:

- *Define.* Determine the project goals and the requirements of customers (external and internal).
- *Measure.* Assess customer needs and specifications.
- *Analyze.* Examine process options to meet customer requirements.
- *Design.* Develop the process to meet the customer requirements.
- *Verify.* Check the design to ensure that it's meeting customer requirements.

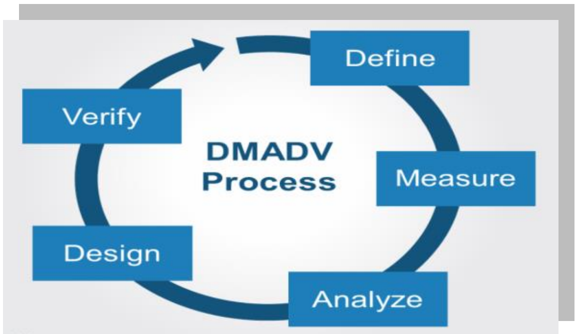

Figure 2
DMADV Process

Staring with the Define stage the project is selected, choosing the team to work on the project, conduct trainning, establish objectives for the project while setting goals or determing a tim line to achive those goals.

For the Measure phase the needs of the customer are determine as well as specifications for the product, services, process or even voice of the customer. A measurement system analysis or MSA is conducted to collect viable data for the project. Here the quality targets of the project are also identified.

In the Analyze phase understanding the product, process or service is the main purpose. Understanding them enough to produce design options. The team needs to examine options and alternatives to meet the objectives stablish before in the Design phase. This examination are determine buy using advanced statistical tools and modeling.

For the Design phase the purpose is to develop or stablish the best option for the process or product while meateing the objectives and requierments of the project. This design will allow the process to maintain the desire quiality and cost effectiveness.

Moving to the final phase which is to Verify the design implemented, and demostrate that this new design can meet the requierments and/or objectives previously stablish.

In this methods you can probably recognize some of the steps of one of the most common Six Sigma mythology which is the DMAIC, but even though the first three steps are very similar this two studies are completely different. The DMAIC methodology should be use to improve an existing product or process and instead the DMADV methodology is use when a new product or process needs to be implemented.

This investigations will propose new technologies in the market of water efficiency to reduce the high level of water wasted within the system

RESULTS AND DISCUSSION

As an initiative to reduce water losses in the PRASA system, a plan to review the water losses in the raw water treatment plant losses, the Enrique Ortega Water Treatment Plant was analyze. Typically water treatment plant loss 12% to 15% the amount of the produce water [5]. This analysis is using the Six Sigma Methodology DMADV to reduce the amount of water that is being loss in the production.

Define Phase

Improving water efficiency for the PRASA system is define as the main focus of this project. Correct utilization of our resources is key on this day for the authority and implementing the idea that every drop counts tries to make everyone aware and responsible for the well management of our resources. After analyzing the water production balance for the last fiscal year and understanding that 55.1% of the produce water doesn't not bring any revenue into the authority, the flag was raised as of why the high demand of production. Therefore it was decided to visit at least one of the water treatment plant to understand the process of clean water production.

The goal of the visits to the water treatment plant is to improve water production methods and/or possibly find any deficiencies that can represent a significant number in the water production balance. With water treatment plant typically ranging with losses from 12% to 15%, the goal of the investigation is to bring that number to about 5% for the water treatment plant.

Measure Phase

With the visits to the Enrique Ortega water treatment plant we hope to understand the process of the plant and optimize any key point to their full potential. The Enrique Ortega water treatment plant raw water source is the La Plata River, here a pumping station serves directly to the plant.

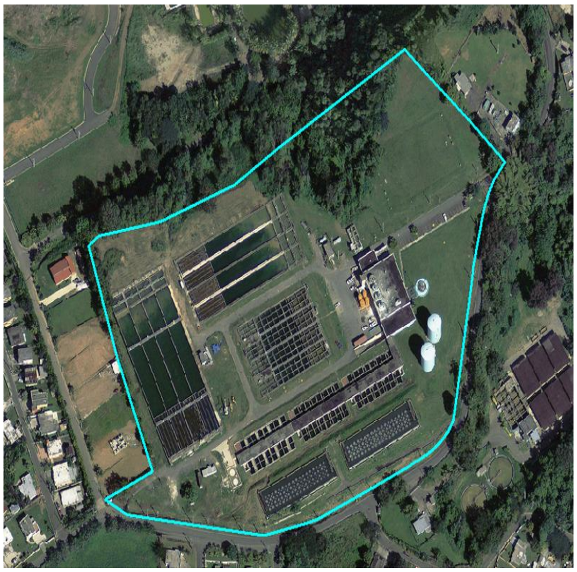

Figure 3
Enrique Ortega Plant

Currently the plant is producing an average of 70 MGD of water, but it has the capacity to produce at peak up to 100 MGD. Production has been affected after the catastrophic hurricane Maria hit Puerto Rico, because a good number of sectors which this plant supplies don't have electricity for the pumps. Also at the time the plant has a waste of an average of 5 MGD, this will represent a loss to production ratio of 7%. Not far from the 5% average goal, the plant is in good standing but we are still looking for possible deficiencies to erase that 2%.

Analyze Phase

Enrique Ortega is the second largest water treatment plant in the PRASA system and it has been expanded in two different occasions after its construction. The different expansion on the plant have been made to meet the demand of the growing population. And this new redesign have made the treatment plant the most unique and/or complex water treatment plant in the PRASA system.

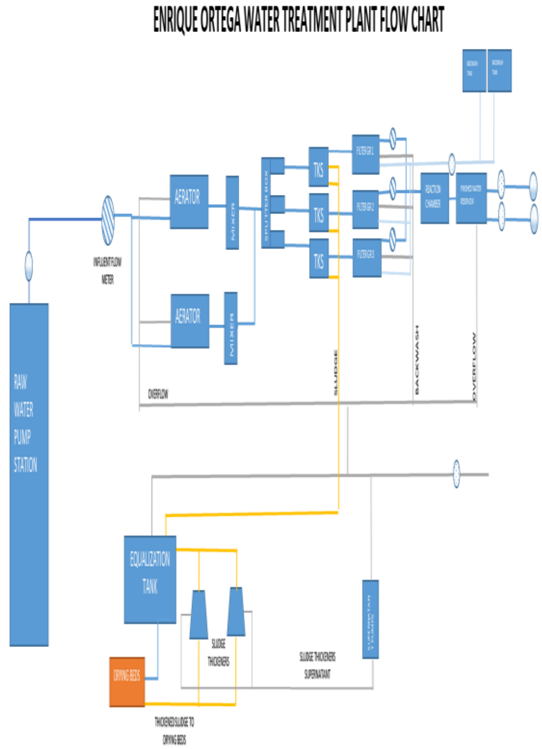

Figure 4
Plant Flow Chart

At the beginning of the water treatment plant a venturi meter is supposed to measure the intake of raw water coming from the La Plata River, the meter is currently broken, which means that the plant doesn't not have an exact amount of the raw water that comes in the plant. The plant staff reports cumulative flows from all operating filters to average what will be the intake flow of the process compare to the outtake meter. After the aeration chemicals are added going to the flash mixing tanks, the flow is divided to three different sets of weirs, each one of this weirs serves four sedimentation tanks which then serve eight conventional filters. The filtered water is then metered before all the water from this process is chlorinated and passes to the finish water reservoir stage.

With a total flow of 78.45 MGD divided by the twenty four filters show in Table 4.3. Each filter in facts has 2 filters, meaning there a total of 48 filters. Twelve filters are wash daily, four for each daily work shift, an average of 3.3 MGD of water is use in the washing of the filters. The make and model of backwash meter was not register because it did not have an identification tag from the manufacturer.

Table 2
Raw Water Flow

Filter	Flow (MGD)	Filter	Flow (MGD)	Filter	Flow (MGD)
1	2.37	9	3.71	17	4.21
2	2.17	10	2.61	18	3.59
3	3.52	11	3.93	19	3.78
4	2.65	12	3.71	20	3.01
5	3.2	13	2.94	21	3.42
6	3.11	14	3.84	22	2.90
7	3.42	15	3.52	23	3.47
8	2.41	16	3.4	24	3.56

The sedimentation tanks which are used to remove any solid particles in the raw influent water by gravity settling, are backwash every six months, the sedimentation tanks have a “Spyder” system that allows for organic or inorganic materials in continuous flow condition to be removed. The “Spyder” system allows for high sludge volume recollection and removal.

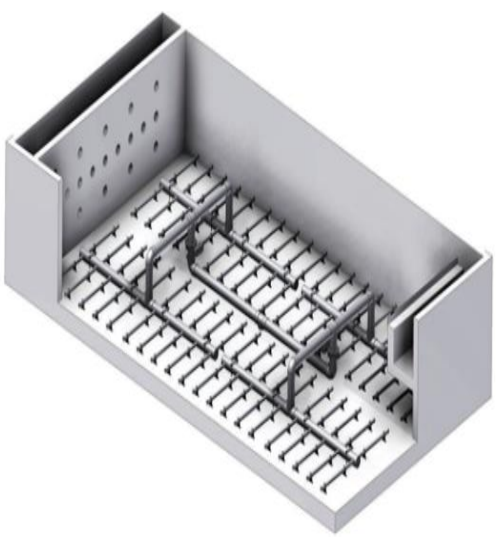

Figure 5
Spyder System

This system was installed in 2011 by PRASA in the Enrique Ortega water treatment plant but it has presented multiple problems of leakages since the system was install. This system operates with “butterfly” valves, this valves work automatically when there is air pressure present in the system. In this assessment we found out that since the installment this valves don’t close completely, having a constant leakage in the sedimentation tanks.

Figure 6
Typical Butterfly Valve

Design Phase

The purpose of the design phase, is to introduce a system that will reduce the water lost in the production of the treatment plant. A 5% goal was set to for this plant, which currently presents a 7% average loss in the MGD production. The Enrique Ortega is a highly efficient water treatment plant except for the “Spyder” system in the sedimentation tanks, the system is causing unnecessary losses in the process of production. Base of the valves frequency of opening and issues with the installation.

An Optimization or replacement of this system is the solution for the water treatment plant, and achieving the 5% or less of water loss in the process for making clean water.

Verify Phase

The recommendations on the Design Phase were presented to PRASA for confirmation bias, past studies on the treatment plant have confirm that the “Spyder” system are presenting significant losses for the process. Still the agency has not acted on the replacement of this system based on budget limitations. Also the authority is hopeful that this DMADV analysis can be applied in the other 112 water treatment plants in the PRASA system to find possible deficiencies and optimize their process as we did in the Enrique Ortega plant.

CONCLUSION

After visiting the Enrique Ortega water treatment plant and applying the DMADV six sigma methodology, it was determine the source of water loss in the production process. With the help of the plant director and the information provided by the plant staff the numbers for the plant production and process losses were stablish. Finding that the plant has a production to lose ratio of just 7%, just below the 12% to 15% for most of water treatment plants. And setting a goal of just 5% in loss of the process can be achieve by accepting the recommendations for the "spyder: system, a change in the system will result in more water being recycle resulting in the minimization of the discharged as waste.

The organization is already has a numerous of different initiatives to attack the water losses. The majority of this initiatives are for commercial loss, and possible leakage in the infrastructure. This project can serve as a blueprint to find loss in the production, by applying the DMADV in all water treatment plant process. It can also be use in waste water treatment plant.

This project demonstrate how Lean Six Sigma methodologies can be applied in any industry and not just for the manufacturing industry. Good management of any organization resources is the key for quality.

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