Operational Optimization Of A Potable Water Refilling Station

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Abstract
This descriptive study delved on the determination of the current practices of a water refilling station in terms of operational efficiency tracking and evaluation, forecasting, and warehouse management as well as to introduce an optimization plan using baseline data to improve the operational efficiency of the water station employing forecasting method (time series, Failure Mode Effect Analysis and Warehouse Management System. Secondary data analysis and key informant interview were used as inputs of the study. Results indicate that the operations of the water station is not optimized, There is no forecasting technique used, no maintenance plan and no records of items used for the operation are maintained. Currently, the water station does not have any system for tracking the operation in the previous months. Using the recommended time series forecasting employing Exponential Smoothing yielded the minimum mean absolute percentage error was only 8.55%. Further, by using the Failure Mode Effect Analysis (FMEA) , it was found that the maintenance of the machine and equipment should be given priority if losses were to be avoided. This process is critical with the RPN of 800. Finally, using the warehouse management systems could improve the operational efficiency especially in terms of inventory management.

Keywords: *Optimization plan, operational efficiency and water refilling.*

I. INTRODUCTION

Worldwide, access to safe drinking water is often used as a measure for progress in fighting against poverty, disease and death (Muyot, 2017) . Access to safe drinking water is also considered to be a human right, whose economic benefits include higher economic productivity, more education, and health-care savings owing to the absence of water-borne diseases (WHO, 2011). In San Jose, a first class municipality in the island province of Occidental Mindoro, more than 50% of the population depend on water refilling stations for their drinking water supply. (San Jose Planning and Development Office, 2019).With a captive market, water refilling stations should be doing well in business to cater to the drinking water needs of their clients. However, data obtained through informal interviews with water refilling station owners reveal that very few used standard business practices to optimize their operation. There is also an utter absence of baseline data on the minimum daily output, projection for equipment breakdown among other significant inputs to efficient business operation. Frequent plant breakdowns could lead to temporary shortage of inventory to supply the drinking water needs in the refilling station's service area. Forecasting, process flow study and warehousing practices are essential components of optimized store operation. Forecasts can be used in an extraordinarily diverse range of ways across many domains with each of these domains requiring the analysis of different kinds of inputs and special considerations (Seaman, 2018). Time series forecasting is one of the most widely used applications of data science whose primary purpose is to predict sales from historical data which is well applicable in consumer product suppliers (Kotu, 2019).

In terms of operational efficiency and identification of and risk management, Lo (2019) contends that increasing the reliability of machine tools and reducing possible risks during the water purification and refilling process is crucial for the future of business establishments like water refilling stations. The failure mode and effects analysis (FMEA) method is reliant upon the experience of people working in the water refilling stations to determine the primary failure modes and detect the most critical factors for preventing risks like machine breakdowns. The FMEA scientifically estimates when equipment used would break down. Warehouse management is also an important aspect of optimized operation.Although water refilling stations gains from their current operation, the lack of engineering controls hinders them from achieving the highest possible profit. The researchers believe that optimizing the operation of the Labangan Water Station would result to better sales , more efficient use of equipment and maximized volume of products produced with the least use of resources.There are few studies and applications on how to optimize business processes and operations however these studies do not introduce the use of various engineering principles in their optimization process. In this paper, the researchers endeavor to introduce various Industrial Engineering principles and methods to optimize the operations of the Labangan Water Refilling Station. Results of this study can be used as practical guide and industrial example of water refilling stations. Their optimization and performance assessment may result in substantial value gains for the company.

II. OBJECTIVES

This study primarily aimed to formulate an operational optimization plan using engineering approaches for Labangan Water Station. It specifically endeavored to:

1. Describe the current operational practices of Labangan Water Station in terms of:
   a) Performance of the Water Station for the past years ,
   b) Forecasting method used,
   c) Warehouse management practices;

2. Develop an operational optimization plan in :
   a) Forecasting ;
   b) Operational Efficiency; and
   c) Warehouse Management

III. METHODS

Research Design

This is a descriptive case study using the Labangan Water Refilling Station which sells potable water to consumers, as the subject of the research. The conceptual model used the the input, process, and output in operational optimization plan for the said company.The input of the study includes the current practices of the Labangan Water Refilling Station in its core aspects of operation such as production process, forecasting and storage. The process involves the use of various industrial engineering concepts such the forecasting method (Time series) analyzing time series data in order to extract meaningful statistics to predict future sales.

It is the use of a mode to predict future values based on previously observed values will be used in designing a scientific projection of future demand.The Warehouse Management System was used to manage the efficient storage and movement of products using the ABC approach based on the Pareto Principle for determining which items should get priority in the management of the company's inventory (Ramaa et al., 2012). The Failure Mode Effect Analysis (FMEA), was used in order to determine the corrective and preventive actions to minimize the downtime and breakdown of the machine and equipment needed in the daily operation. The output is the Operational Optimization Plan for the Labangan Water Refilling Station, San Jose, Occidental Mindoro which is expected to help achieve its best possible revenues by using an improved process from inventory to delivery of its product.

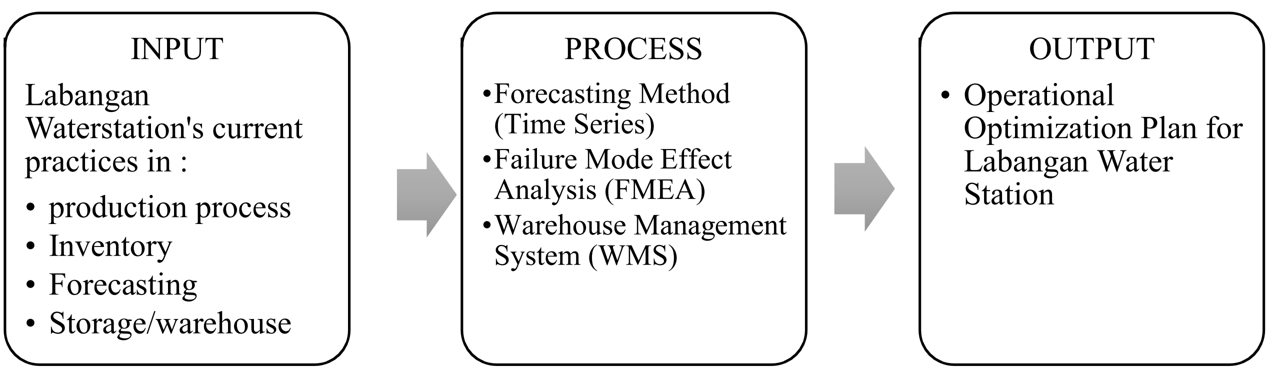

Fig 1. Research Paradigm

Optimization Plan Methodology

The optimization plan was developed using a series of steps from identifying the problem to final application and testing of the proposed project.

Problem Contextualization

The researchers search identified the problems that water refilling stations in the province were currently encountering by interviewing the key players and then contextualizing these with Labangan Water Station.

Data Gathering and Planning

This involved gathering of data on the company's practices on operation, warehousing (warehouse dimension, warehousing methods, manpower, equipment and machineries), maintenance practices for the machine breakdown. These data were necessary in developing the optimization method that is based on industrial engineering techniques and practices.

Designing of an Optimization Method

Various Industrial Engineering tools and techniques were used in developing the optimization plan for an improved and efficient operation of the water station. The following IE tools and techniques were used in the optimization method: Time and Motion study for the process and the oprations, forecasting the demand of products for the following months, application of FMEA for the reduction of the breakdown of machine and equipment, ABC Analysis on company's warehouse management, application of the Dijkstra algorithm on the delivery points.

Application of Operational Optimization Plan

The gathered data from the company's manager and observation from its operation were applied on the optimization methodology.

Adjustments of the Proposed Optimization Technique

The application of the proposed optimization technique to the Labangan Water Refilling Station was a delicate move as it may cost the company its revenues if not properly checked and approved. After the results were analyzed, the researchers coordinated with the manager of the company on the figures and necessary changes on the proposed technique to ensure that the implementation of the optimization plan would not negatively affect the company's operation.

Final Application and Testing

After the adjustments were done, the researchers together with the manager of the Labangan Water Station worked together towards the application and testing of the proposed optimization plan.

IV. RESULTS AND DISCUSSION

Current Operational Practices

Assessment of the current practice of the Labangan Water station yielded the following:

1. Operational Efficiency

Based from current practices of the water station, there is no established operational efficiency evaluation tools in place;

2. No forecasting method is used. Reports of sale is kept for records purposes only and to quantify the daily sales. Apart from these, sales data have no practical use; and

3. Warehousing practices are ad hoc, water containers are lined up where there are empty spaces. No warehouse management systems have ever been used and stocks inventory is not recorded.

Development of Operational Optimization Plan

Taking off from the assessment of the current operational practices of the water station, an operation optimization plan was designed. The following consisted the steps in drawing up the optimization plan.

Forecasting Method

1. Using 3-Months Moving Average Forecasting Technique

The Researchers used the data from the sales of January-May,2019 as given by the management of the Labangan Water Station in drawing up a forecast. Table 1 shows the result of the 3 Months Moving Average Forecasting Technique. This shows the mean absolute percentage error is 12.15% and the water container that should be produced by the water refilling station is 3300.

Table 1. Months Moving Average

Time Series Forecasting (3 Months)						
	Sales	3 Month Forecast	Error	Absolute Value	Error^2	%error
January	3100					
February	2520					
March	2850					
April	3150	2823.333333	-326.67	326.6666667	106711	10.3704
May	3300	2840	-460	460	211600	13.9394
June		3100	-393.33	393.3333333	159156	12.1549

2. Forecasting Using Exponential Smoothing

The simplest of the exponentially smoothing methods is naturally called simple exponential smoothing. This method is suitable for forecasting data with no clear trend or seasonal pattern. As shown in Table 2, the mean absolute percentage error for the Exponential Smoothing is 8.55% and the recommended water containers to be filled must be 3,055.

Table 2. Exponential Smoothing

Time Series Forecasting (Exponential Smoothing)						
		0.166666667	0.83333			
	Sales	Exponential Smooting	Error	Absolute Value	Error^2	%error
January	3100	3100	0	0	0	0
February	2520	3100	580	580	336400	23.0159
March	2850	3003.333333	153.333	153.3333333	23511.1	5.38012
April	3150	2977.777778	-172.22	172.2222222	29660.5	5.46737
May	3300	3006.481481	-293.52	293.5185185	86153.1	8.8945
June		3055.401235	53.5185	239.8148148	95144.9	8.55157

3. Forecasting Using 3-Months Weighted Average

As discussed with the management, the weights given are 0.2, 0.3 and 0.5. These weights were used to compute the 3 Months Weighted Average, 0.5 was given to the latest sales of the water containers. By using this technique, mean absolute percentage error of 11.08% was obtained and the recommended water container to be filled for the month of June should be 3,100 (Table 3).

Table 3. Months Weighted

Time Series Forecasting (3 Months Weighted)						
	Sales	3 Month Weighted Forecast	Error	Absolute 'Error^2		%error
January	3100					
February	2520					
March	2850					
April	3150	2801	-349	349	121801	11.0794
May	3300	2934	-366	366	133956	11.0909
June		3100	-357.5	357.5	127879	11.0851

Most Appropriate Forecasting Technique

After using the recommended time series forecasting technique as shown in Table 4,it was decided that the Exponential Smoothing must be used by the top management to forecast sales since this will method gave the minimum mean absolute percentage error of 8.55%. Forecasting is essential since it is the cornerstone of every enterprise.(den Brauke, 2019).

Table 4. Mean Absolute Percentage Error Summary

Mean Absolute Percentage Error Summary			
	Exponential Smoothing	3 Months Moving Average	3 Months Weighted
June Forecast	8.55	12.15	11.08

Failure Mode and Effects Analysis

Failure Mode and Effects Analysis (FMEA) is a structured approach to discovering potential failures that may exist within the design of a product or process. Failure modes are the ways in which a process can fail. Effects are the ways that these failures can lead to waste, defects or harmful outcomes for the customer. Failure Mode and Effects Analysis is designed to identify, prioritize and limit these failure modes.Table 5 details the result of the Failure Mode Effect Analysis (FMEA) of the Labangan Water Station. Using the standard basis of the FMEA template, occurrence, severity and detection of risks were rated. The result shows that the maintenance of the machine and equipment has the highest Risk Priority Number (RPN) which is 800. This means that the top management must give priority to the maintenance of machine and equipment if losses should be minimized or at best, avoided

Table 5. Failure Mode Effect Analysis (FMEA) of Water Station

Failure Mode Effect Analysis								
Function	Potential Failure Mode	Severity	Potential Effects of Failure	Occurrence	Current Process Control	Detection	RPN	Recommended action
Refill the container	Failure of equipment	8	No available water bottles for delivery	2	Refill whenever there is order	7	112	Follow the forecasted number of water bottles to refill
Maintenance of the equipment, machines and tricyle	Unable to carry out maintenance	10	Machine breakdown	8	No maintenance	10	800	Maintenance should be done daily
Delivery of the water container	Unable to deliver water bottles	7	Unsatisfied customers/ Lost customers	5	Deliver when there is available staff	7	245	Designate one worker for the delivery of water bottles
Cleaning	Unable to clean the premises	7	Prone to hazard	2	Cleaning every morning	7	98	Clean whenever there is water on the floor that may cause accident

Warehouse Management System

The warehouse management system allows for the efficient tracking of the products sold by the Labangan Water Station. The following figures and tables present the inventory system and warehouse management system designed for the optimized operation of the Laangan Water Station. To address the lack of a warehouse management system, a system was designed by the researchers with the following features:

1. Inventory System

The proposed inventory system was designed using Visual Basic. The system would allow a real-time management of all stocks maintained by the Water Refilling Station. The landing page appears on Figure 2,

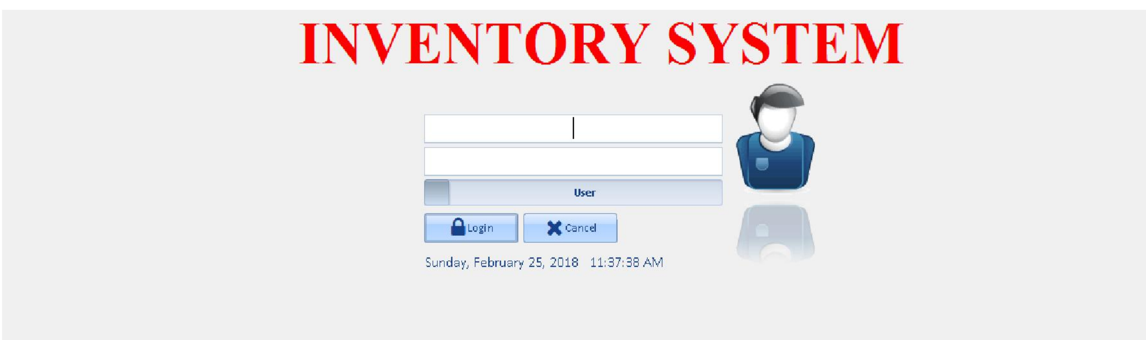

Fig 2. Proposed Inventory System Landing Page

Figure 3 is the Admin or the Authorized person is the only one authorized to add or delete data about the product. In this part, the Item code, descriptions (name of the product), size, quantity, price and date when item is being ordered will be encoded.

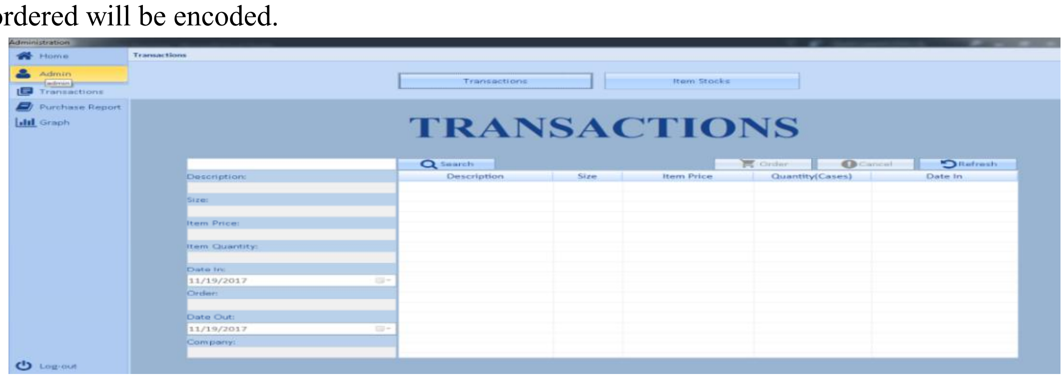

Fig 3. The admin page for transactions

Figure 4below is the item stock, page all the data on transactions made can be seen here. The user can also add data about the number of filled water containers in the warehouse andwhen these should be delivered.

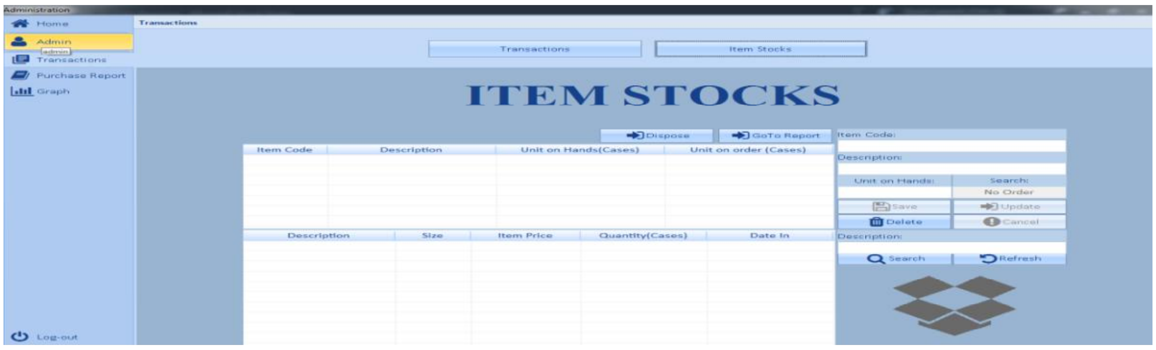

Fig 4. Admin page for item stocks

Figure 5 below displays the page for product: description, size, item price, quantity and the date. This part of the system can be seen by the store clerk but cannot edit or delete. Data are exclusively manipulated by the admin, usually the water refilling station owner or manager.

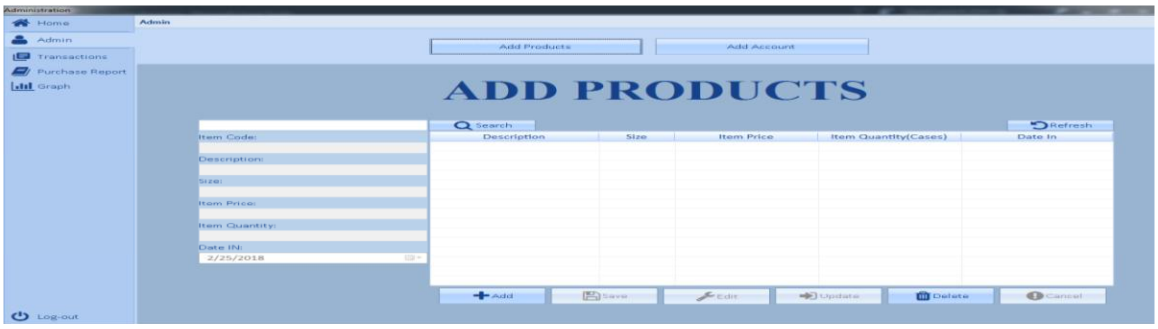

Fig 5. Admin page for adding products.

Figures 6, 7 and 8 present the admin registration account which has the username, password, name and position, the purchase report and a graphical presentation of the monthly delivery report.

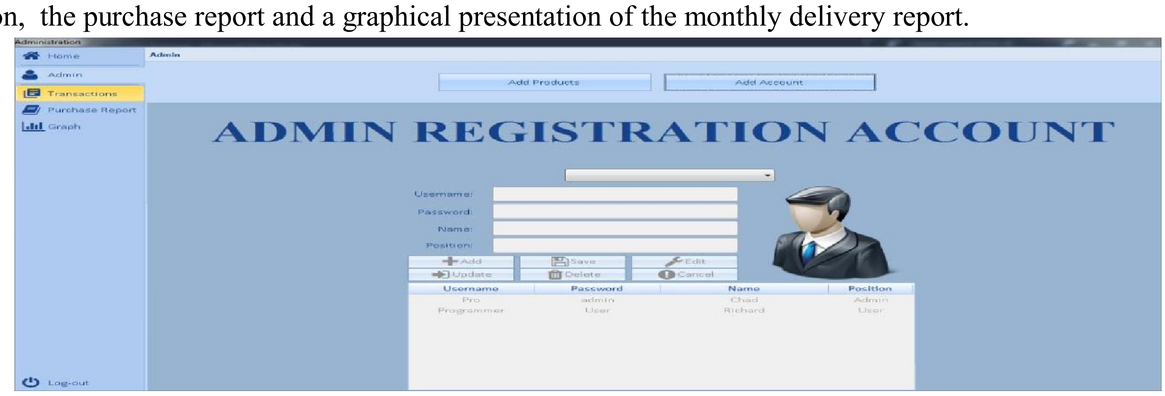

Fig 6. Inventory system administrator registration page.

Figure 7 presents the purchase report where the daily and monthly inventory can see. It consists the daily and monthly purchases which can specify the exact date and month of the transaction.

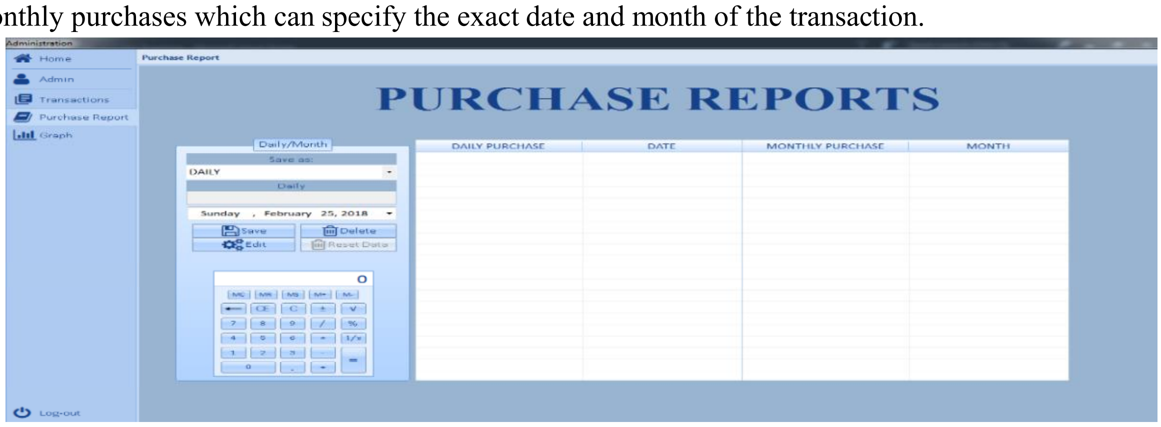

Fig 7. Warehouse management system purchase report page

Figure 8 shows the graph on the monthly delivery of the different kinds of products that depict the sales in the warehouse.

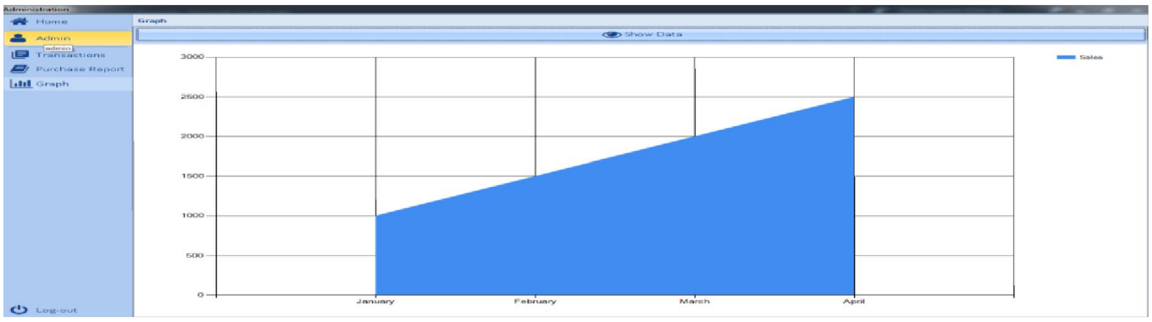

Fig 8. Inventory system sample graph of stocks.

Time and Motion Study of the Proposed Inventory System

To determine the length of time it takes to undertake the tasks in the proposed Warehouse Management System, a time and motion study was done. Normal speed of using the system would take 607 seconds from log in to completing the encoding of inventory data.

Table 6 .Time and Motion Study Result on the proposed warehouse management system

Job Elements	Average actual time (secs)	Rating (%)	Normal time (secs)	Allowance (%)	Standard Time (secs)
Open the Application	4.10	100.00	4.10	0.10	4.51
Log-in Admin	5.60	100.00	5.60	0.10	6.16
Encode Data	542.00	100.00	542.00	0.10	596.20
Save Transaction	1.00	100.00	1.00	0.10	1.10
Total					**607.97**

V. CONCLUSION

Based from the results of the study, the following are concluded

1. The operations of the Water Station is not optimized, There is no forecasting technique used, no operational efficiency evaluation tool and there are no records of items used for the operation. Currently, the Labangan Water Station does not have any system for tracking the operation in the previous months.
2. The Exponential Smoothing must be used to forecast sales since it gives minimum mean absolute percentage error. Among the time series forecasting methods used.
3. FMEA analysis reveals that the maintenance of the machine and equipment must be given the highest priority among the identified risks if losses were to be avoided. This process is critical for water refilling stations which are dependent on water purifying equipment.
4. Using the warehouse management system will allow management to have a real time information on inventory movement.

VI. RECOMMENDATION

In light of the findings of the study, the researchers hereby recommend the following:

1.The proposed operational optimization plan may be adopted by all water refilling stations in Occidental Mindoro to increase efficiency and improve the profitability of the industry;

2. Conduct further studies on different forecasting techniques to come up with more accurate forecasts.
3. Use industrial engineering tools for the optimization of the delivery route for the water station.

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